**Characteristics of Low Speed Vehicle Run Over Events in Children: An Eleven Year Review.**

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## ABSTRACT

### Objectives

The purpose of this study was to investigate the characteristics associated with fatal and non-fatal Low Speed Vehicle Run Over (LSVRO) events in relation to person, incident and injury characteristics, in order to identify appropriate points for intervention and injury prevention

### Methods

Data on all known LSVRO events in Queensland, Australia over 11 calendar years (1999-2009) were extracted from five different databases representing the continuum of care (pre-hospital to fatality) and manually linked. Descriptive and multivariate analyses were used to analyse the sample characteristics in relation to demographics, health service usage,outcomes, incident characteristics, and injury characteristics.

### Results

Of the 1,641 LSVRO incidents, 98.4% (n=1,615) were non-fatal, and 1.6% were fatal (n=26). Over half of the children required admission to hospital (56%, n=921); mean length of stay was 3.4 days. Younger children aged 0-4years were more frequently injured, and experienced more serious injuries with worse outcomes. Patterns of injury (injury type and severity), injury characteristics (e.g., time of injury, vehicle type, driver of vehicle, incident location), and demographic characteristics (such as socioeconomic status, indigenous status, remoteness), varied according to age group.  Almost half (45.6%; n=737) of events occurred outside major cities, and approximately 10% of events involved Indigenous children. Parents were most commonly the vehicle driver in fatal incidents.  While larger vehicles such

as Four-wheel Drive (4WD) were most frequently involved in LSVRO events resulting in fatalities, cars were most frequently involved in non-fatal events.

**Conclusion**

This is the first study to the authors’ knowledge to analyse the characteristics of fatal and non-fatal LSVRO events in children aged 0-15 years on a state-wide basis. Characteristics of LSVRO events varied with age, thus age-specific interventions are required. Children living outside major cities and Indigenous children were over-represented in these data. Further research is required to identify the burden of injury in these groups..

**<u>What is already known on the subject?</u>**

- Queensland has the highest low speed vehicle run over fatality rate in Australia and non-fatal LSVRO rates in the world.
- Common time of injury for fatal events is late afternoon (3-6pm).

**<u>What this study adds</u>**

- While the majority of LSVRO events occur in the home/driveway, a substantial proportion of events occur in the street or a public space, especially among older children
- Almost half of LSVRO events occur outside of major cities.
- The most frequent vehicle type associated with non-fatal LSVRO events is a car (not larger vehicles such as SUVs/4WDs).

## INTRODUCTION

Low speed vehicle run-over (LSVRO) incidents occur when a pedestrian, usually a child, is injured or killed by a slow moving vehicle (moving forward or in reverse) in both traffic and non-traffic areas at less than 30 kilometres per hour [1]. They were first documented in 1964 [2] and sporadically reported since in Australia, the United Kingdom[3], United States of America[4-7] , Brazil[8], Austria[9], and New Zealand[10-13]. LSVROs are a significant cause of transport pedestrian fatalities in young children, and are the second most frequent cause of death due to unintentional injury among children aged 1-4 yrs in in Australia [1]. More recent studies [14-17] have highlighted this problem as more complex than simple "reversing" or "driveway" injuries.

To date, most studies have described fatal events where data are typically collected through coroners' data, police reports and or child death reviews[5,14,18,19] separately from non-fatal events (where data typically are collected through one or two hospitals via admission data or trauma registry data). Where non-fatal events have been described, this has been done separately for either hospital admissions [6,9], admissions to trauma centres [7,20,21], or ambulance-attended cases [22] - rarely are all relevant databases interrogated.. One previous Australian study included data on both fatal and non-fatal events [17] but nonfatal data were extracted from hospital admissions in one major children's hospital, and fatality data were collected on a state-wide basis, so the two populations were not directly comparable. Both ED and hospital admissions data were accessed in a study which utilised data from the Canadian Hospitals Injury Reporting and Prevention Program (CHIRPP)[23], but the results are not generalisable because not all Canadian EDs and hospitals participate in the injury surveillance program. Three studies from Auckland, New Zealand [12,13,24] included fatal and non-fatal incidents, however the study area was restricted to events within Auckland (the largest city in New Zealand) only, so results were not generalisable to non-metropolitan regions. In addition, studies have limited their focus to LSVROs that involved a reversing vehicle [9,20,23] or that were location-specific (e.g., driveway [7])

This mechanism of injury has not been described in detail at a population level, and the methodological limitations of previous work on LSVROs has resulted in a lack of adequate information about the circumstances surrounding fatal and non-fatal incidents [25, 26].

A recent systematic review on LSVRO events found that the incidence of non-fatal LSVROs varied from 7.09 to 14.79 per 100,000, and from 0.63 to 3.2 per 100,000 for fatal events [25]. Previous studies have highlighted that LSVROs are a particular problem among young children aged 0-4yrs [1,4-7,9,12-14,17-20,23,24,27, 28]. A recent population-based study of fatal and non-fatal LSVRO events over an 11 year period in Queensland, Australia indicated that the incidence in Queensland may be the highest (14.6 per 100,000) in the world [27]. However, this study used sophisticated methodology [26] to identify all known LSVROs identified across the continuum of care (from pre-hospital to fatality), which may account for the higher incidence compared to other countries. Incidence of LSVROs varied by gender (males 20.97/100,000; females 12.55/100,000; per annum); and was highest among children aged 0-4years (IR=21.45/100000/annum), who comprised 85% of fatal events and 38% of non-fatal events. The incidence among children aged 0-4years decreased over the 11 year study period, but increased among children 5-9years (IR=16.47 /100,000/annum) and 10-15years (IR=13.59/100,000/annum). Whether characteristics associated with LSVRO events vary with factors such as age, gender and severity of event remains un-investigated.

More detailed information is required to identify specific risk factors relevant to LSVRO events, using improved methodology and consistent and comprehensive classification of events. Potential risk factors identified in previous literature [12,13,17,19,28,29] include: culture; geographical location (metropolitan/rural/remote); incident location (e.g., driveway, car park, beach); dwelling design, demographic factors (socioeconomic status, gender, age, family composition, etc), supervision; driver of the vehicle; vehicle size and design. More comprehensive data about the injury event itself are required – i.e., the number and types of injuries, and the severity of injury.

We therefore aimed to investigate fatal and non-fatal LSVRO events in order to fully comprehend their characteristics from a population-based perspective – specifically person characteristics, incident characteristics, and patterns of injury. We also aimed to investigate the associations between person characteristics (e.g., age-group), incident characteristics and patterns of injury. In this paper, we identify appropriate points for intervention to inform injury prevention..

## METHODOLOGY

This is a retrospective case-series of all fatal and non-fatal LSVRO incidents that occurred from 1999-2009 in Queensland, Australia (1999-2009) among children aged 0-15 years.

Data were extracted separately from multiple databases across the continuum of care: pre-hospital (Queensland Ambulance Service - QAS); 2) Emergency Department Information System (EDIS), 3) Queensland Health Admitted Patient Data Collection (patients admitted to hospital for 24 hours or more) (QHAPDC); 4) Commission for Children, Young People and Child Guardian - Child Death Review (CCYPCG); and were supplemented with injury surveillance data (Queensland Injury Surveillance Unit). Because the QAS, CCYPCG and QHAPDC databases have 100% coverage of the state, data were obtained for every LSVRO event that resulted in death, hospital admission, or attendance by Ambulance. The majority of ED presentations in QLD are captured in EDIS, including all major Emergency Departments. Injury surveillance data are captured in the QISU database, which covers approximately 25%

of ED presentations in QLD. A detailed description of case ascertainment and data linkage is provided elsewhere [26]. Method of data extraction was dependent on the data source and was accomplished by a combination of ICD and place of occurrence codes (Y codes) for hospitalisations, presenting complaint / case nature (of pedestrian crashes) for Emergency Department and pre-hospital presentations, free text descriptions, and information provided in supporting medical notes. Where any ambiguity existed, additional information was sought for clarification. Any case for which insufficient data existed to determine whether it was definitely an LSVRO incident, was not included. LSVRO cases from the separate databases were identified and manually linked using name, gender, age/date of birth, date of incident, and hospital, so that each individual row of data represented a unique LSVRO event. .

**Variables**

Location of child's usual residence was based on postcode and categorised using ARIA (Accessibility/Remoteness Index of Australia), which was developed by the National Centre for the Social Applications of Geographic Information Systems (30). Each geographical area was allocated a score (0-15) based on the (road) distance to nearby towns that provide services, which was then allocated to one of five categories: Major city: 0.0-0.2; Inner Regional: 0.2-<2.4; Outer Regional: 2.4-<5.92, Remote: 5.92-<10.53; Very Remote: 10.53-15 (31). For analyses, inner and outer regional were combined into one category, as were remote and very remote Geographical residence was also used to calculate SEIFA (Socioeconomic Index For Areas), which in turn was used to estimate socioeconomic status of the families of children injured through LSVRO events in this study (32). The Index of Relative Socioeconomic Advantage and Disadvantage was used, where higher deciles reflect higher relative advantage, and lower deciles reflect lower relative advantage.

Data on location of incident were collected using various methods: for hospitalised patients, Y-codes (used by International Classification of Diseases to indicate place of occurrence) were used [33], and where textual case descriptions were available in QAS, EDIS and CCYCPG databases, data on location was extracted manually. QISU data on location of incident were used where possible to supplement or enhance location information (for ED or admitted patients that also appeared in QISU data). Data on incident location were thus combined into one variable.

Information on vehicle type involved in LSVROs was available from Child Death Review data for fatal events, and from QISU data for non-fatally injured children.  The data from the Child Death Review was more sensitive (e.g., type and size of car), while QISU data did not generally include size of vehicle.

Date of incident was recoded into month of year, day of week, and where possible, time of incident. Because actual time of incident was recorded for very few cases, time of call to ambulance was used as a proxy for time of incident. While this is not always a reliable indicator for time of injury, given the nature of this mechanism of injury, it is reasonable to assume that time of ambulance call closely reflects time of injury. Time of incident was categorised into 3hour blocks for analyses.

Type of health service through which treatment of the LSVRO was delivered was used as a proxy measure of injury severity. Children who received pre-hospital (ambulance) treatment only were considered the least seriously injured, treatment provided at an Emergency Department only was considered the next most serious type of injury, hospital admissions were indicative of more serious injuries, , and events that resulted in death were the most serious. For analyses, patients who received pre-hospital or ED treatment only were combined.

**Data analysis:**

Descriptive analyses were used to analyse human factors (i.e., demographic characteristics of the sample such as age, gender, socioeconomic status, geographical location, Indigenous status), event characteristics (driver characteristics, vehicle involvement, time of injury (month of year, day of week, time of day)); health service usage/outcomes (proxy measure for injury severity), and injury characteristics (activity and location at time of injury, type of injury (body region and nature of injury)). Associations between human factors,, event characteristics, health service usage, outcomes, and injury characteristics were investigated using appropriate chi-square tests for categorical variables (or Fisher's Exact tests where expected cell count was less than 5), and t-tests or ANOVA for numerical variables, Data are presented by age-group and by injury severity. All data were analysed using SPSS (Statistical Package for Social Scientists), Version 21.0.

**Ethics**

This study was approved by the Behavioural and Social Sciences Ethics Research Committee, University of Queensland; and the Health Research Ethics Committee, Queensland Health.

## RESULTS

### Human Factors

Between January 1999 and December 2009 there were 1,641 LSVROs among 0-15year-olds in Queensland. Most were non-fatal (n=1615, 98.4%; $p<0.001$). Demographic characteristics of children involved in LSVRO events (i.e., Human Factors) are shown in Table 1, and Injury and Event Characteristics are shown in Table 2. Incidents occurred more frequently among children aged 0-4 years (n= 638; 38.9%, of which 24 were aged <1 year, and 17 of these were male) compared with 5-9 year olds (n=501; 30.5%) or 10-15 year olds (n=502; 30.6%; $X^2=22.7$; df= 2; $p<0.001$). Almost two thirds of LSVRO events occurred in males ($p<0.001$), and this was true for all age groups. Gender of children involved in LSVROs did not vary by age group ($p>0.05$).

LSVRO events were not evenly distributed according to socio-economic status (as estimated by SEIFA) ($p<0.001$). Just over one quarter of incidents occurred in children living in areas categorised as lowest relative advantage (Deciles 1-4), and 52% of incidents occurred among children whose usual residence reflected higher advantage (Deciles 7-10). Socio-economic status varied with age-group (n=1484, $X^2=39.93$, df=8, $p<0.001$); LSVRO events in younger aged children (aged 0-4 years) more frequently involved areas reflecting lower advantage than for older aged children (e.g., 34.0% of LSVRO events occurred in Deciles 1-4 for younger children, compared with 24.2% in 5-9 year olds and 23.5% 10-15year olds, respectively).

Almost 10% of children involved in LSVROs were identified as Indigenous (9.8%; n=143). Indigenous status varied significantly by age group, such that the majority of events in Indigenous children occurred in 0-4 year olds (n=80, 55.9%), whereas the frequency of LSVROs was more evenly distributed by age group for non-Indigenous children.

Over half of all LSVRO incidents occurred amongst children whose usual geographical residence was in a metropolitan area ($p<0.001$). Remoteness of usual residence varied significantly by age group: a higher proportion of LSVROs among young children (0-4years) occurred outside metropolitan areas (inner/outer regional: n=280; 44.7%; remote/very remote: n=43; 6.9%) than for older children.

Data on relationship of driver to the injured child was available only for fatally injured children (23 of the 26 fatal LSVROs). The parent was the driver in 58% (n=15) of incidents, and friends/family in 19% (n=5).

**Table 1. Sample Characteristics (Demographics)**

| Variable | | Total 0-15years (N=1641) n(%) | 0-4years (n=638 ) n(%) | 5-9years (n=501 ) n(%) | 10-15years (n=502) n(%) |
|---|---|---|---|---|---|
| **Gender** | | | Difference between age groups: $X^2$=0.49; df=2, p>0.05 | | |
| $X^2$=126.16, df=1, | Male | 1048 (63.9%) | 408 (63.9%) | 325 (64.9%) | 315 (62.7%) |
| p<0.001 | Female | 593 (36.1%) | 230 (36.1%) | 176 (35.1%) | 187 (37.3%) |
| **Indigenous Status** [a] | | | Difference between age groups: $X^2$=26.7, df=2, p<0.001 | | |
| n=1453; $X^2$=937.29, | Indigenous | 143 (9.8%) | 80 (14.0%) | 44 (10.0%) | 19 (4.3%) |
| df=1, p<0.001 | Non-Indigenous | 1310 (90.2%) | 490 (86.0%) | 396 (90.0%) | 424 (95.7%) |
| **Socio-economic status** [b] | | | Difference between age groups: $X^2$=39.93, df=8, p<0.001 | | |
| n=1484; $X^2$=199.31, | Decile 1&2 | 175 (11.8%) | 95 (16.4%) | 46 (10.3%) | 34 (7.4%) |
| df=4, p<0.001 | Decile 3&4 | 238 (16%) | 102 (17.7%) | 62 (13.9%) | 74 (16.1%) |
| | Decile 5&6 | 300 (20.2%) | 132 (22.8%) | 88 (19.7%) | 80 (17.4%) |
| | Decile 7&8 | 498 (33.6%) | 162 (28%) | 159 (35.5%) | 177 (38.6%) |
| | Decile 9&10 | 273 (18.4%) | 87 (15.1%) | 92 (20.6%) | 94 (20.5%) |
| **Remoteness** [c] | | | Difference between age groups: $X^2$= 17.53, df=4, p<0.01 | | |
| n=1617; $X^2$=617.636, | Metropolitan | 880 (54.4%) | 303 (48.4%) | 283 (57.4%) | 294 (59.0%) |
| df=2, p<0.001 | Inner and Outer Regional | 650 (40.2%) | 280 (44.7%) | 186 37.7%) | 184 (37.0%) |
| | Remote and Very Remote | 87 (5.4%) | 43 (6.9%) | 24 (4.9%) | 20 (4.0%) |

Note. For each variable, two separate analyses are presented. The analyses in the first column (under heading “variable”) relate to the whole sample (0-15 yr olds). The analyses presented in the row heading prefixed by “Differences between age groups” relate to between group analyses for that variable.

[a] There were missing data for location of residence, Indigenous status, and socioeconomic status. The number of cases for which there were available data for each variable is provided in the table (under the variable heading). Percents were calculated as a proportion of the available data for each variable.

[b] SEIFA (Socioeconomic Index For Areas) was used to estimate socioeconomic status in this study (ABS, 2008). Specifically, the Index of Relative Socioeconomic Advantage and Disadvantage. Higher deciles reflect higher relative advantage, lower deciles reflect lower relative advantage.

[c] Location of usual residence was categorised using ARIA (Accessibility/Remoteness Index of Australia), developed by National Centre for the Social Applications of Geographic Information Systems (GISCA). Each geographical area was allocated a score between 0 and 15, based on the (road) distance to nearby towns that provide services. Scores were then allocated to the following categories (OESR Queensland, 2011): Major city: 0.0-0.2; Inner Regional: 0.2-2.4; Outer Regional: 2.4-5.92, Remote: 5.92-10.53; Very Remote: 10.53+).

**Vehicle Type**

Information on vehicle type involved in LSVROs was available for 22 of the 26 fatally injured children (Child Death Review data). Among non-fatally injured children (n=1615), data on vehicle type were available via QISU for 437 cases (27.05%), 178 of whom were admitted to hospital (the remainder required treatment in the ED only);  this comprised 11% of non-fatal incidents overall). The vehicle most frequently involved LSVRO events was a car, but vehicle type differed significantly by age group ($p<.001$). Larger vehicles such as SUVs/4WDs/trucks/utility-trucks/tractor were more frequently involved in incidents among younger children aged 0-4years than older children (Table 2.). Vehicle type differed by injury severity ($X^2$=86.86, df=4, $p<.001$).  For fatally injured children, vehicle type most frequently involved was a larger vehicle (e.g., SUV/4WD/truck/utility-truck/tractor;n=17, 77.3%), and medium sized vehicles such as sedans were involved in 5 (22.7%) of the 26 incidents.  In contrast, cars were the most frequently involved vehicle type for injured children requiring ambulance attendance or treatment at an emergency department only (n=223, 86.1%), and for children who were hospitalised (n=142, 79.8%) (See Table 3).

(Insert Table 2 about here)

**Table 2. Sample Characteristics (Injury and Event)**

| Variable | | Total 0-15years (N=1641) n(%) | 0-4years (n=638 ) n(%) | 5-9years (n=501 ) n(%) | 10-15years (n=502) n(%) |
|---|---|---|---|---|---|
| **Vehicle type**[a*] n=749; $X^2$=464.79, df=2, p<0.001 | | | Differences between groups: $X^2$=11.88, df=4, p<0.05 | | |
| | 4WD/Truck/Tractor/Utility | 60 (13.1%) | 32 (17.8%) | 16 (10.4%) | 12 (9.6%) |
| | Car | 370 (80.6%) | 140 (77.8%) | 122 (79.2%) | 108 (86.4%) |
| | Motorbike/other | 29 (6.3%) | 8 (4.4%) | 16 (10.4%) | 5 (4.0%) |
| **Time of incident**[*] **n=615;** $X^2$=311.23, df=5, p<0.001 | | | Differences between groups: $X^2$=29.20, df=10, p<0.001 | | |
| | 6am-9am | 100 (16.3%) | 38 (14.1%) | 33 (16.8%) | 29 (19.6%) |
| | 9am-12pm | 56 (9.1%) | 32 (11.9%) | 16 (8.1%) | 8 (5.4%) |
| | 12pm-3pm | 93 (15.1%) | 45 (16.7%) | 29 (14.7%) | 19 (12.8%) |
| | 3pm-6pm | 256 (41.6%) | 90 (33.2%) | 99 (50.3%) | 67 (45.3%) |
| | 6pm-9pm | 83 (13.5%) | 48 (17.8%) | 17 (8.6%) | 18 (12.2%) |
| | 9pm-6am | 27 (4.4%) | 27 (6.3%) | 3 (1.5%) | 7 (4.7%) |
| **Primary injury**[*] **(n=517)** | | 1. Fracture of lower leg incl ankle (n=128, 7.8%)<br>2. Superficial Injury to Head (n=107, 6.5%)<br>3. Intracranial injury (n=90, 5.5%)<br>4. Other injuries of head (n=74, 4.5%)<br>5. Open wound of head (n=63, 3.8%) | 1. Superficial Injury to Head (n=58, 9%)<br>2. Unspecified injuries of head (n=48, 7.5%)<br>3. Intracranial injury (n=41, 6.4%)<br>4. Fracture of skull and facial bone (n=37, 5.8%)<br>5. Fracture of lower leg incl ankle (n=33, 5.2%) | 1. Fracture of lower leg incl ankle (n=48, 9.6%)<br>2. Superficial Injury to Head (n=35, 7%)<br>3. Intracranial injury (n=34, 6.8%)<br>4. Open wound of head (n=28, 5.6%)<br>5. Fracture of skull and facial bone (n=17, 3.4%) | 1. Fracture of lower leg incl ankle (n=47, 9.4%)<br>2. Superficial injury of ankle and foot (n=33, 6.6%)<br>3. Superficial injuries involving multiple body regions (n=28, 5.6%)<br>4. Dislocation sprain strain of joints and ligaments at ankle foot (n=28, 5.6%)<br>5. Superficial injury lower leg (n=27, 5.4%) |

Table 2 continues over page

**Table 2. Sample Characteristics (Injury and Event), continued**

| Variable | | Total 0-15years (N=1641) n(%) | 0-4years (n=638 ) n(%) | 5-9years (n=501 ) n(%) | 10-15years (n=502) n(%) |
|---|---|---|---|---|---|
| **Ward type** n=833; $X^2$=195.517, df=4, p<0.001 | | | Differences between groups: $X^2$ =32.901, df=8,p<0.001 | | |
| | Short Stay | n=177 (21.2%) | 81 (19%) | 52 (20.5%) | 44 (28.8) |
| | General | n=311 (37.3%) | 166 (39%) | 94 (37%) | 51 (33.3%) |
| | Ortho or Neuro | n=156 (18.7%) | 63 (14.8%) | 50 (19.7%) | 43 (28.1) |
| | Surgical or Burns | n=118 (14.2%) | 71 (16.7%) | 39 (15.4%) | 8 (5.2%) |
| | PICU | n=71 (8.5%) | 45 (10.6%) | 19 (7.5%) | 7 (4.6%) |
| **Number of procedures during admission** | | | Differences between groups: F=.906, df=2, p>0.05 | | |
| n=517 Mean, +/-Standard Deviation | | $\bar{X}$=3.54, SD +/- 3.06 | $\bar{X}$=3.47;SD+/-3.02 | $\bar{X}$=3.79; SD+/- 3.38 | $\bar{X}$=3.32; SD +/- 2.58 |
| **Length of days stay in hospital** | | | (n=461) Differences between groups: F=.227, df=2, p>0.05 | (n=282) | (n=178) |
| n=704 Mean, +/-Standard Deviation | | $\bar{X}$=3.37,SD+/-8.88 | $\bar{X}$=3.4, SD+/-10.98 | $\bar{X}$=3.59, SD+/-6.43 | $\bar{X}$=2.92, , SD+/-4.53 |

Note 1.: For each variable, two separate analyses are presented. The analyses in the first column (under heading "variable") relate to the whole sample (0-15 yr olds). The analyses presented in the row heading prefixed by "Differences between age groups" relate to between group analyses for that variable.
Note 2. There were missing data for all variables. The number of cases for which there were available data for each variable is provided in the table (under the variable heading). Percents were calculated as a proportion of the available data for each variable.
[a]"4WD" is a type of vehicle where all four wheels receive torque from the engine (otherwise known as SUV, AWD, 4x4). "Ute"(known also as a "coupe utility" or "bakkie" in South Africa or "medium sized pick-up truck" in the United States) is a term used in Australia and New Zealand to describe a two door vehicles with a rear tray which is less than 1 tonne (more than 1 tonne is classified as a "truck"). For the term "Motorbike/other", "*other*" includes ride-on mowers and golf buggies. The different vehicle types were combined for analyses – however the most frequent vehicle type in this category is motorbike (n=11 out of 29).

$\bar{X}$: Mean; SD = Standard Deviation

## Environment

Data on incident location were combined into one variable (n=1002; 61% of all cases, Table 3.). The most frequent location for LSVROs among 0-15year olds was a private residence (i.e., at the home, or driveway;45.2%; $p<.001$. Incident location varied by age group; a higher proportion of LSVROs occurred in the home/driveway among children aged 0-4years (n=259, 57%) than older children (5-9yrs: n=121, 38.1%; 10-15yrs: n=73,31.6% $p<.001$), but not by gender ($p>.05$).

Date of incident was recorded for 1,632 cases. There were nine fatal cases where date of incident was unknown (date of death was known but not date of incident). Actual time of incident was recorded for seven of the 26 fatalities, and 608 non-fatal incidents. Overall, LSVROs occurred most frequently between 3-6pm (41.6%; n=256). Time of incident varied by age group ($p<0.001$); approximately half of LSVRO events among children aged 5-9years (50.3%; n=99) and 10-15years (45.3%; n=67) occurred between 3-6pm, compared with one-third of events in younger children (0-4yrs) (Table 2). LSVROs did not vary significantly by day of week or month of year and no significant differences between groups were observed as a function of age or gender.

## Injury Severity

Less than 10% of children involved in LSVRO events required treatment by Ambulance only (7.6%; n=125), treatment was provided at an Emergency Department only for approximately one-third of events (n=569; 34.7%), just over half of events resulted in hospital admission (n=921; 56.1%), and 26 events resulted in death (1.6%). Table 3 shows the LSVRO characteristics as a function of injury severity (patients who received pre-hospital or ED treatment only were combined for analyses).

Injury severity differed significantly by gender - boys more frequently sustained serious injuries resulting in hospital admission (n= 616, 66.9%) and fatalities (n=19, 73.1%) than girls. Injury severity also varied as a function of age group: age and severity were inversely related. Over half of events resulting in hospitalisation involved children 0-4years, as did 81% of fatalities (n=21). Injury severity differed by remoteness. While the majority (n=407; 59.7%) of lower acuity events treated pre-hospital or in ED only occurred in major cities, 49.1% (n=466) of incidents resulting in hospitalisation and 65% (n=13) of fatalities occurred outside major cities.

Injury severity differed by incident location - the majority (80%; n=16) of fatalities occurred in the home/driveway, compared with 48% of events that resulted in pre-hospital or ED treatment only and 43% of events resulting in hospital admission ($p<.001$).

Type of injury varied as a function of injury severity. The most common injury type for injuries resulting in death was head injury, and four of the top five injuries resulting in hospitalisation were head injuries. None of the top five injuries resulting in treatment at ED only involved the head.

Table 3 about here

## Table 3. Characteristics of LSVRO Incidents by Injury Severity

| Variable | | Ambulance or ED only (n=694) | Admission (n=921) | Fatalities[a] (n=26) |
|---|---|---|---|---|
| **Gender** (n=1641, $X^2$=10.29, df=2, p<0.05) | | | | |
| | Male | 413 (59.5%) | 616 (66.9%) | 19 (73.1%) |
| | Female | 281 (40.5%) | 305 (33.1%) | 7 (26.9%) |
| **Age Group** (n=1641, $X^2$=13.34, df=4, p<0.001) | | | | |
| | 0-4years | 156 (22.5%) | 461 (50.1%) | 21 (80.8%) |
| | 5-9years | 215 (31.0%) | 282 (30.6%) | 4 (15.4%) |
| | 10-15years | 323 (46.5%) | 178 (19.3%) | < 3 |
| **Remoteness** (n=1617, $X^2$=16.96, df=4, p<0.001) | | | | |
| | Major Cities | 407 (59.7%) | 466 (50.9%) | 7 (35.0%) |
| | Inner and outer regional | 109 (16.0%) | 201 (22.0%) | 6 (30.0%) |
| | Remote and very remote | 166 (24.3%) | 248 (27.1%) | 7 (35.0%) |
| **Incident Location[b]** (n=1002, $x^2$= 68.75, p<0.001) | | | | |
| | Home / Driveway | 125 (48.1%) | 312 (43.2%) | 16 (80.0%) |
| | Street /Public Road | 62 (23.8%) | 328 (45.4%) | <3 |
| | Carpark/ farm/ park/ footpath /Unspecified /other | 73 (28.1%) | 82 (11.4%) | 3 (15.0%) |
| **Vehicle Type[c]** (n=459; $x^2$=86.85, df=4, p<0.001 | | | | |
| | 4WD/Ute/Tractor | 22 (8.5%) | 21 (11.8%) | 17 (77.3%) |
| | Car | 223 (86.1%) | 142 (79.8%) | 5 (22.7%) |
| | Motor bike or Other | 14 (5.4%) | 15 (8.4%) | 0 |
| **Top 5 Injury Type[d]** | | 1. Not Recorded (n=130, 19%)<br>2. Superficial injury of ankle foot (n-49, 7.1%)<br>3. Superficial injury involving multiple body regions (n-47, 6.8%)<br>4. Dislocation sprain strain of joints and ligaments at ankle foot (n=44, 6.3%)<br>5. Non-Injury (n=40, 5.8%) | 1. Fracture of lower leg incl ankle (n=111, 12.1%)<br>2. Intracranial injury (n=73, 7.9%)<br>3. Superficial Injury to Head (n=69, 7.5%)<br>4. Other unspecified injuries of head (n=67, 7.3%)<br>5. Open wound of head (n=55, 6%) | 1. Head +/- other injuries (n=18, 70%)<br>2. Multiple Injuries +/- asphyxia (n=7, (27%) |

[a]: Where fewer than three fatalities occurred, the exact number has not been reported to avoid potential identification of persons involved.
[b]: For incident location, "home" refers to private residence.
[a]"4WD" is a type of vehicle where all four wheels receive torque from the engine (otherwise known as SUV, AWD, 4x4). "Ute"(known also as a "coupe utility" or "bakkie" in South Africa or "medium sized pick-up truck" in the United States) is a term used in Australia and New Zealand to describe a two door vehicles with a rear tray which is less than 1 tonne (more than 1 tonne is classified as a "truck"). For the term "Motorbike/other",

“*other*” includes ride-on mowers and golf buggies. The different vehicle types were combined for analyses – however the most frequent vehicle type in this category is motorbike (n=11 out of 29).
[d]Injury type does not apply to patients treated pre-hospitally only).

## DISCUSSION

We conducted an 11 year retrospective case-series analysis of comprehensive, state-wide data on fatal and non-fatal LSVRO events across the continuum of care (pre-hospital to fatality)to obtain an understanding of the risk factors associated with LSVRO incidents in children aged 0-15years.

From 1999 to 2009, 1,641 children aged 0-15years across Queensland were involved in an LSVRO. These events most frequently involved children aged 0-4years. As has been previously highlighted, this age group is most at risk [1,4-7,9,12-14,17-20,23,24,29], however our results indicate that this age group also experiences more serious injuries with worse outcomes than older children. Importantly, we demonstrated that patterns of injury (type and severity), characteristics (time of injury, vehicle type, driver of vehicle, incident location), and risk factors associated with LSVROs, vary according to age group. This reinforces the need for age-specific interventions to reduce LSVROs.

Several other findings in this paper are worthy of comment. Almost 10% of LSVRO events involved Indigenous children, but only 4.78% of the Queensland paediatric population is Indigenous [34]. This is consistent with previous studies conducted in New Zealand [11-13,24] which highlighted the overrepresentation of Maori and Pacific Islanders in children who sustained injuries from LSVRO events.

Only one previous study (conducted in Victoria, Australia) has reported on the association between LSVROs and geographical remoteness [19]. It highlighted remoteness as a risk factor for LSVRO deaths, as does our study. We found an inverse association between injury severity and remoteness - the majority of fatal LSVROs, half of hospital admissions and one-third of events that required pre-hospital or ED treatment only occurred outside major cities. More information is required about incidents occurring outside metropolitan areas. Is the higher fatality rate due to the large distance to definitive trauma care, or are there are contributing factors such as behaviour or vehicle type involvement? Importantly, almost half of LSVROs occurred outside major cities, yet 72% of children aged 0-15years in Queensland reside in major cities[35].

While associations have been observed between socio-economic status and higher risk of transport-related injury in general [36], the association between socioeconomic status and LSVROs has not been investigated outside New Zealand[12,24,37]. Those studies consistently identified that LSVROs occurred more frequently in children from economically disadvantaged backgrounds. In contrast, just over one-quarter of LSVRO events in the current study involved children living in areas reflecting lower relative advantage, compared with over half of events that occurred in children living in areas reflecting higher relative advantage. This relationship varied by age – a lower proportion of younger children lived in areas reflecting higher advantage than older children. It is possible that there exist reporting differences between Australia and New Zealand (i.e., that events occurring among children in areas reflecting lower advantage are under-reported). However, this is unlikely because invariably, this type of event requires some kind of medical intervention, which would have been captured in our database. It is also possible that there are differences in the definitions of social advantage used between studies. The observed differences may highlight cultural differences between Australia and New Zealand, and warrants further examination for cultural inferences that can be included in educational interventions.

As in previous literature [6,13,14,16,19,21], parents in this study were most frequently the driver in fatal LSVROs. Unfortunately this level of information is not available for non-fatal events. Parental (or carer) supervision is sporadically reported in the literature and was not consistently documented in our data set. Effective supervision in child injury prevention requires a dynamic approach[38], including three major components (attention, proximity and continuity). Information about these dimensions at time of the LSVRO event, as well as driver characteristics (e.g., age, years driving experience, etc) would be beneficial in future data collection, especially for non-fatal LSVROs.

This study contributes important information about vehicle types involved in LSVROs. Previous studies highlight the role of larger vehicles such as four- wheel-drives and sports utility vehicles in LSVROs. While our data indicate that larger vehicles were more frequently involved in fatal injuries, the vehicle type most frequently involved in non-fatal injuries was cars. Analyses on vehicle type was limited by available data – further research on specific vehicle type is essential to effectively inform injury prevention strategies. The “cars” category is very broad and it is important to understand more about the specific vehicles involved (e.g., hatchbacks, medium-sized cars, etc). These cars vary widely in relation to their blind spots [39]. It is also essential to capture information on the technical aides of vehicles involved in LSVROs (reversing cameras, sensors). Such information can be obtained only via a dedicated, prospective data collection.

Observations of fatal pedestrian data in the 1980s indicated that children 0-5years were most often fatally injured in non-traffic areas [5,40]. Since then, the majority of studies have focused solely on “non-traffic” incidents, or more commonly, events involving “driveway-related pedestrians”. Our study shows that although LSVROs most frequently occur in the home/driveway environment, a substantial proportion occur on the street/public road, and this is especially true for older children. Clearly, both locations are important points for intervention, and additional analyses are required to determine whether other characteristics vary with incident location.

The most frequent time of incident was late afternoon (3-6pm), for all age groups, consistent with other studies [5,12-13,17,20,22.24,29,41], except for one study in Victoria [19], where 57% of fatal LSVROs among children 0-15 years , occurred before midday. Early morning (6am-9am) was the second most frequent time period for LSVRO events in our study. LSVROs were equally likely to occur in every month of the year, for all age-groups, unlike most other studies [5,13,19,24,41], where LSVROs were more likely to occur in summer months. This could be due to Queensland's temperate environment, which has minimal seasonal variation in weather patterns. Only a small number of studies (each with small samples) have investigated day of the week of LSVROs [19,20,41] and in these studies LSVROs occurred most frequently between Thursday and Sunday. In our study, LSVROs were equally likely to occur on every day of the week, for all age groups

**Strengths and Limitations**

This study has strengths in comparison to previous LSVRO studies. All possible cases across the continuum of care (pre-hospital to fatality) that occurred in Queensland between 1999-2009 were included. This represents an improvement on previous studies that have been limited to major cities, or have focussed on either fatalities, hospital admissions, or cases transported by ambulance. Secondly, the case definition for LSVROs in our study is broader than that used previously, and is not limited by location (driveway) or external cause (non-traffic pedestrian) (discussed in detail elsewhere [27]). Inclusion of pre-hospital data, and data from QISU (a dedicated injury surveillance database) allowed identification of important event characteristics (location of incident, vehicle type involved, driver of vehicle) that are not recorded elsewhere for non-fatal events, and have not been described elsewhere in the literature.

Our analyses were limited by availability of data, especially for non-fatal LSVROs. While data on the number of events and some important demographic variables (age and gender) were almost 100% complete from most data sources, data regarding circumstances (e.g., information on vehicle type and size) leading to the event were not routinely or consistently recorded, because most data sources (other than QISU – a dedicated injury surveillance database) are administrative databases. Initially, it was intended that data on injury severity would be obtained from the Queensland Trauma Registry for children admitted to hospital. For various reasons, this was not possible. The Registry has now been de-funded. Instead of injury severity score, type of health service accessed was used as a proxy measure (with cases requiring only pre-hospital treatment representing the least severe injury, and fatalities the most severe). Time of call to ambulance was used as a proxy measure for time of injury. We recognise the limitations associated with both these proxy measures, however, in the absence of other information, these measures provide reasonably accurate information. Finally, it was not possible to obtain other information that would crucially inform injury prevention strategies – such as direction of vehicle at time of impact. A dedicated, prospective data collection would address most of these limitations..

**Conclusions:**

This is the first study to analyse the characteristics of fatal and non-fatal LSVROs in children 0-15years on a state-wide basis. Younger children are at greater risk for these events, and experience worse outcomes. Characteristics of LSVROs varied with age, thus age-specific interventions designed to reduce LSVROs are required. Children living outside major cities and Indigenous children were over-represented. Very little is known about the characteristics of LSVROs in these latter two groups. Further research is required to identify the burden of injury in these groups and to assist in developing appropriate injury prevention stratagem.

## Authors' Contributions

Bronwyn R Griffin: Ms Griffin conceptualised and designed the study, carried out the analysis, drafted the initial manuscript and approved the final manuscript as submitted.

Kerrianne Watt: Associate Professor Watt assisted in the design of the study, carried out quality control of analysis, reviewed and revised the manuscript and approved the final manuscript submitted.

Belinda A Wallis: Ms Wallis assisted in the design of the study and approved the final manuscript as submitted.

Linda E Shields: Professor Shields reviewed and revised the manuscript and approved the final manuscript.

Roy M Kimble: assisted in conceptualisation of the study, reviewed and revised the manuscript and approved the final manuscript as submitted.

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**Competing interests**

None

**Provenance and peer review**

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**Acronyms used**

LSVRO – Low speed vehicle run over

4WD – Four wheel drive

SUV – Sports Utility Vehicle

ICD – International classification of diseases

QISU- Queensland injury surveillance unit

EDIS- Emergency department information system

QAS – Queensland Ambulance Service

SEIFA- Socioeconomic index for ages

ED – Emergency department

## References


1. Commission for Children Young People and Child Guardian (CCYPCG). Annual Report: Deaths of Children and Young People, 2005. Commission for children and Young People and Child Guardian Queensland, Brisbane; 2005.

2. Kravitz H, Korach A. Deaths Due to Car Driveway Accidents. IMJ Ill Med J. 1964:126:688. Epub 1964/12/01.

3. Campbell-Hewson G, Egleston, C., Cope, A. Traumatic asphyxia in children. J Accid Emerg Med 1997;**14**(1):47-9. Epub 1997/01/01.

4. Bell M, Ternberg, J., Bower, R. Low velocity vehicular injuries in children--"run-over" accidents. Pediatrics 1980;**66**(4):628-31. Epub 1980/10/01.

5. Brison R, Wicklund, K., Mueller, B. Fatal pedestrian injuries to young children: a different pattern of injury. Am J Public Health 1988;**78**(7):793-5. Epub 1988/07/01.

6. Nadler EP, Courcoulas AP, Gardner MJ, Ford HR. Driveway injuries in children: risk factors, morbidity, and mortality. Pediatrics 2001;**108**(2):326-8. Epub 2001/08/03.

7. Silen M, Kokoska, E., Fendya, D., Kurkchubasche, A., Weber, T., Tracy, T. Rollover injuries in residential driveways: age-related patterns of injury. Pediatrics 1999;**104**(1):e7. Epub 1999/07/02.

8. Cavalcanti A, Barros de Alencar, C. Injuries to the head and face in 0-4 year old child victims of fatal external causes in Campina Grande, PB, Brazil. Turk J Pediatr. 2010;**52**(6):612-7.

9. Mayr JM, Eder C, Wernig J, Zebedin D, Berghold A, Corkum SH. Vehicles reversing or rolling backwards: an underestimated hazard. Inj Prev 2001;**7**(4):327-8. Epub 2002/01/05.

10. Murphy F, White S, Morreau P. Driveway-related motor vehicle injuries in the paediatric population: a preventable tragedy. N Z Med J. 2002;**115**(1160):U148. Epub 2002/10/04.

11. Shepherd M, Austin, P. and Chambers, J. Driveway runover, the influence of the built environment: A case control study. Journal of Paediatrics and Child Health 2010;**46**(12):760-7.

12. Hsun-Hsiao K, Newbury, C., Bartlett, N., Dansey, R., Morreau, P., Hamill, J. Paediatric driveway run-over injuries: time to redesign? Journal of the New Zealand Medical Association 2009;**122** (1298).

13. Roberts I, Kolbe, A., White, J. Non-traffic child pedestrian injuries. J Paediatr Child Health 1993;**29**(3):233-4. Epub 1993/06/01.

14. Griffin B, Watt K, Wallis B., Shields L, Kimble R. Paediatric low speed vehicle run-over fatalities in Queensland. Inj Prev 2011;**17**(Suppl I):i10-i3.

15. Parliamentary Travelsafe Committee. Investigation into child deaths and injuries from low speed vehicle run-overs. Queensland Parliament, 2007. Report No.

16. Anthikkat AP, Page A, Barker R. Low-speed vehicle run over fatalities in Australian children aged 0–5 years. Journal of Paediatrics and Child Health 2013;**49**(5):388-93.

17. Holland A, Liang R, Singh S, Schell D, Ross F, Cass, D. Driveway motor vehicle injuries in children. Medical Journal of Australia 2000;**173**(4):192-5. Epub 2000/09/29.

18. Byard R, Jensen L, Jensen L. Toddler run-overs--a persistent problem. J Forensic Leg Med 2009;**16**(4):202-3.

19. Robinson P, Nolan T. Paediatric slow-speed non-traffic fatalities: Victoria, Australia, 1985-1995. Accid Anal Prev 1997;**29**(6):731-7. Epub 1997/11/25.

20. Fenton SJ, Scaife ER, Meyers RL, Hansen KW, Firth SD. The prevalence of driveway back-over injuries in the era of sports utility vehicles. J Pediatr Surg 2005;**40**(12):1964-8. Epub 2005/12/13.

21. Partrick D, Bensard D, Moore E, Partington M, Karrer F. Driveway crush injuries in young children: a highly lethal, devastating, and potentially preventable event. J Pediatr Surg 1998;**33**(11):1712-5. Epub 1998/12/18.

22. Davey J, Clark MJ, Freeman J, Johnston TC, White J, Woods SD. The Prevalence and Characteristics of Paediatric Driveway Accidents in Queensland J Australas Coll Road Saf 2007;**18**(2):34-40.

23. Nhan C, Rothman L, Slater M, Howard A. Back-over collisions in child pedestrians from the Canadian Hospitals Injury Reporting and Prevention Program. Traffic Injury Prevention 2009;**10**(4):350-3.

24. Murphy F, White S, Morreau P. Driveway-related motor vehicle injuries in the paediatric population: a preventable tragedy. N Z Med J 2002;**115**(1160):U148. Epub 2002/10/04.

25. Griffin B, Watt K, Wallis B, Shields L, Kimble R. Systematic Literature Review of Incidence Rates of Low Speed Vehicle Run Over Incidents in Children. Worldviews on Evidence-based Nursing 2013(online 22 July).

26. Griffin B, Watt, K, Shields L, Kimble R. Low speed vehicle run-over incidents: Methodological issues in describing incidence and characteristics in Queensland children aged 0 – 15 years. Australasian Epidemiologist 2013;**20**(1).

27. Griffin B, Watt K. Wallis B, Shields L, Kimble R. Incidence of paediatric fatal and non-fatal low speed vehicle run over events in Queensland, Australia: eleven year analysis. BMC Public Health (under review).

28. Paine M, Henderson M. Devices to reduce the risk to young pedestrians from reversing motor vehicles. Sydney: Motor Accidents Authority of NSW, , 2001.

29. Pinkney KA, Smith A, Mann NC, Mower GD, Davis A, Dean JM. Risk of pediatric back-over injuries in residential driveways by vehicle type. Pediatr Emerg Care 2006;**22**(6):402-7. Epub 2006/06/28.

30. Geographic Information Systems. ARIA and Accessibility. South Australia [cited 2013 29th May 2013]; Available from: http://www.adelaide.edu.au/apmrc/research/projects/category/aria.html.

31. Office of Economic and Statistical Research. Accessibility and Remoteness Index of Australia. Queensland Government2012 [29th May 2013]; Available from: http://www.oesr.qld.gov.au/about-statistics/statistical-standards/national/aria.php.

32. Australian Bureau of Statistics. Socio-Economic Indexes for Areas (SEIFA). Canberra: Australian Government; 2013 [29th May 2013]; Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/2033.0.55.001Main+Features12011?OpenDocument.

33. World Health Organisation. International Classification of Diseases, ICD-10-AM, 3rd -6th Edition. WHO-Press, editor. Geneva2002.

34. Australian Bureau of Statistics. Population Characteristics, Aboriginal and Torres Strait Islander Australians. Canberra: ABS; 2010.

35. Australian Bureau of Statistics. Australian Social Trends: 2001 census of population and housing. Canberra: Australian Bureau of Statistics; 2010 [cited 2010 12 August]; Available from: http://www.abs.gov.au/AUSSTATS/abs@.nsf/2f762f95845417aeca25706c00834efa/add11adceb024dfaca2570eb0082e465!OpenDocument.

36. Poulos R, Hayen A. Finch C, Zwi A. Area socioeconomic status and childhood injury morbidiy in New South Wales, Australia. Injury Prevention Journal **2007;13**(5): p. 322-327.

37. Roberts I, Norton R, Jackson R. Driveway-related child pedestrian injuries: a case-control study. Pediatrics **1995**;95(3):405-8. Epub 1995/03/01.

38. Saluja G, Brenner R, Morrongiello B, Haynie D, Rivera M, Cheng, T. The role of supervision in child injury risk: definition, conceptual and measurement issures. . Injury Control and Safety Promotion 2004;**11**(1):17-22.

39. NRMA WEBSITE ON BLIND SPOTS

40. Mueller BA, Rivara FP, Bergman AB. Factors associated with pedestrian-vehicle collision injuries and fatalities. West J Med 1987;**146**(2):243-5. Epub 1987/02/01.

41. Winn D, Agran P, Castillo D. . Pedestrian injuries to children younger than 5 years of age. Pediatrics 1991;**88**(4):776-82. Epub 1991/10/01.