Safety of child bicyclists

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Abstract

Children walk and travel by bicycle to a lesser extent than previously. Physical activities are generally positive from a health perspective and life quality perspective. The design of the traffic environment and the regulation of traffic can support safe and independent freedom of movement for children.

Two sources were used to explore safety problems for cycling children: school questionnaires and accident statistics. A meta-analysis based on previously conducted questionnaires addressed to school children on the subject of safety as vulnerable road users in the urban environment revealed that children perceived poor visibility, intensive motor traffic and high vehicle speed as the dominant factors for a dangerous traffic environment. The factors that were found to be most problematic for children according to the accident statistics compared with older age groups were also mentioned by the children as dangerous in the traffic environment. The result is a description of safety problems based on accident statistics for children bicyclists linked to children's own opinions on characteristics and safety problems as bicyclists.

1. Introduction and purpose

Free movement of children in the physical environment is important for their health as well as for their social, cognitive, and motor development. With increasing age, children's desire for free movement increases and their territory gradually expands. However, this leads to increased exposure to risk: accidents to children are a function of mobility. There is a link between a child's freedom of movement, development and risk exposure, and how parents and other adults encourage or restrict children's freedom of movement, by driving children to destinations, for example (Adams, 1993). If motor vehicle traffic in children's immediate surroundings is poorly designed and controlled, parents may react by taking them by car to more places, and children are being driven today to a greater extent than previously (Björklid, 2002 and 2005). It is therefore important that the design of the traffic environment and the regulation of traffic permit safe and independent freedom of movement for children.

Cognitively, crossing the street is a difficult task, and children have not developed the necessary capabilities before the age of 11 or 12. Children under 12 have difficulty in estimating the direction, speed, and distance of vehicles in motion (MacGregor et al, 1999, Piaget 1969, presented by Demetre and Lee, 1992), (von Hofsten, 1980 and 1983 presented by Demetre and

Lee, 1992), (Foot et al, 1999), and (Leden, 1989). Of course, the younger the child, the more inaccurate is its assessment of speed.

The aim was to find key parameters according to children's opinions which are crucial in explaining why crashes involving children as bicyclists occur, and key parameters which were found to be more problematic for children according to the accident statistics compared with older age groups.

2. Meta-analysis

A meta-analysis of schoolchildren's opinions of what is dangerous when travelling to school is presented next. The analysis is based on school questionnaires reported by Leden et al (2006a), Leden et al (2006b), Leden (1989) and Wilhelmsson (2000), see Table 1. The investigations of Wilhelmsson (00) and Leden et al (2006b) were based on school surveys at Ribersborg Schools and Fridhem School in Malmö, Sweden. The investigations of Leden et al (2006a) were based on school surveys at the Munksund school in Piteå, Sweden. Leden (1989) refers to a larger Nordic study including studies in Högsby, Onsala, Kungsbacka, Karlshamn, Jönköping, Linköping in Sweden, Kuopio, Esbovik in Finland and Stavanger in Norway. In the study of Leden (1989) separated P/C routes (pedestrian and bicyclists routes) were also included.

Results correspond well in the later studies with the perception that it is vehicle speed that is regarded as dangerous, while the Leden joint study (1989) found that poor visibility is the most critical factor, see Table 1. This is a common reason on separated P/C routes. Generally vehicle speed, poor visibility, intensive motor traffic and failure of motorists to stop at the P/C crossing are regarded as dangerous factors.

Table 1. Schoolchildren's opinions on causes of dangerous sites. (For Leden (89) intersections.) Share of answers (%).

	Piteå, Sweden Leden et al (2006a)		Malmö, Sweden Leden et al (06b)		Malmö, Sweden Wilhelmsson (00)	Leden (89)
	Before 2004	After 2006	Before 2003	After 2006		
Vision obstructed	*10*	*14*	*8*	*9*	*7*	*24*
Intensive motor traffic	*10*	*10*	*10*	*6*	*19*	*18*
Vehicles approach from several directions	*1*	*2*	*0*	*0*	*2*	*7*
Turning motor traffic	*0*	*0*	*3*	*1*	*1*	*1*
Motorists drive fast	*25*	*17*	*30*	*20*	*34*	*16*
No traffic signals	*4*	*4*	*10*	*14*	*8*	*2*
Intensive P/C traffic	*0*	*0*	*0*	*0*	*1*	*1*
Motorists do not stop at P/C crossing	*4*	*8*	*9*	*13*	*14*	*1*
No pedestrian crossing	*6*	*8*	*1*	*1*	*1*	*2*
Carriageway too wide	*0*	*1*	*0*	*1*	*3*	-
Fear of being struck by car	*0*	*0*	*3*	*5*	*1*	
Overtaking at P/C crossing	*0*	*0*	*0*	*0*	*2*	
Miscellaneous	*40*	*35*	*27*	*31*	*5*	*14*
No. of answers	114	133	157	147		9129

The investigation of Leden et al. (06b) is, like Leden et al. (06a), an evaluation of reconstruction (regarding traffic calming) of intersections, and, in both cases, the reconstruction led to a smaller proportion of children perceiving that cars are driving fast, and a slightly larger proportion of children that cars do not stop at the crossing.

According to Johansson (2004), the result based on behavioural studies is somewhat different; pedestrians of all ages were more often given way to just after implementation of speed-reducing devices at a pedestrian crossing than before. Bicyclists also benefited. Children and the elderly did not benefit perceptibly more than other age groups. According to Johansson (2004), the waiting times were on average less than one second at all reconstructed sites two years after reconstruction, indicating good mobility. Two years after reconstruction, fewer children looked around for traffic and fewer stopped at the kerb before crossing the street at marked pedestrian crossings compared with just after, which can be interpreted as a sign of behavioural adaptation due to a feeling of increased security.

3. Crash data analysis

Three data sets were made available. The first data set is the Finnish road crash investigating teams' data (VALT in-depth crash data) from the years 1995–2005 which includes a detailed description of 459 fatalities involving bicyclists in varying road environments. The data is classified into the age groups: children (0–17 years), adults (18–64 years), and the elderly (65 years and older). However, some of the analyses presented here were made earlier (Johansson et al., 2004) using a somewhat smaller VALT data set with fatal injuries from 1995–2001. This data set is now presented with the focus on child bicyclists' safety. The second data set is based on Swedish travel surveys and self-reported crash data from 1996–2000. This data set is compared with crash data from the Swedish Road Administration as presented by Gustafsson and Thulin (2003). The third data set includes 17,843 police-reported fatalities and injuries with pedestrians and bicyclists in Finland during the years 1989–2002.

Swedish travel surveys and self-reported crash data from 1996–2000 have been compared with crash data from the Swedish Road Administration (Gustafsson and Thulin, 2003). The data is used to calculate the risk for bicyclists of different ages, and is reported as fatal injuries or severe injuries per million kilometres cycled, see Table 1. There appears to be a trend of a higher risk for older children. The elderly (64 years and over) always have higher risk than younger age groups, and the consequences of the crashes are also always most serious for them. This is largely explained by the fact that the elderly have more fragile bodies.

Regardless of road user age, most bicyclists cross the street at sites not equipped with marked pedestrian or cyclist crossings or signals, see Table 2 (based on data by Gustafsson and Thulin, 2003). The risk of injury and the consequences of the crashes are also the highest there. The risk of injury and the consequences of the crashes are always highest for elderly bicyclists than for other age groups, regardless of whether there is a marked crossing or not. In the analysis above, speed limit and crossing facility type were analysed independently. Co-variation may mean that the isolated 'true' effect of either facility type is not that which is described above. Rather, it may be that most marked pedestrian crossing are located in low-speed downtown areas, whereas many pedestrian (and bicycle) crashes occur along outlying arterials where the spacing between pedestrian crossing is much greater. Also, facilities such as pedestrian crossing are often provided where pedestrian volumes are high, and high pedestrian volumes by themselves lower the risk of an individual pedestrian or cyclist being involved in a crash (Ekman, 1996; Leden, 1997). The youngest children, 0-6 years, had a lower risk in non-urban areas than children aged

7-14 years. It is likely that children aged 0-6 years seldom travel unaccompanied by adults especially in non-urban areas, which can explain the lower risk in non-urban areas. Children aged 7-14 more often travel unaccompanied. The risk was higher for children than for adults, although the elderly always have the highest risk.

Table 1. Risk of injury and fatal crash for bicyclists per million kilometres cycled and consequence of bicycle crashes 1996–2000 (Gustafsson and Thulin, 2003).

Age (years)	Risk of injury	Risk of fatal or severe injury	Risk of fatal injury	Consequence
Urban traffic				
1–6 years	1.219	0.179	0.007	0.006
7–14 years	1.263	0.242	0.009	0.007
15–24 years	1.394	0.238	0.005 (low risk)**	0.004
25–44 years	1.081	0.199 (low risk)**	0.007 (low risk)**	0.006
45–64 years	1.221	0.283	0.015	0.012
65–84 years	1.664	0.506 (high risk)**	0.075 (high risk)* **	0.045
1–84 years	1.244	0.255	0.014	0.011
Non-urban traffic				
1–6 years	0.261	0.058	0.000	0.000
7–14 years	0.331	0.112	0.009 (low risk)**	0.026
15–24 years	0.282	0.084 (low risk)**	0.012 (low risk)**	0.041
25–44 years	0.330	0.119	0.009 (low risk)**	0.029
45–64 years	0.321	0.141	0.028	0.086
65–84 years	0.379	0.180 (high risk)* **	0.071 (high risk) * **	0.188
1–84 years	0.325	0.125	0.023	0.071

* Significantly different from the expected value based on exposure and total number of crashes (at 95% significance level) Poisson.

** Significantly different from the expected value based on exposure and total number of crashes (at 95% significance level) Normal distribution.

Consequence is defined as number of fatal injuries per reported injury crash.

Table 2. Exposure and risk of injury (injury, severe injury or fatal) and consequences in urban areas for bicyclists per million bicycle passages, 1996–2000 (Gustafsson and Thulin, 2003). (Crossings in a tunnel or on a bridge separated from the vehicle traffic are not included in the exposure presented in the table.)

Age (years)	No crossing facility			Marked crossing			Marked crossing with signal			Total no. of million person passages
	Exposure (%)	Risk of injury	Consequence	Exp.	Risk	Conseq.	Exp.	Risk	Conseq.	
1–6	*72*	0.4387	0.0114	*24*	0.4350	0.0000	*1*	5.4278*	0.0000	89
7–14	*68*	0.5813	0.0130	*17*	0.5839	0.0038	*4*	0.7550	0.0000	674
15–24	*58*	0.4376	0.0040	*21*	0.5930	0.0000	*14*	0.3550	0.0205	1099
25–44	*56*	0.3839	0.0039	*21*	0.4722	0.0065	*15*	0.2361	0.0179	1601
45–64	*65*	0.3138	0.0166	*17*	0.7358	0.0060	*11*	0.2896	0.0086	1024
65–84	*59*	0.9268*	0.0683	*19*	1.6982*	0.0538	*13*	0.4221	0.0435	238
1–84	61	0.4339	0.0152	19	0.6239	0.0104	*12*	0.3178	0.0163	4725

* Significantly higher than the expected value based on exposure and total number of crashes (at 95% significance level).

Table 3. Share of bicyclists fatally injured at posted speeds 60 km/h or more and actual speeds of 31 km/h or more.

	Total no. of fatal crashes*	*Share at posted speed 60 km/h or more (%)*	No. of bicyclists fatally injured	*Vehicle speed 31 km/h or more (%)*
Children	80	*69*	57	*93*
Adults	88	*43*	106	*83*
Elderly	86	*52*	120	*86*
Total	255	*54*	283	*86*

An examination was made of the posted speed fatalities for different age groups. As can be seen in Table 3, children in particular, but the elderly too, are frequently fatally injured on roads with posted speeds of 60 km/h or higher, but the data do not show the risk. The difference between age groups is significant ($p<0.01$). Of all bicyclists fatally injured in Finland 1995–2001, 86% were killed at actual (estimated) vehicle speeds of 31 km/h or higher. There is no significant difference with respect to different age groups.

Table 4. Consequence for bicyclists by age and speed limits (Swedish travel surveys, Gustafsson and Thulin, 2003).

Speed	Children	Adults	Elderly	All
	On marked crossing at intersection, no turning vehicles			
30	0.000	0.000	0.000	0.000
40	0.000	0.012	0.050 (low)*	0.014
50	0.008	0.010	0.075 (high)*	0.020
60	0.032	0.023	0.125 (high)*	0.043 (high)*
	On marked crossings at intersections, turning vehicles			
30	0.000 (low)*	0.062 (high)*	0.000 (low)*	0.035 (high)*
40	0.000 (low)*	0.010	0.046 (high)*	0.014
50	0.011	0.015	0.049 (high)*	0.019
60	0.000 (low)*	0.000 (low)*	0.045 (high)*	0.006
	On marked crossing on link			
30	0.000 (low)*	0.000 (low)*	0.000 (low)*	0.000 (low)*
40	0.012	0.000 (low)*	0.038	0.008
50	0.002	0.015	0.085 (high)*	0.024
60	0.032	0.024	0.100	0.049 (high)*

* Significantly different from the average (at 95% significance level).

The consequence of the crash was more serious for children at a higher speed, although the consequence was even worse for elderly, see Table 4. In most of the different types of crashes the *consequences* (number of fatal crashes per sum of fatal and other crashes) increased with vehicle speed and the age of the vulnerable road user. The consequence of crashes at intersections was less serious when a turning vehicle was involved than if the vehicle was not turning.

Child bicyclists are more often involved in fatal collisions outside built-up areas compared with other age groups according to the analysis of 1995–2005 data. The figure is 56%, compared with the elderly 39% and other adult bicyclists 30% ($p<0.001$). In fatal crashes (from 1995–2001) child bicyclists are more often (18%) in hurry compared with other age groups (6%).

It is clear (in Finnish road crash investigating teams' data, VALT in-depth crash data) from the years 1995–2005 that children are more significantly involved in accidents when visibility has been poor for the specific vehicle speed (21% of the accidents involving children, as compared with 6% for adult age groups ($p<1.0e\text{-}7$)).

There are no significant differences with respect to age in the number of bicyclists fatally injured on streets that had a downhill grade. About one-third of all fatally injured bicyclists were killed on downhill streets. No significant difference with respect to age is seen in the number of bicyclists fatally injured on streets that had an uphill slope either, with about 20% of all bicyclists fatally injured on uphill streets. In darkness (including dawn and dusk), non-elderly adult bicyclists are significantly ($p<1.0e\text{-}9$) more often involved in crashes (37%) than children (13%) and the elderly (11%).

The majority, about two-thirds, of all bicyclist crashes at marked cyclist crossings occur at intersections. Child bicyclists are not more often involved in fatal crashes at intersections than other age groups. However, both children and the elderly are somewhat less involved in crashes with injuries at intersections than the younger adult age group. Most of the crashes do not involve a turning vehicle, as one-third of all accidents involve a turning motor vehicle.

14% of the children intend to turn left in fatal crashes compared with 8% for adults and 22% for the elderly. The difference is significant ($p<0.002$) between the three age groups, although children are not more involved in those types of accidents than the other age groups. Child bicyclists are not significantly more involved in crashes when intending to *turn left* compared with other age groups.

18% of the adult bicyclists are involved in single-vehicle crashes compared with 2% for children and 5% for the elderly. The differences are significant ($p<1.0e\text{-}05$). For crashes involving other pedestrians, other bicyclists or mopeds, the share is about 7% for all age groups. Child bicyclists are not over-involved in crashes where the road surface is in disrepair; the share was about 10% for all road users.

The share of child bicyclists who fail to obey rules is somewhat lower than for other bicyclists. 71 % of the children failed to obey rules compared with 82% of the older age groups, although the difference is not statistically significant. Failure to obey rules could mean, for example, that the shortest way is chosen though forbidden, that the cyclist is impaired by alcohol or is not sufficiently alert.

Non-elderly adult bicyclists are significantly more often ($p<1.0e\text{-}20$) affected by alcohol (50% proven impaired) than elderly bicyclists (9%) or children (2%). ‘Affected’ is in this analysis defined as a measured blood alcohol level above 0.0 percent. Children affected by alcohol are most likely to be teenagers.

The data shows that 46% of child bicyclists involved in single-vehicle crashes use a mountain bike compared with 11% of adults and 1% of the elderly. The difference is significant ($p<1.0e\text{-}19$). Future studies should include information on usage of different types of bicycles by children and the other age groups, to be able to estimate risks related to type of bicycle.

There are significantly ($p=1.0e\text{-}08$) more gears on child bicycles, when involved in fatal crashes, compared with other age groups. The share without gears is 29% for child bicycles, 40% for adults and 67% for the elderly. The front lights on children’s bicycles are less often in working order compared with other age groups, 22 % of children had front lights in order, compared with 47% for other age groups ($p<0.001$).

A slightly lower percentage of children’s bicycles are equipped with a front reflector, but the difference is not significant. About 80% of all age groups’ bicycles were equipped with a reflector at the rear and about 40% had reflectors on the front. About 50% had reflectors on the front and rear wheels. Children’s bicycles were often equipped with pedal reflectors (85%), although a higher proportion (92%) of elderly bicyclists had them fitted.

4. Conclusion and discussion

Children mentioned poor visibility, intensive motor traffic and high vehicle speed as the dominant factors for a dangerous traffic environment. The factors that were found to be more problematic for children in the accident statistics compared with older age groups were also mentioned by the children as dangerous in the traffic environment.

Child bicyclists do not have higher risks the younger they are, if risk exposure is defined as distance travelled. On the contrary, there appears to be a slight increase in risk the older the child is. This is a surprising result. One explanation may be that younger children are more often cycling together with parents and on streets with lower speeds. Child bicyclists are more often involved in accidents at sites with speeds higher than 60 km/h, and most of the accidents occur at an actual vehicle speed above 30 km/h. However risk data is missing. Child bicyclists are more often involved in fatal collisions outside built-up areas compared with other age groups. This can largely be explained by the higher speeds outside built-up areas. This supports the importance of the correct vehicle speeds where child bicyclists intermingle with vehicle traffic.

Child bicyclists are more often in a hurry compared with other age groups, although the difference is not statistically significant. Children's unpredictability has been suggested as the clearest explanation for traffic accidents involving children as pedestrians (Van der Molen presented by Cross, 1988, Räämä, 1993, Gaskell et al, 1989), but there is less documented evidence of whether this is also true for children as bicyclists.

In fatal crashes child bicyclists are more often involved at sites with poor visibility for the specific vehicle speed. Children's ability to assess traffic, and their overall overview of their surroundings, depends on factors such as their height (Connely et al, 1998). Parked cars, trees, and buildings make it difficult for children to get a good view of traffic (Arnold et al, 1990). Good visibility is therefore crucial.

Adults (18-64 years) are significantly more often involved in accidents in darkness than the children and the elderly, which means accidents involving children most often occur in daylight. One likely explanation is that children rarely cycle during darkness. Better data is need about exposure during daylight and darkness to be able to estimate the risk for different light conditions.

Child bicyclists are not more involved in crashes when intending to turn left compared with other age groups. This is perhaps not as unexpected as the result that the elderly have higher risk when intending to turn left (Leden, 2008).

Child bicyclists are not more often involved in fatal single-vehicle crashes and in crashes with pedestrians and other bicyclists compared with other age groups; in fact it is the adult age group that are more involved in single accidents, or accidents with other non-motorised road users. The road surface is not a clear problem either, as child bicyclists are not more often involved in fatal crashes when the road surface is damaged compared with other age groups.

In fatal crashes, child bicyclists obey rules at least as often as other age groups. It has been proven in previous studies that children behave more carefully than other age groups at least as pedestrians (Arnold et al, 1990).

An analysis has also been made of whether the bicycle itself is a factor contributing to the accident. Mountain bikes involved in fatal crashes are ridden more often by child bicyclists than other age groups. Children's bicycles involved in fatal crashes also have significantly more gears compared with other age groups. Children's bicycles involved in fatal crashes have front lights in working order less often than compared with other age groups. Children's bicycles involved in fatal crashes have reflectors as often as other age groups. However, better data is needed about the type of bicycles used in general to be able to estimate risk for different types of bikes and equipment.

Acknowledgement

The authors would like to thank Trygg-Hansas forskningfond for kindly providing funding for the project.

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