Characteristics of bicycle crashes in an adolescent population in Flanders (Belgium)

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Subtitle: Retrospective study design using a school and insurance-based data collection

ABSTRACT

Introduction: In regions where transportation is mainly motorized, air pollution and traffic congestion are rife. Active transportation such as cycling might be a solution but safety is a major concern. An efficient science based safety policy is needed. The aim of this paper is to analyze in depth the bicycle crash causes and characteristics in an adolescent population (14-18 yr).

Methods: By using questionnaires for self-reported bicycle crashes, bicycle crash data were collected from insurance companies (January 2014 to June 2015) and from schools (November 2013 to March 2014). Six bicycle crash causes were predefined and possible differences between schools and insurance companies were analyzed.

Results: Eighty-six school and 78 insurance registered crashes were analyzed. “Distraction of the cyclist” and “third party crossing a bicycle path failing to see the cyclist” are the main causes of bicycle crashes (both 29%). Bad (maintained) infrastructure accounted for 21% of the crash causes. Bicycle crashes reported at insurance companies needed significantly more medical attention and led to high absenteeism (57% at least one day of absenteeism). Only 21% of the bicycle crashes reported at insurance companies were also reported in the official police database.

Conclusion: The human factor was the main cause accounting for 79% of the crashes. Bicycle crashes involving a car accounted for 42% and single bicycle crashes accounted for 31% of the total number of crashes. From the bicycle crashes registered at insurance companies 21% was also registered in official police statistics. A combination of information, education and changing the bicycle specific environment might reduce the consequences of human errors more efficiently.

Key words: bicycling; safety; crash causes; adolescents; active mobility

Introduction

Exposure to noise and air pollution and traffic jams are important drawbacks in regions where transportation is mainly motorized. Policy makers are seeking solutions such as a modal shift from motorized to active transportation (cycling and walking) in order to reduce congestion and environmental pollution. Additionally, when replacing car trips by bicycle trips the increased physical activity has the potential to improve public health since physical inactivity is a major cause of several health issues like obesity and cardiovascular diseases (1-3). These health benefits far outweigh the small health risk associated from increased air pollution exposure (4-7). Despite the many advantages of cycling for transportation, the limited distance that can be overcome, the weather and safety are some serious drawbacks cited for not (taking up) cycling for daily transportation. The weather and distance cannot be influenced by policy makers, but some other factors such as the crash risk (perception) can be decreased with effective policies. Safety is for many people (adults and parents who decide for their children) a reason for not (taking up) cycling (8). Therefore, policymakers should invest in increasing the safety, by decreasing the prevalence and severity of crashed cyclists. This will have a positive influence on the health of those who already cycle and those who would like to take up cycling. Devising efficient and effective safety policies requires a good collection of data and sound analysis of cycling crashes.

Multiple approaches are used specifically to analyze bicycle crashes. Each method focuses on different aspects of bicycle safety. Studies analyzing bicycle crashes using hospital data often focus on the risk factors for serious injury (9-14). Whatever the outcome of these studies, they are based on incomplete bicycle crash data (15, 16) since only a small fraction are registered in hospital databases. Hospital registered events and injuries are biased towards more serious, major (crashes leading to a hospitalization of more than 24h) and fatal bicycle crashes. Additionally, these studies are more focused on the consequences of the crash rather than the cause and circumstances of these crashes. By understanding the causes and circumstances of bicycle crashes, policy makers can take appropriate steps to improve bicycle safety and reduce bicycle crash prevalence.

Studies using officially registered bicycle crash data (data that is used for policy guidelines such as police databases) contain wide age ranges because each bicycle crash victim that is registered through this instance will be recorded no matter the age of the victim. In contrast, the available studies that use self-reported bicycle crashes in a bicycling population are mostly done in a working population (17) (e.g. asking employees whether or not they were involved in a bicycle crash), meaning adults between 18 years and 65 years are overrepresented in the available studies. There are no studies focusing on self-reported bicycle crash characteristics in an adolescent population (17). However, in Belgium between 2000 and 2007, 1713 adolescents (12–17 yrs) were involved in officially registered bicycle crashes compared to 831 young adults (18-24 yrs) or 1284 adults aged 25-39 yrs (18).

The self-reported method gives a more accurate representation of the crashes within an bicycling population regardless of the severity of the crashes and in addition it gives access to detailed information on the crash circumstances. However, this method registers a very small number of major crashes and therefore focuses more on minor crashes (19, 20). We suggest here that a combination of self-reported bicycle crashes and officially registered bicycle crashes could contain enough data for the analysis of both, minor and major bicycle crashes.

Therefore, the aim of this study was to analyze in depth the bicycle crash causes and characteristics in an adolescent population. By using self-reported bicycle crashes, detailed information on crash circumstances could be collected. Also aspects of subjective safety were taken into consideration (21-24). For this study, we collected bicycle crash data from insurance companies and from schools. We hypothesize that the self-reported crashes and injuries are less severe on average than those reported by insurance companies.

Methods

Definitions

A crash (25) was defined as either a collision or single bicycle crash. A collision was a crash with a third party involved regardless of fault. A single bicycle crash was a crash with no third party involved (including a collision with a fixed or stationary object) (26).

The term "self-reported" indicates that a questionnaire was filled out by the victim of a bicycle crash.

Bicycle crashes needed to comply with all of the following inclusion criteria: (i) crash occurred during commuter cycling (cycling for transportation); (ii) acute crash; (iii) crash with material and/or physical damage; (iv) victims aged between 14 and 18 years at the time of the crash and (v) victims were riding a bicycle at the time of the crash. An acute crash was defined as a crash with a sudden etiology (e.g. slipping on a wet surface), as opposed to gradual or progressive etiology (e.g. pain in the knee from an overuse injury).

Bicycle crashes were excluded when the questionnaires were not filled out by the victims themselves or when the description of the bicycle crash circumstances was lacking .

Study design

In order to collect data of bicycle crashes in an adolescent population, this study combined bicycle crash data collected through eight schools and bicycle crashes registered at two insurance companies.

In Belgium, students are insured by the school during the trips from and to school. Therefore, if a student is involved in a crash with medical and/or material consequence, the school will report it to their insurance company. For the insurance registered bicycle crashes, insurance companies were asked to participate in the study.

Their crash database was screened by the research team for relevant crashes from January 2014 to June 2015. Subsequently, a letter with a link to an online questionnaire was sent to the victims of all relevant cases (N=527).

For the bicycle crashes collected through schools from November 2013 to March 2014, a total of 1600 adolescents were personally contacted and asked whether they were involved in a bicycle crash in the past 12 months. When they were involved in a bicycle crash, the same questionnaire used for the insurance companies was filled out. Although adolescents could report more than one crash in the past 12 months, no one reported more than one crash. Before analysis, all questionnaires were screened for duplicates between insurance and school registered crashes. One duplicate in insurance and school registered crashes was excluded. After exclusion, we looked at both data sources separately since we expected the insurance registered crashes to be more severe.

The Vrije Universiteit Brussel ethical committee approved the study (B.U.N. 143201318030).

Questionnaires

For this study, recent literature on adolescents (8, 27, 28) was used to adapt the questionnaire used by de Geus et al. (2012) to the specific adolescent population. The questionnaire from de Geus et al. (2012) was inspired by existing national official registration systems for traffic crashes and recent literature (29). The questionnaire was designed to collect detailed information on the (i) context and circumstances of the crash, (ii) cause of the crash, (iii) presence and cause of possible physical injuries or material damage, (iv) type of injury, (v) protective and preventive measures taken at the time of the crash, (vi) medical care, (vii) reporting by police, insurance or hospital. The first two questions were open questions: “Where were you cycling, what were the circumstances?” and “How did the crash happen, what went wrong?”. Those two first questions were used to define the cause of the crash. *The remaining questions were multiple choice. If the victims could not answer the question (couldn’t remember) they were asked to choose the “unknown” option.*

Injury severity

Information about injury severity was retrieved by several questions. For the first question, a detailed dummy figure showing 23 body parts was shown. Crash victims were asked to indicate each body part that was injured. In the second question the type of injury (eg, fractures, deep cuts, abrasions, contusion, sprain, muscle injury, burns) for each body part was asked. These two questions were used to identify the International Classification of Diseases (ICD-9-CM) and its related Survival Risk Ratios (SRR). The ICD-9-CM and the related SRRs of all reported injuries (based on US databases) were used to calculate the International Classification of Injury Severity Score (ICISS) according to Osler et al. 1996 (30). The ICISS score is defined as the product of all SRRs for each individual person’s injuries. Scores range from 0 (fatal) to 1 (complete recovery). **Victims without injury got an ICISS score of 1 and were also included in the analysis**. For more details on different types of injury scores we refer to Van Belleghem et al. 2015 (31).

To further evaluate the severity of the crash, the following questions were asked: “Did you get any medical attention?” where the victims had four choices: 1) Yes, an ambulance brought me to the hospital; 2) Yes, someone brought me to a doctor or/hospital; 3) I took care of the injury myself with or without the help of my parents or school staff; 4) No medical attention needed. Another question concerning the injury severity was: “Did you stay in the hospital?”, were three answers were possible: 1) No; 2) Yes<24h; 3) Yes>24h. The last question concerning the severity of the crash was whether or not there was an official police report where the victims had four choices: 1) the police came to the location of the crash; 2) **the victim** made a police report or 3) the victim did not remember.

Defining crash causes

We predefined five crash causes based on literature (32, 33), police recommendations and policy guidelines. First, there are the crashes caused by “distraction of the cyclist”. These are typically crashes were no other cause could be identified but the victim himself. Examples of these crashes are when cyclists ride side by side and they then hit each other with the handlebar or when a cyclist is riding hands free. The second defined cause was “infrastructure in bad state”. These crashes are characterized by single bicycle crashes and infrastructure plays an important role in the cause of the crash. Typically holes, bumps, branches, snow or ice are the cause of these crashes. A third defined cause was “failed to notice”. In these crashes a third party is involved and at least one party failed to notice the other party in an early phase of the decision making (32) and therefore a collision could not be avoided. A fourth cause was “technical failure” such as a shoe lace stuck in the bracket. The last predefined cause was “traffic rule infringement”. Typically **traffic rule infringements** are characterized by a misunderstanding when one party does not respect the traffic rules. For example a bicycl**ist** crossing a street on a pedestrian crossing or expecting to have priority at a crossing where there is none **(traffic rule infringement of the bicyclist)**, **or a car driver overtaking a bicyclist when there is not enough space and thereby hitting the bicyclist (traffic rule infringement of the third party).**

These predefined causes were used in the analysis of the open question “How did the crash happen and what went wrong?”. nVIVO 10 (34) was used to perform thematic analysis of these open questions. Before analysis, possible variables were thought of based on bicycle crash literature. This included variables concerning involvement of a third party, crash type and crash cause. After an initial analysis we split up “traffic rule infringement” into “traffic rule infringement of the cyclist” and “traffic rule infringement of the third party”. We also redefined “failed to notice” in “third party crosses bicycle path” as this definition suited more the descriptions given by the crash victims. The causes “distraction of the cyclist", "traffic rule infringement", "traffic rule infringement of the cyclist" and "third party crosses bicycle paths" were defined as 'human error'. The final crash causes are shown in Table 5.

To avoid discussion on what the actual cause of the crash was, a secondary crash cause was defined in chronological order of the crash event. For example, when a victim described he was talking to a friend and failed to see the bump in the road, the first defined cause was "distraction" and the secondary cause was "bad infrastructure". Primary and secondary cause were identical if no different secondary cause could be identified.

Statistical analysis

SPSS version 23 was used for statistical analysis. A chi-square test of independence was performed to examine the independence between data source (insurance vs school) and crash characteristics. Data with less than 6 cases were excluded for the post-hoc analysis due to a lack of power. Statistical significance was set at $p<0.05$ and corrected for alpha inflation due to multiple testing.

Study area

Data collected through the insurance companies covered the northern part (Flanders and Brussels Capital Region) of Belgium. Flanders is a small industrialized European region of 13.682 km² with approximately 7,500,000 inhabitants. The largest city next to Brussels is Antwerp with approximately 500,000 inhabitants on 204 km². Cities between Antwerp and Brussels tend to sprawl into their peripheries leading to dense road networks and favoring car use for commuting trips. In the Flanders region there is a road network of 70,604 km which comprises 4.3% of the surface (35). Fifty percent of the trips shorter than 5 km are done by car, 22.7% by bicycle and 19.1% are pedestrians. The modal share for trips more than 5 km is 61.8% for car trips, 14.6% for cyclists and 11% are pedestrians (36).

Figure 1. shows the major land-use categories in the Flemish and Brussels Capital region. The black dots indicate the location of the participating schools in urban and suburban areas.

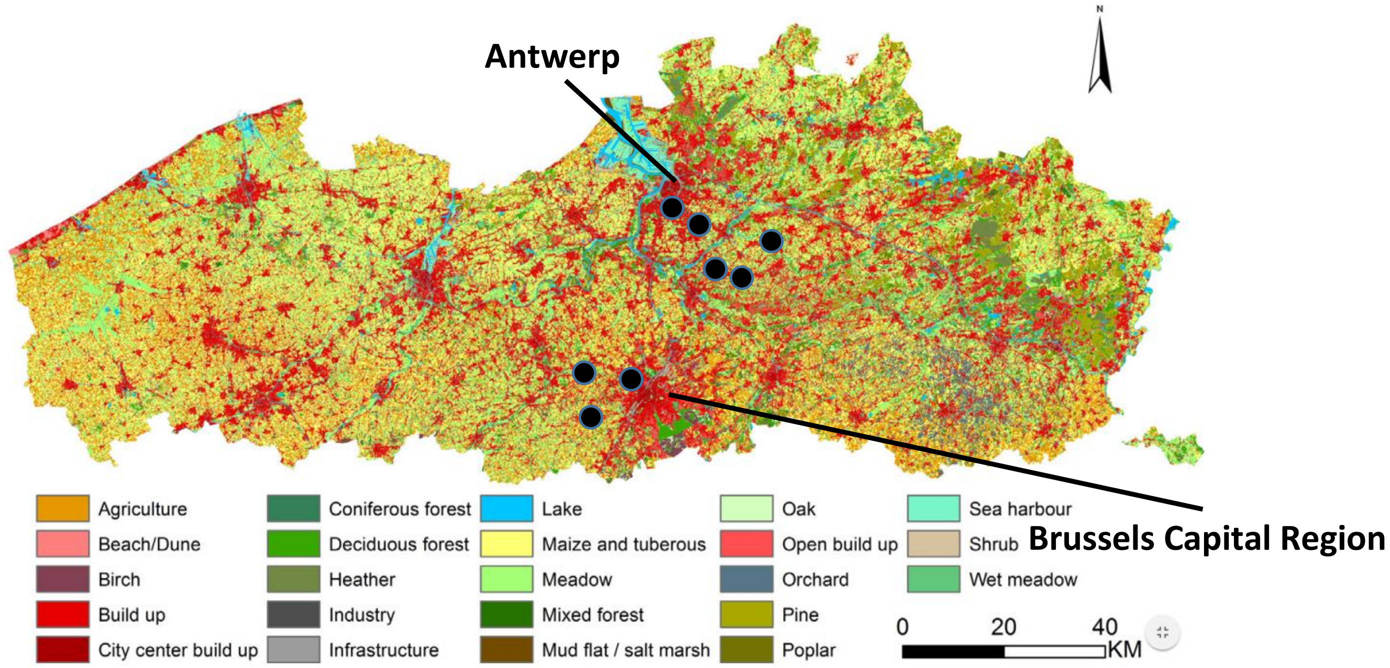

Figure 1. Study area and location of participating schools (37)

Results

Participants

All participants were aged between 14-18 yrs. Hundred and two adolescents out of 1600 adolescents that were contacted through the eight schools reported to have been involved in a bicycle crash in the past twelve months. Eighty-six of them could be included for further analysis. The other crashes occurred during leisure cycling or were bicycle crashes where the adolescent was not the cyclist but a witness of a bicycle crash.

Five hundred and twenty-seven crashes were considered relevant in the insurance companies databases. With a response rate of 16% and after filtering for the inclusion criteria, 77 completed questionnaires remained (14.6%).

The average time between filling out the questionnaire and the date of the crash was shorter for the crashes registered at the insurance companies than for the crashes collected through schools, 94 ± 26 days and 150 ± 116 days respectively ($p=0.002$). Differences between genders could not be analyzed due to missing data. There were no differences according to age.

Road characteristics

Sixty seven percent of the crashes occurred on straight tracks and 12% of the crashes occurred in a curve. Nine percent of the crashes happened at an intersection with no traffic lights and 8% happened at intersections with traffic lights. The remaining crashes happened at a roundabout or at a pedestrian crossing.

In 47% of the crashes cyclists cycled on a road without any markings for cyclists. In another 16% of the crashes, cyclists were cycling on a bicycle path at road level separated with markings only. Twenty-two percent of the crashes occurred on a separated bicycle path and 9% of the crashes occurred on roads or tracks where no motorized vehicles were allowed. The remaining 5% of the crashes were on pedestrian paths.

In Table 1, road characteristics **(Infrastructural characteristics and bicycle path characteristics)** are split up for both sources, data collected through schools and data collected through insurance companies. A Chi square test was performed and no relationship was found between data sources and **infrastructural** characteristics X^2 (df=5, N=163)=10.7 $p=0.058$ **nor** between data sources and bicycle path characteristics X^2 (df=4, N=163)=4.43 and $p=0.489$.

Table 1. Infrastructure characteristics and bicycle path characteristics

Infrastructural characteristics	**Schools (N=86)**	**Insurance companies (N=77)**	**TOTAL (N=163)**

Unknown #	9% (N=8)	3% (N=2)	7% (N=10)
Straight tracks	53% (N=46)	79% (N=61)	67% (N=107)
Curve #	12% (N=10)	7% (N=5)	12% (N=15)
Intersection without traffic-lights #	11% (N=9)	5% (N=4)	9% (N=13)
Intersection with traffic-lights #	13% (N=11)	5% (N=4)	8% (N=15)
Other #	3% (N=2)	2% (N=1)	4% (N=3)
Bicycle path characteristics	**Schools**	**Insurance companies**	**TOTAL**
No bicycle markings	49% (N=42)	44% (N=34)	47% (N=76)
Cycling on road level with markings	13% (N=11)	22% (N=17)	16% (N=28)
Cycling on separated bicycle path #	24% (N=21)	19% (N=15)	22% (N=36)
No motorized vehicles allowed #	7% (N=6)	15% (N=11)	10% (N=17)
Pedestrian paths #	7% (N=6)	0% (N=0)	5% (N=6)

 # 6 cases or less for at least one of the data sources

Time of day and weather conditions

Forty-four percent of the victims couldn't remember the weather at the time of the crash and forty-two percent of the victims couldn't remember the road condition in respect to the weather. From the available questionnaires, 40% of the crashes occurred in dry weather but only 33% had also dry road surfaces. Nine percent of the crashes occurred in the rain and 12% of the crashes happened on a wet surface. Four percent of the crashes happened in snow or glazed frost and 11% of the crashes happened on snowy, icy or frozen surface.

In Table 2 and Table 3, weather and road conditions are split up for both sources, data collected through schools and data collected through insurance companies. A chi-square test was performed and a relation was found between data source and road condition, X^2 (df=4, N=163)=20.97 ($p<0.000$) and between data source and weather, X^2 (df=5, N=163)=18.57 ($p<0.005$). Bicycle crash characteristics collected through schools had less information on weather and road condition (more victims reported they couldn't remember).

Table 2. Weather conditions

Weather	Schools (N=86)	Insurance companies (N=77)	TOTAL (N=163)
Unknown	57%* (N=49)	30%* (N=23)	44% (N=72)
Dry	26%*(N=22)	55%* (N=43)	40% (N=65)
Rain	8% (N=7)	10% (N=8)	9% (N=15)
Snow or glazed frost #	7% (N=6)	1% (N=1)	4% (N=7)
Foggy #	1% (N=1)	1% (N=1)	1% (N=2)
Strong winds #	1% (N=1)	1% (N=1)	1% (N=2)

 # 6 cases or less for at least one of the data sources

**post-hoc p<0.01*

Table 3. Road conditions at the time of the crash

Road condition	Schools (N=86)	Insurance companies (N=77)	TOTAL (N=163)
Unknown	57%* (N=49)	25%* (N=19)	42% (N=68)
Dry	20%* (N=17)	47%* (N=37)	33% (N=54)

Wet	10% (N=9)	15% (N=11)	12% (N=20)
Glazed frost, snow	12% (N=10)	11% (N=8)	11% (N=18)
Dirt, leaves, branches, etc. #	1% (N=1)	3% (N=2)	2% (N=3)

 # 6 cases or less for at least one of the data sources

**post hoc p<0.01*

Involvement of third party

Thirty one percent of all registered bicycle crashes were single bicycle crashes. The other crashes involved cars (42%), other cyclists (22%), pedestrians (4%) or a motorcycle (1%) (Table 4, second last column). All crashes were subdivided based on the data source: schools and insurance (Table 4, 'TOTAL' columns). A chi-square test was performed and no **statistically significant relationship** was found between data source and third party involvement, X^2 (df=4, N=163)=6.71 (p=0.15).

Because in Belgium, official statistics are based on statistic from police reports, we were interested to know which accidents were reported to the police (Table 4, 'Reported to police'). In 12% of the crashes the police came to the place of the crash and made an official police report. A chi-square test was performed and a **statistically significant relationship** was found between data source and police registration , X^2 (df=1, N=163)=9.03 (p=0.003).

Table 4 Portion of bicycle crashes categorized per involvement of a third party, with and without an official report of the police

Third party	Bicycle crashes collected through schools		Bicycle crashes collected through insurance companies		SUM of bicycle crashes collected through schools and insurance companies	
	TOTAL	Reported to police	TOTAL	Reported to police	GRAND TOTAL	Reported at police
Single bicycle crashes	N=30	N=1 (3%)	N=20	N=3 (16%)	N=50 (31%)	N=4 (8%)

Cyclist	N=15	N=0 (0%)	N=21	N=1 (5%)	N=36 (22%)	N=1 (3%)
Car	N=40	N=2 (5%)*	N=29	N=9 (35%)*	N=69 (42%)	N=11 (17%)
Pedestrian	N=2	N=1 (50%)	N=4	N=1 (25%)	N=6 (4%)	N=2 (33%)
Motor cycle	/		N=2	N=1 (50%)	N=2 (1%)	N=1 (50%)
Total	N=87	N=4 (5%)	N=76	N=16 (21%)	N=163	N=20 (12%)

/ = no bicycle crashes registered in this category

*post hoc p<0.05

Cause of the crashes (circumstances)

The frequency of **the primary** 6 predefined crash causes are shown in table 5. Infrastructure in bad condition accounted for 21% of the crash causes. This cause could be split up into “bad road condition” accounting for 6% of the crash causes and into “ice, snow, branches or other debris on the surface” accounting for 15% of the causes. 79% of the crashes were due to human error. A Chi square test was performed and no relationship was found between data sources and crash causes, $X^2(df=5, N=163)=11.1$ ($p=0.087$). Primary and secondary cause were identical in 87% of the cases.

Table 5 Primary bicycle crash causes

Cause	Schools (N=86)	Insurance companies (N=77)	TOTAL (N=163)
Distracted cyclist $	34% (N=29)	23% (N=18)	29% (N=47)

Infrastructure in bad condition	26% (N=22)	15% (N=12)	21% (N=34)
Traffic rule infringement # $	6% (N=5)	6% (N=5)	6% (N=10)
Traffic rule infringement of third party $	12% (N=10)	19% (N=15)	15% (N=25)
Third party crosses bicycle path and failed to notice cyclist $	23% (N=20)	35% (N=27)	29% (N=47)
Technical failure #	0% (N=0)	1% (N=1)	0% (N=1)

 # 6 cases or less for at least one of the data sources

$ human error

Injury severity

Hundred forty-five victims out of 163 included crashes reported whether or not they had a physical injury. The average ICISS score was 0.9921 ± 0.0277. There was no statistically significant difference in ICISS score between the schools and the insurance companies (ICISS scores: 0.9938 ± 0.0308 and 0.9902 ± 0.0237 respectively). A Chi square test was performed and a relationship was found between data sources and medical attention, $X^2(3, N=105)=55.7$ ($p<0.001$) (figure 2). For the insurance companies, 43% of the victims had no absenteeism due to the bicycle crash whereas for the schools this was 98% ($p<0.001$). Two percent of the victims were wearing a helmet at the time of the crash and 11% was wearing high visibility clothing.

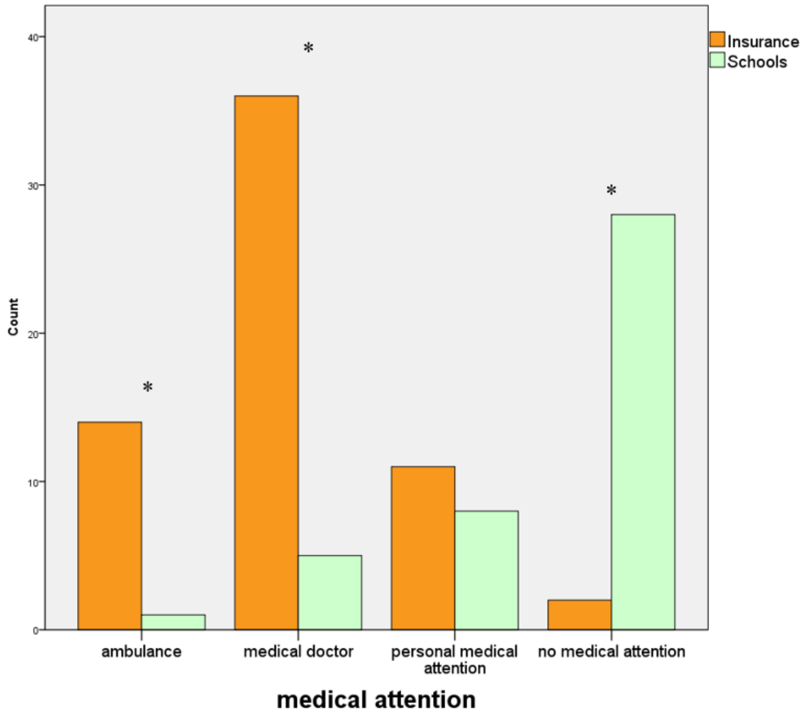

*Figure 2. Medical attention needed due to the bicycle crash; * significant difference between insurance and schools data (p<0.005)*

Discussion

The aim of the study was to analyze bicycle crash causes and characteristics in an adolescent population in Flanders. **Hundred sixty-three** crashes were identified and analyzed in detail. Distraction by the cyclist and bicycle path crossing by a third party were the most frequent causes of bicycle crashes (both 29%). Traffic rule infringement accounted for 21% of the crashes. Together with distraction and third party crossing a bicycle path, 79% of the crash causes in this study are due to a 'human factor'.

The importance of the 'human factor' in traffic crashes has been shown and studied before (33, 38-40). It has been shown before that the use of mobile phones lead to lower cycling speeds, reduced peripheral vision and had a negative impact on cycling performance (41). Using information and publicity or changing traffic legislation on their own was shown to be unsuccessful in reducing road traffic crashes (42, 43). Nevertheless, active participation and education in traffic at younger age might improve the skills on public roads. However, reducing the human error to 0 is impossible. Therefore, rather than focusing solely on the 'human behavior', changing the immediate environment might reduce the consequences of human errors, made by all road users (44).

The crash cause "third party crossing a bicycle path" is often due to the "looked but failed to see" phenomenon (45). A cyclist is hard to perceive as a potential danger for a car driver, especially when there is a large number of dangers that might be expected for example at an intersection (45). By reducing other potential dangers and by concentrating the bicycle traffic on large lanes with bicycle specific infrastructure, a (group of) cyclist(s) might be recognized as potentially dangerous in an earlier phase in the decision making when exiting a driveway or making a turn.

Another important cause for bicycle crashes was the poorly maintained infrastructure (21%). These findings are in line with the results of de Geus et al. (19) where "distraction" and "third party crossing bicycle path" were not defined but poorly maintained road surface was found to be a major cause for bicycle crashes in an adult population. Often bicycle paths are not sprayed with brine or otherwise de-iced in the winter in contrast to the main road or they are not cleaned after a storm, leaving branches and other debris on the surface. Therefore, separated bicycle paths should be designed in such a way that frequent maintenance can be performed without restraint. Also the weather seems to have played an important role since 8% of the crashes occurred in the rain whereas in Belgium, it rains only 6% of the time. The same goes for snow and glazed frost.

Bicycle crashes involving a car account for 42% of the reported crashes. Crossing bicycle paths and turning right are the most frequent causes (28%). These crashes are typically "failed to notice" incidents (45, 46). When a cyclist is on a straight track, the speed will be relatively high and when taken by surprise (e.g. opening doors or car exiting a driveway) crash consequences can be severe due to the higher speed and shorter reaction time. In order to reduce this type of crashes, car drivers (and passengers) need to be more aware of the presence of cyclists or cyclists should cycle at a lower speed. Decreasing the number of “failed to notice” accidents can be achieved by increasing the visibility and the traffic situations should be made understandable and legible, so that (young) cyclists can focus on oncoming traffic (8). Urban planners should take into account that (young) children cycle at a lower height and are less visible for other road users and have a more limited view of the traffic situation compared with adults. Hedges, walls or other obstacles that obstruct the view of all road users should be avoided, cars should not be allowed to park in the direct surrounding of intersections and mirrors could be placed so road users can see what comes around the corner.

Single bicycle crashes accounted for 31% of the total number of crashes. They were caused by “distraction of the bicyclist” or “infrastructure in bad condition”. It has been shown that in countries where the modal share of bicyclists is high, single-bicycle crashes are common (47). Schepers et al. (28) found that about 50% of the single-bicycle crashes are related to infrastructure: the cyclist collides with an obstacle (12%), veered off the road (21%), the bicycle skidded due to a slippery road surface (18%), or the rider was unable to stabilize the bicycle or stay on the bike because of an uneven road surface (7%). The first two categories happen due to the cyclist inadvertently taking a dangerous riding line, while the last two happen under more direct influence of the road surface conditions.

Only 12% of all the bicycle crashes were reported by the police. The under-reporting of bicycle crashes is well known (19, 48, 49). In the study of de Geus et al., involving mostly minor bicycle crashes, 11% of the crashes had a police intervention but only 7% were also officially recorded. Despite this under-reporting, police databases are still the major source of information used to inform transportation and traffic safety policy. Our data shows that insurance companies register 5 times more bicycle crashes compared to the police databases. Therefore, by using data from insurance companies, a more complete and diverse dataset of bicycle crashes can be addressed and better science based decisions can be made when setting up transportation policy.

According to the ICISS scores there is no difference in Injury severity between the data collected through schools and data collected through insurance companies. Therefore our hypothesis that the datasets would be different in terms of severity needs to be rejected. However, when looking at figure 2, the number of short hospitalizations and medical attention needed due to the bicycle crash was higher for crashes registered at insurance companies**. This suggest that they are associated with more severe injuries or that crashes with severe injuries are more likely to be reported to the insurance companies**. Therefore we can hypothesize that crashes registered at insurance companies may have a more important economic impact than self-reported bicycle crashes (50).

Some limitations must be considered when interpreting our results. **The answers at the end of the questionnaire were missing in many cases. This was probably due to the length of the questionnaire and the inherent loss of motivation to fill out the questionnaire. Therefore the relationship between gender and accident risk could not be analyzed.** *A weakness of a retrospective study design is the recall bias, resulting in the fact that especially the most serious crashes will be remembered or registered. There might be a difference in recall bias between schools and insurance companies since the average time between filling out the questionnaire and the date of the crash was shorter for the crashes registered at the insurance companies (*94 ± 26 days*) than for the crashes collected through schools (*150 ± 116 days*). Additionally, the response rate to the questionnaire from the insurance companies was very low (15%). Therefore, this data may not be representative for the whole insurance database. Also here, we could expect that victims of serious crashes were more likely to respond to the questionnaire. No measure of exposure* (*e.g. distance, time, trips) could be included. Therefore we cannot make any statement on what would be the safest or most risky type of bicycle infrastructure (17).*

Conclusion

We found that the human factor was the main cause in 79% of the crashes in our study. These crashes occurred at places where a third party crossed the bicycle path (and failed to see the cyclist) or because there was a lack of attention of the cyclist. Safety can be improved by: building adapted infrastructure (to improve mutual visibility and avoid conflicts), interventions to keep road users focused on the road and each other and avoid traffic rule infringements.

All bicycle crashes reported at insurance companies are relevant crashes for the society since they have medical and/or financial consequences. However, only 21% of the bicycle crashes registered at insurance companies were registered in police databases and thus 79% of the crashes are excluded in official statistics used for policy makers. Incorporating data from insurance companies in national statistics might lead to a better decision **and policies on cycling**.

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