An epidemiological study of the risk of cycling in the dark: The role of visual perception, conspicuity and alcohol use

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Abstract

To curtail the rising numbers of cyclists seriously injured in road crashes, more insights are needed into the factors that contribute to these crashes. For instance, darkness is known to be associated with higher injury rates, but little is known about the relative influence of factors such as poor conspicuity, impaired perception and alcohol use among cyclists. To examine these factors, the present study analyzed the epidemiological crash data for three meteorological light conditions: daylight, late evening darkness and early morning darkness; for two crash types: crashes with (M-crashes) and without motorized traffic (NM-crashes); and for different age groups. The relative injury rates (injury risk per distance travelled in darkness corrected for daylight injury risks for each age group) confirmed findings from earlier studies that cycling in late evening darkness is associated with higher injury rates than cycling in daylight conditions. This is the case for both crash types with only small differences between the age groups suggesting that poor conspicuity (M-crashes) and impaired perception (NM-crashes) may play a role. In comparison to late evening darkness, relative injury rates in early morning darkness are much higher. This is the case for both crash types with large differences among the age groups, suggesting that in addition to the absence of daylight also age related risk factors are at play. Support for this hypothesis was found from the analyses of hospital records, showing that the proportion of seriously injured cyclists who have been drinking is highest in early morning darkness and has strongly increased over the last decades. These insights provide input for the selection of countermeasures such as improved lighting (both street and bicycle lights) and interventions targeting alcohol use among cyclists.

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1. Introduction

Motorization has opened up horizons and stimulated economic growth. As a downside of its success, Western world has to cope continuously with congestion, pollution and noise. Because of these negative side effects, many cities now promote cycling as an alternative to short-distance car trips. However, as the injury risk of cyclists is higher than that of car occupants (e.g., Steriu, 2012; Stipdonk and Reurings, 2012), the current increase in bicycle use has resulted in an increase in casualties, more or less inevitably. In the Netherlands, for instance, where 34% of all road trips shorter than 7.5 km is made by bicycle, bicycle use has increased by 50% since 1985 (Fruianu et al., 2009). Despite the country's high standards of cycling culture and safety (Pucher and Buehler, 2007), the number of seriously injured cyclists has increased by 28% over the last two decades. Without a thorough understanding of the nature of these crashes it will not be possible to design an effective prevention strategy (see Reurings et al., 2012; Wegman et al., 2012 for an overview). To contribute to the understanding of the contributing factors in cycling crashes, the present study analyses the influence of 'light condition'. Just as for car drivers, injury risks for cyclists are higher in darkness than in daylight (Johansson et al., 2009). Whereas, for car drivers, studies into these risks have led to the identification of factors such as the role of street lights, reflective markings, car lights configurations and the role of visual perception, fatigue and alcohol use, little is known about these factors for cyclists. The present study focuses therefore on the influence of conspicuity, visibility and alcohol use on cycle injury risk. To this end, the study analyses epidemiological data and compares cycling injury risks (injuries per distance cycled) by light conditions and age group. In addition, it sets out to study the effects of visibility and conspicuity by comparing two crash types: those with (M-crashes) and without motorized traffic (NM-crashes). To assess the role of alcohol, the incidence of alcohol use among seriously injured cyclists was analyzed, by age group and light condition.

1.1. Injury risk of cycling in the dark by age group

Several studies have already shown that cycling during late hours (evening and early morning) is more hazardous than during
daytime. For instance, based on data from Sweden, Norway and the Netherlands, Johansson et al. (2009) examined the natural variation in darkness over the seasons, and compared the accident frequencies of a case hour during daylight in summer with the accident frequencies when that case hour was dark in winter. For the Netherlands, 8.00 and 18.00 h were selected as case hours, and the Odds Ratio analysis showed that in urban areas the risk of cycling in the dark was about a factor of 2 higher than cycling in daylight. For rural areas, this was about a factor of 5 higher. The study further showed that in the Netherlands, compared to Norway and Sweden, the difference between the crash risk in daylight and in darkness is much greater, especially in rural areas. The Odd Ratio analysis has many advantages, as it controls for most confounding factors and does not rely on the availability of mobility data. Its main assumption is that mobility during the case hour is similar to that during the reference hour, and that therefore the reference hour can be used to control for seasonal fluctuation in mobility patterns.

We checked the above assumption for the Netherlands by comparing travelling patterns as derived from the Dutch Travel database, for both case and reference hour. As injury cycling risk differs by age group, we also decomposed the travel data by age group. Fig. 1 presents the similarity between the two hours, expressed as the ratio between case and reference hour, for different age groups and for winter and summer. The ratios show that for the evening case hour (hour 18) the reference hour (hour 16) presents an adequate proxy of the cycling distance by age group, both in summer and in winter. In contrast, for the morning case hour (hour 8) the ratios show that the reference hour (hour 10) is not an adequate proxy, especially not in winter. In order to take this asymmetry in mobility patterns into account, the present study used travel data to calculate injury risks – cyclist injuries per distance travelled – by age group, corrected for seasonal variations, and used ‘actual dark hours’ by including not only clock time of the crash, but also calendar date in the analyses.

1.2. Risk-contributing factors: conspicuity, visibility and alcohol

Several factors may contribute to a higher injury risk at night. Known risk factors for other travelling modes are: ‘low conspicuity’, ‘low visibility’, ‘fatigue’, and ‘high alcohol use’. Conspicuity is the extent to which a cyclist is visible for other road users. If reduced conspicuity plays a role, the injury risk resulting from crashes between cyclists and other road users is expected to be higher during dark hours than in daylight. Fatigue may play a role in those dark hours that corresponds with the period that a cyclist would normally be at sleep. A wide range of studies on driving, but also on other critical tasks have shown task performance to deteriorate during those hours (SWOV-Factsheet, 2008), but to date little is known about this effect on cyclists.

Alcohol use in the Netherlands is higher during night-time hours than during day-time hours, with alcohol use in weekend nights being higher than in weekday nights. The question is whether alcohol use has a strong relationship with cycle injuries. To answer this question, Li et al. (2001) replicated for cyclists, the case-control study that in the early Seventies was conducted for car drivers (Borkenstein et al., 1974), by comparing the distribution of BAC among injured cyclists (case group) with that among cyclists on the street (reference group). Similar to the risk for car drivers, injury risks for cyclists were shown to rise with increasing BACs. However, the detrimental effects for cyclists already started at a much lower BAC than for car drivers. At a BAC of 0.02 g/dl or higher the adjusted odds ratio of bicycle injury was a factor of 5.6 higher than at a BAC lower than 0.02 g/dl. The study further showed that the injury risks also increased more sharply, with a 20 times higher injury risk for cyclists with a BAC over 0.08 g/dl than for ‘sober’ cyclists. A case control study in Finland reached similar conclusions (Olkkonen and Honkanen, 1990), with large differences in alcohol use between cases (24.1%) and controls (4.0%). At BACs above 0.1 mg/dl injury risk of an intoxicated bicyclist was at least 10-fold that of a sober bicyclist. It was further shown, that these intoxicated cyclists mainly pose a danger to themselves, and seldom endanger other road users.

Despite the strong evidence that alcohol use may contribute to the injury risk at night, only a handful of studies have actually examined the prevalence of alcohol use among injured cyclists, and those that did, only included a relatively small number of cases in their study. For instance, Andersson and Bunketorp (2002), using telephone interviews, gathered information from 95 alcohol-intoxicated and 112 sober injured cyclists in Gothenburg, and they found that these alcohol-related injuries happened more often at night and during weekends, and were more often the result of a single- rather than a multi-vehicle crash. Alcohol use was also examined in cycling crashes in New York, in the years 1996–2005. Alcohol was detected in 21% of the 225 cyclists who had died within three hours of a crash (Nicaj et al., 2009). The only study to date about alcohol use among injured cyclists in the Netherlands was based on self-reported alcohol use among 723 cyclists, treated at a hospital emergency department, because of injuries sustained in a single vehicle crash (Ormel et al., 2008). From the 28 cyclists treated during weekend nights, which covered the time period between midnight and 6 a.m. on Saturdays and Sundays, 71% reported to have consumed more than two glasses of alcohol 6 h
before the crash. This was only 8% at other crash times. Similar to the Goteborg study, the information on alcohol use in this study was based on a very low number of cases, did not consider actual ‘light condition’ at the time of the crash, and solely relied on self-reporting. These issues seriously limit the generalisability of the findings. To improve our insights into the prevalence of alcohol use among injured cyclists, the circumstances of their crashes, and the development of prevalence over time, an analysis of a large and representative number of cases is required.

1.3. Research questions and study approach

The present study used data obtained from hospital records, containing information on crashes and injuries of 128,000 cyclists who had been seriously injured and admitted to a Dutch hospital in the period 1993–2008. This data was analyzed to study the development of injury rates (number of injuries per distance travelled) in the last two decades in relation to the light condition at the time of the crash. In order to understand the role of darkness in terms of its effects on conspicuity and visibility, the study compared injury rates for daylight and darkness for two crash types: with and without motorized traffic. If poor conspicuity plays a role, injury risk of crashes with motorized traffic would be expected to be higher in darkness than in daylight. Similarly, if poor visibility plays a role, injury risk of crashes without motorized traffic would be expected to be higher in darkness than in daylight. In order to understand the role played by alcohol, the information in hospital records about alcohol use was used to calculate the proportion of intoxicated cyclists, by age, light condition, and crash type, and to study the development of these proportions over the last decades.

2. Method

2.1. Data bases for injury severity, crash type, cyclist age, crash time and day of week

This study only included seriously injured cyclists, who were defined as cyclists who had been admitted to a hospital with a minimum injury severity of 2 (Gennarelli and Wodzin, 2005) on the Maximum Abbreviated Injury Score (MAIS). The decision not to include cyclist fatalities was prompted by their low number, which was too low for disaggregating the data by age, time of day and alcohol use.

In the Netherlands, information about road casualties is generally available from the Road Crash Registration (BRON) of the Dutch Ministry of Infrastructure and the Environment’s Centre for Transport and Navigation (DVS). This database contains information collected by the police and is hence also referred to as the police registration. BRON is known to be more complete for serious crashes and crashes involving motorized vehicles – M-crashes – (Bos et al., 2009; Derricks and Mak, 2007), than for crashes not involving motorized vehicles – NM-crashes. NM-crashes, even those with serious injury, are often unknown to the police and therefore absent from BRON. A comparison made in previous studies between the hospital-based National Medical Registration (LMR) and BRON indicated that BRON contains about 60% of the serious road injuries in M-crashes and only about 4% of the serious road injuries in NM-crashes. However, the combination of the two databases provides a fairly accurate estimate of the total number of serious road injuries in the Netherlands for the period 1993–2008. Note, that NM-crashes also include a small proportion of cycle–cycle and cycle–pedestrian crashes, but because of the limitations of the database these cannot be separated from the single cycle crashes.

The data on cyclist age, time and date of crash, and crash type was derived from BRON and LMR. For seriously injured cyclists registered in BRON, the estimated time of the crash and crash date as recorded by the police were included. If a seriously injured cyclist was only registered in the LMR, only the time and the date of hospital admittance were available. Reurings and Bos (2009) estimated that, on average, hospital admittance is 2.17 h after the crash. Therefore, in this paper the time of admittance minus 2.17 h was used as an approximation of the time of the crash. It is not known, however, whether the time lag between crash and hospital admittance differs by crash type and time of day.

2.2. Mobility data

Mobility data in the Netherlands was obtained from the Dutch National Travel Statistics (Data source CBS-OVG, lenM-MON). This database contains the following information relevant for the present study by calendar year: distance travelled by bicycle, travelling time, trip date and duration, and age of cyclist. This data is collected by the Dutch Central Bureau of National Statistics (CBS), using surveys conducted among Dutch households. To calculate national averages, CBS corrects for over- or underrepresentation of certain groups and weights and imputes the data, using advanced statistical techniques (DVS, 2008). The present study used these national averages.

2.3. Light condition

Daily information on the time of sunrise and sunset was obtained from the Royal Netherlands Meteorological Institute. Five light conditions were distinguished: ‘Daylight’, ‘Dawn’, ‘Dusk’, ‘Darkness late at night’ and ‘Darkness early in the morning’. In correspondence with meteorological definitions, the time of sunrise was defined as the time when the upper edge of the sun appears at the horizon; the time of sunset was defined as the time when the trailing edge of the sun disappears below the horizon. ‘Daylight’ was defined as the period between sunrise and sunset. ‘Dawn’ was defined as the twilight period in the morning between the moment when the sun is 6° below the horizon and the time of sunrise. ‘Dusk’ was defined as the twilight period in the evening between sunset and the time when the sun is 6° below the horizon. In the Netherlands, both twilight periods last about 40 min. ‘ Darkness’ was defined as the period between dusk and dawn, with two periods of darkness: late at night (between the end of dusk and midnight) and early morning darkness (from midnight to the beginning of dawn). The data on sunrise and sunset applies to the centre of the Netherlands. Yet, because of the country’s small geographical size, this data differs only slightly (5 min maximum) for its other geographical regions. The daily data about light conditions was used to determine the light condition at the time of the crash. In addition, the daily data about light conditions was combined with the information from the Dutch Mobility Survey on departure and arrival times of bicycle trips, to determine the amount of travel during each of the five light conditions.

2.4. Alcohol use among seriously injured cyclists

Data on alcohol use was also obtained from the national hospital records (LMR). LMR, being a medical registration, contains codes for types of injuries and diseases, based on the 9th revision of the International Classification of Diseases (ICD9), including codes for several levels of alcohol use, abuse and intoxication. These codes are 291 (alcoholic psychoses), 303 (alcohol intoxication and other alcohol dependence), 305.0 (nondependent alcohol abuse) and 980 (toxic effect of alcohol), with their respective subcategories. For the present study these codes were used as an indicator of a seriously injured cyclist being under the influence of alcohol at the time of the crash. Actual Blood Alcohol Concentration (BAC) at the time of
2.5. Measures and data analysis

The injury rates were calculated as the number of seriously injured cyclists divided by the distance travelled by bicycle (in millions of kilometres) per light condition. To control for possible confounding factors due to a higher mobility of high-risk cyclists – for instance senior cyclists (Zeegers, 2010) – during specific light conditions, injury rates were calculated by age group. To control for age-specific risks, relative injury rates were calculated as the ratio between the injury risk in darkness (two conditions) and the injury rate for that particular age group during daylight. In this way, the daylight injury rate served as a baseline condition. In that context, relative injury rates greater than 1 indicated an ‘over-risk’ in darkness, whereas rates smaller than 1 indicated an ‘under-risk’ in darkness.

Theoretically, injury rates for M-crashes are not only dependent on the cyclist’s ‘own’ exposure to risk but also on the exposure created by the crash-opponent. This type of exposure is especially relevant when comparing daytime travel conditions versus those in night time. In the latter period of the day, traffic densities are low creating fewer potential crash conditions (see for a discussion of the topic Stipdonk and Berends, 2008). However, to enable the comparisons between N- and NM-crashes, in this study injury rates were calculated, taking only ‘own’ exposure to risk defined as the number of injured cyclists per kilometre travel, into account.

The sampling error for travel data was assessed following the guidelines of the Dutch CBS, while the error in victim counts was assessed assuming the victim counts to be the result of a random sum of weights. Both error terms were assumed to be Gaussian. The errors in the rates where then derived using linearization as described in Rice (1995, pp. 149–154).

3. Results

3.1. Injury rates per light condition

Table 1 presents the distribution of crashes and mobility over the 5 light conditions. For both crash types, the results show that the majority of seriously injured cyclists were involved in crashes during daylight. Nevertheless, as only 10% of the total distance was cycled during darkness, the injury rates for both crash types were higher in darkness than in daylight. Because of dusk and dawn being only short time spans (40 min each), and because of the time of a crash for seriously injured cyclists being estimated on the basis of time of hospital admittance rather than on actual crash time, the crash rates in dusk and dawn may not be reliable. Therefore, the analyses are further based on the two darkness conditions and the daylight condition.

To compare the development over time, Fig. 2 presents the injury rates (number of seriously injured per kilometre) of cyclists in M-crashes and NM-crashes, for daylight and the two darkness conditions. In daylight, injury rates for NM-crashes are about twice as high as for M-crashes. In darkness, and injury rates for both crash types are higher than in daylight. There are, however, large differences between late evening and early morning darkness. Especially, for NM-crashes, the rates in early morning darkness were much higher than in late evening darkness, whereby the developments over the years clearly indicated a growing problem. In 1993, early morning injury rates in the dark were a factor of 4 higher than in other light conditions. In 2008 this had risen to a factor of 10. Note though, that as indicated by the error bars the daytime and late evening estimates were more reliable than those for the early morning period.

The higher crash rate for M-crashes in both darkness conditions provides support for the expectations that reduced conspicuity may play a role. The higher crash rate for NM-crashes in both darkness conditions provides support for poor visibility of the cyclist’s environment increasing injury rates. However, the higher injury rates in early morning darkness compared to late night darkness suggest that ‘darkness’ in itself is not the sole contributing factor, and that additional factors are at play.

3.2. Relative injury rates by age group

To study the injury rates in the two darkness conditions and to control for overall safety differences by age group, relative injury rates were calculated whereby the daylight injury rate for that age group served as a baseline. Fig. 3 presents these relative risks by age group, crash type and two darkness conditions. It shows that all relative injury rates were larger than 1, suggesting that for all age groups, for both crash types, and for both darkness conditions, cycling in the dark is more dangerous than cycling in daylight. The magnitude of the relative injury risk, however, differs by darkness conditions. In late evening darkness, the relative injury risk for each age group and crash type was relatively low with only small differences among the age groups (rates between 1.2 and 2.3). In early morning darkness, however, these rates were much higher.

<table>
<thead>
<tr>
<th></th>
<th>M-crashes (%)</th>
<th>NM-crashes (%)</th>
<th>Mobility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early morning</td>
<td>4.8</td>
<td>9.7</td>
<td>2.4</td>
</tr>
<tr>
<td>Dawn</td>
<td>2.8</td>
<td>2.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Daylight</td>
<td>79.3</td>
<td>78.2</td>
<td>85.1</td>
</tr>
<tr>
<td>Dusk</td>
<td>2.9</td>
<td>1.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Late night</td>
<td>10.2</td>
<td>7.6</td>
<td>7.1</td>
</tr>
</tbody>
</table>
(rates between 2 and 5.2 for M-crashes and between 4 and 11 for NM-crashes), with large differences among the age groups. These findings show in ‘late evening darkness’ the risks of injuries are higher for all age groups, irrespective of crash type. Thus, both conspicuity and impaired vision may play a role in every age group. However, ‘the absence of light’ is not the sole explanation, given the consistently higher rates in early morning darkness compared to those in late evening darkness and the differences among the age groups. In addition to ‘darkness’, additional factors may therefore play a role, for example alcohol use.

3.3. Proportion of alcohol use

The LMR records provide information about alcohol use among seriously injured cyclists. Table 2 presents the proportion of seriously injured cyclists, who had used alcohol before the crash, by crash type and light condition. The table shows that in both crash types, alcohol use among injured cyclists is higher during the dark hours than in daylight, but that the proportion of alcohol use in those hours is far higher among injured cyclists in NM-crashes than in M-crashes. These proportions for NM-crashes have been rising over the years.

Table 3 presents these proportions by crash type and age group. It shows that the highest proportions are concentrated in the 18–59 age group, which is mainly due to the high proportion of injured cyclists of this age group in NM-crashes, who had been drinking (about 25%). Only for the age group 60–74-year olds, alcohol use does not seem to play a role in the high relative injury rate. Further analyses, not presented here, showed that the proportions of seriously injured cyclists under the influence of alcohol are even higher during weekends. These proportions have been increasing over the years, primarily due to the rising ‘alcohol’ proportions among the 18–59-year olds in NM-crashes. Whereas in 1993 this proportion for 18–24-year olds was 24%, by 2008 it had risen to 58%. For 25–59-year olds, the proportion rose from 21% to 44%.

4. Discussion

Three main findings result from this study. First, the results provide support for earlier findings that cycling in the dark is more hazardous than cycling in daylight conditions, whereby poor conspicuity and poor visibility may both play a role. Second, the magnitude of the detrimental effect of darkness differs by crash type. Especially the risk (expressed in the injury rate) of being seriously injured in a NM-crash in dark conditions is high and has been rising in the last decades. Third, given the known risks of alcohol use among cyclists, and the reported prevalence of alcohol use among cyclists admitted to hospital because of a cycle crash, the higher injury rates in early morning darkness may – amongst other factors – be related to alcohol use. Over the last decades, the proportion of injured cyclists who has been drinking has increased, especially among the 18–59-year olds and especially during early morning darkness during weekends. In this age group, about one in every two seriously injured cyclists was under the influence of alcohol during those hours.

4.1. The influence of darkness

Because of poor visibility and conspicuity, the above-average risk during dark hours may lie in the darkness itself. Cyclists are less visible in the dark, which may lead to collisions between cyclists and other road users. Thornley et al. (2008) studied the relation between conspicuity and bicycle crashes in New Zealand. They concluded that low cyclist conspicuity may increase the risk of crash-related injuries, and suggested the promotion of high-visibility clothing as a simple intervention to increase cycling safety. However, it will take extra efforts to convince cyclists of the necessity of it, as studies on the accuracy of the cyclists’ estimates of their own night-time conspicuity showed cyclists to overestimate their visibility for approaching drivers (Wood et al., 2013), and to underestimate the effect of the value of conspicuity devices, such as reflectors and bicycle lights.

The high incidence of injuries sustained in NM-crashes may suggest that lack of visual detection of hazards related to the road itself may also play a role. Schepers (2008) found that, in almost half of the crashes not involving motorized vehicles, one or more infrastructural factors played a role, and in a later study, Schepers and den Brinker (2011) showed that these types of crashes were often related to poor visual characteristics of road environment facilities, such as absent or poor pavement markings. Unfortunately, their study did not differentiate between light conditions, but it is plausible that such (visibility) problems are even greater in darkness than in daylight.

Table 2
The proportion of injured cyclists who were under the influence of alcohol, according to LMR registration, by light condition and crash type in the period 1993–2008.

<table>
<thead>
<tr>
<th></th>
<th>M-crashes (%)</th>
<th>NM-crashes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early morning dusk</td>
<td>7.5</td>
<td>15.9</td>
</tr>
<tr>
<td>Dawn</td>
<td>0.4</td>
<td>2.3</td>
</tr>
<tr>
<td>Daylight</td>
<td>0.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Dusk</td>
<td>1.9</td>
<td>11.4</td>
</tr>
<tr>
<td>Late night dusk</td>
<td>4.0</td>
<td>19.0</td>
</tr>
<tr>
<td>Total</td>
<td>1.2</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Table 3
The proportion of seriously injured cyclists (in total and during the dark, early morning) who were under the influence of alcohol, according to LMR registration, by age group, in the period 1993–2008.

<table>
<thead>
<tr>
<th>Age</th>
<th>M-crashes</th>
<th>NM-crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daylight</td>
<td>Dark, early morning</td>
</tr>
<tr>
<td>12–17</td>
<td>0.03</td>
<td>3.07</td>
</tr>
<tr>
<td>18–24</td>
<td>0.42</td>
<td>10.46</td>
</tr>
<tr>
<td>25–29</td>
<td>0.78</td>
<td>14.45</td>
</tr>
<tr>
<td>30–39</td>
<td>0.89</td>
<td>11.41</td>
</tr>
<tr>
<td>40–49</td>
<td>1.34</td>
<td>3.00</td>
</tr>
<tr>
<td>50–59</td>
<td>0.72</td>
<td>6.21</td>
</tr>
<tr>
<td>60–74</td>
<td>0.28</td>
<td>0</td>
</tr>
<tr>
<td>≥75</td>
<td>0.16</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0.42</td>
<td>7.48</td>
</tr>
</tbody>
</table>
Road lighting and bicycle lights may improve both cyclist visibility and conspicuity, but only a few studies have assessed the actual effects of relevant measures. Based on Dutch police registration (BRON) of bicycle crashes, Wanvik (2009) estimated that the presence of road lighting reduces bicycle crashes by 58%. However, these conclusions may be correct for M-crashes, but not for NM-crashes. This because of the selective underreporting of the latter crash type in this database. The effect of bicycle lights on safety is associated with two questions. The first question is how to increase the proportions of cyclists who actually use bicycle lights. Based on recent road side counts in the Netherlands, it was estimated that only 65% of the cyclists carry properly working front and back lights (Boxum and Broeks, 2010). The challenge is to increase light use among the 35% non-users, especially now that we know that cyclists tend to underestimate the extent to which they are visible to other road users. The second question deals with the technical specifications of bicycle lights and the need to present information on what constitutes an ‘adequate’ light, both in relation to cyclists’ needs to perceive the trajectory of the road and to detect hazardous situations in time, and in relation to the needs of other road users to detect cyclists and to recognize their intended manoeuvres.

4.2. The influence of alcohol and fatigue as confounding factor

The contributing role of alcohol is concentrated in the early morning of weekend days, with high proportions of injured cyclists who have used alcohol. Little is known, however, about the actual BACs, and it is thus not possible to assess whether the BACs were sufficiently high to conclude that cycling performance would have been affected. However, Li et al. (2001) conducted a case-control study for cyclist and alcohol use and showed that even with low levels of alcohol use, the injury rate increased significantly. For an estimated BAC of less than 0.02 g/dL, the injury risk was 5.6 higher than for sober cyclists. In this light, the rising proportions of cyclists admitted to hospital after alcohol use are reasons for concern, especially with respect to the recent findings that alcohol use among youngsters in the Netherlands (20%) is much higher than the European average (9%) (Nationale Drugmonitor, 2012). Roadside alcohol testing is needed to provide more evidence about the actual levels of alcohol use among cyclists.

Alcohol might not be the sole contributor. In addition to darkness and alcohol use, the circadian rhythm (also called the body clock) may also provide an explanation for the high injury rates during early morning darkness. Due to this rhythm, the arousal level of people is lowest between midnight and 6 a.m. Reaction times tend to be longer during these hours and there is less mental and physical capacity available to cope with the demands of the traffic task. For example, Smith et al. (2009) studied the effect of sleepiness on hazard perception among novice drivers and showed that they were significantly slower at anticipating traffic conflicts at night than during daytime. Such a detrimental effect of sleepiness may also apply to cyclists. Unfortunately, the available data in the database were not suitable for distinguishing the effect of sleepiness in early morning darkness from that of alcohol use.

4.3. Limitations of study and need for further research

The present study uses epidemiological data on seriously injured cyclists and the amount of travelling in different light conditions. The data on injuries are highly reliable and provides a good insight into the magnitude, nature and development of the risk of cycling during darkness. However, the study is far less robust on the travel data used and the role of contributing factors and the causal relationships with crashes. The study only demonstrates the expected effects on differences with respect to crash type, age group, and light condition. Still, the associations studied here are not sufficient to establish the causal relationship and the relative contribution of each factor. To this end, studies are required that use an experimental design, whereby the conditions are systematically varied and the effects on the quality of the cycling task performance and the conspicuity of cyclists for other road users are assessed.

5. Conclusion

This analysis of epidemiological data shows that injury risks for cyclists are higher in the dark than in daylight, with alcohol use probably being an additional and increasingly important risk component. The difference between crash types of crashes with motorized traffic and single crashes indicates that low conspicuity and low visibility both play a role. However, experimental studies are needed to understand the relative contribution of these factors and the influence of alcohol and fatigue on task performance. These insights will provide further underpinnings for the selection and development of effective countermeasures, such as improved lighting (both street lighting and bicycle lights), campaigns concerning the effects of alcohol use, low visibility and conspicuity, and technical requirements for adequate bicycle lights. The results presented here have provided a first step towards the mapping of the contributing risk factors for cyclist casualties.

References


