

## Sleep Quality and Motor Vehicle Crashes in Adolescents

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**Study objectives:** Sleep-related complaints are common in adolescents, but their impact on the rate of motor vehicle crashes accidents is poorly known. We studied subjective sleep quality, driving habits, and self-reported car crashes in high-school adolescents.

**Methods:** Self-administered questionnaires (with items exploring driving habits) were distributed to 339 students who had a driver's license and attended 1 of 7 high schools in Bologna, Italy. Statistical analysis were performed to describe lifestyle habits, sleep quality, sleepiness, and their relationship with the binary dependent variable (presence or absence of car crashes) to identify the factors significantly affecting the probability of car crashes in a multivariate binary logistic regression model.

**Results:** Nineteen percent of the sample reported bad sleep, 64% complained of daytime sleepiness, and 40% reported sleepiness while driving. Eighty students (24%), 76% of which were males, reported that they had already crashed at least once, and 15% considered sleepiness to have been the main

cause of their crash. As compared with adolescents who had not had a crash, those who had at least 1 previous crash reported that they more frequently used to drive (79% vs 62%), drove at night (25% vs 9%), drove while sleepy (56% vs 35%), had bad sleep (29% vs 16%), and used stimulants such as caffeinated soft drinks (32% vs 19%), tobacco (54% vs 27%), and drugs (21% vs 7%). The logistic procedure established a significant predictive role of male sex ( $p < 0.0001$ ; odds ratio = 3.3), tobacco use ( $p < 0.0001$ ; odds ratio = 3.2), sleepiness while driving ( $p = 0.010$ ; odds ratio = 2.1), and bad sleep ( $p = 0.047$ ; odds ratio = 1.9) for the crash risk.

**Conclusions:** Our results confirm the high prevalence of sleep-related complaints among adolescents and highlight their independent role on self-reported crash risk.

**Keywords:** Adolescence, car accident risk, sleep, sleepiness  
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Sleep patterns and sleep disorders in young people are influenced by psychological, biologic, cultural, and social factors. Epidemiologic studies have proven the relationship between sleep habits and daytime behavior or cognitive functioning in adolescents, with a detrimental impact of poor sleep hygiene on performance.<sup>1-7</sup> Sleep complaints are common during adolescence (ranging from 9.5% - 46%) and may represent clear-cut sleep disorders such as sleep disordered breathing, restless legs syndrome, narcolepsy, insomnia, or circadian rhythm sleep disorders or they may reflect lifestyle factors affecting sleep quality.<sup>8-16</sup>

Adolescents are physiologically predisposed to develop chronic sleep deprivation because of maturation changes of the circadian and homeostatic regulation of the sleep-wake cycle leading to a delay in the timing of sleep with consequent accumulation of chronic sleep debt.<sup>1,17-22</sup>

The social environment (e.g., academic demands, extracurricular activities) further contributes to the tendency for adolescents to develop advanced sleep phase, which is more evident in adolescents than in prepubertal children. Despite sleep-research data indicating that adolescents require 9 to 10 hours of sleep per night, youths sleep significantly less.<sup>10,17,19</sup> Moreover, even if adolescents typically extend sleep on weekends, they cannot compensate for the chronic sleep deprivation accumulated during weekdays.<sup>23</sup>

### BRIEF SUMMARY

**Current Knowledge/Study Rationale:** Young people are highly exposed to the risk of motor vehicle crashes. Sleep and driving habits and their relation with self-reported car accidents in adolescents were evaluated.

**Study Impact:** Bad sleep, sleepiness at the wheel, male sex and some unhealthy lifestyle habits increased the risk for car crashes among young drivers. Study results stress the need of educational programs for improving sleeping habits among adolescents.

Despite the well-established impact of reduced or disturbed sleep on the ability to concentrate, school performance, behavior, memory, mood, and learning difficulties,<sup>24,25-27</sup> only a few studies have explored the role of sleepiness on the risk of motor vehicle crashes and injuries in young people.<sup>28-30</sup>

Sleepiness is an important cause of car crashes, and young adults are involved in two thirds of all sleepiness-related crashes (SRC), especially those occurring late at night or early in the morning.<sup>29,31</sup> Late-night driving, together with the sleep debt, the poor experience of how to cope with fatigue, and the insufficient driving ability may partially explain the high risk for SRC in young adults.<sup>31-33</sup> Previous studies have suggested that even if young people are aware of sleepiness-related risks, they do not correctly perceive sleepiness while driving.<sup>30</sup> Therefore, the increased risk of SRC in adolescents has been attributed not only to their inadequate experience at wheel, but also to their tenden-

cy to adopt ineffective strategies against drowsiness, together with a propensity for enhanced risk-taking behaviors that seem to be influenced by sleepiness itself (e.g., driving over the speed limits).<sup>34</sup> Moreover, a 1-hour delay in high-school start times has been shown to significantly reduce the risk of motor vehicle crashes through meaningful increases in night-time sleep.<sup>35</sup>

In summary, the actual literature shows an increased risk of adolescents having a SRC that is partially explained by the chronic sleep-deprivation hypothesis, but the individual factors such as sleep and sleepiness complaints or lifestyle habits associated with the SRC risk are poorly understood.

We performed a cross-sectional questionnaire-based study to explore the association of sleep complaints and life habits with self-reported car crashes in driving adolescents attending the last 2 years of 7 different high schools in Bologna.

## METHOD

### Participants and Questionnaire

Data were collected in the year 2004 by means of a self-administered sleep questionnaire for adolescents that was developed by Mary Carskadon, PhD, and coworkers (School Sleep Habits Survey),<sup>36</sup> translated by F. Giannotti and F. Cortesi,<sup>1</sup> and supplemented with questions on driving habits. The questionnaire comprised 71 multiple-choice items, including demographic characteristics, lifestyle habits (use of caffeinated beverages, alcohol, tobacco, and drugs), nocturnal sleep habits and symptoms suggesting sleep disorders (unrefreshing sleep, sleep disordered breathing, restless legs syndrome, hypnagogic hallucinations, sleep paralysis, sleepwalking, sleep terror, and insomnia), and a subjective report of daytime sleepiness. Driving habits and sleepiness at the wheel were evaluated by specific items exploring the frequency (and timing) of car use and car crashes, the perceived causes of vehicle crashes, and the respondents' behaviors toward sleepy driving.

Questionnaires were self-administered to students in their last 2 years at 1 of 7 high schools in Bologna, Italy, (4 classical/scientific and 3 technical high schools) who had signed a written informed consent to participate in the study. The questionnaires were anonymous, and students were informed that their answers could not have any influence on their driving licenses or school reports. Three hundred thirty-nine students with valid driving licenses completed the questionnaire, and the data were analyzed. This study is a research project on lifestyle, sleep habits, and sleepiness in adolescence supported by the Italian Ministry of Health.

### Statistical analysis

Data collected were analyzed using the STATA-statistical package (StataCorp LP, College Station, TX). Starting from a descriptive statistical analysis (evaluating mean and standard deviation for quantitative outcomes, percentages for qualitative ones), we explored the dependence structure firstly between sleepiness and sleep habits and then between observed self-reported car crashes and several predictors, through the analysis of contingency tables in a bivariate setting ( $p < 0.05$ ), together with  $\chi^2$  statistical test or Fisher exact test, as appropriate, ( $p < 0.05$ ) for association. Furthermore, we applied a

logistic regression model, a statistical technique (within the generalized linear modeling approach) that can be used to describe the relationship between several independent variables (or predictors) and a binary dependent variable, i.e., the presence or absence of self-reported car crashes ( $p < 0.05$ ). The forward-selection approach was used to identify the factors significantly affecting the probability of car crashes (namely, sex, driver characteristics, and sleep disorders) together with odds ratios (OR) and 95% confidence intervals (CI). An additional analysis for the fit of the model was performed using the Hosmer-Lemeshow test, in which actual outcomes are compared with the expected ones, given the selected model; low  $p$  values indicate a large deviation and therefore a bad fit to the data ( $p > 0.05$ , good fit).

## RESULTS

The study sample comprised 339 students, 58% of whom were men, aged 18 to 21 years (mean  $18.4 \pm 0.6$ ) with a mean body mass index of  $21.3 \pm 2.5$  kg/m<sup>2</sup>.

### Sleep quality and sleepiness

Sixty-four percent of the subjects complained of excessive daytime sleepiness, as a moderate or severe problem occurring frequently or always. The situations in which students reported that they had commonly fallen asleep were watching television or listening to music (49%), reading or studying (32%), and traveling (46%). Conversely, they did not frequently complain of sleepiness while talking (3%), riding a bicycle or a motorcycle, (2%) and using a computer (8%). Moreover, they often used stimulants such as caffeinated soft drinks (23%), tea (53%), and tobacco (33%); 11% of the sample declared a daily abuse of alcohol or drugs.

Mean total sleep time differed between weekdays and weekends,  $7.3 \pm 0.9$  versus  $8.9 \pm 1.8$  hours respectively, and, even if extended during weekends, sleep time was still shorter than the participants' needs. In fact, students reported that their mean need of sleep was  $9.2 \pm 1.5$  hours, but, on weekdays, only 20 students (6%) and, on weekends, 184 subjects (58%) slept 9 hours or more.

One hundred and thirty-seven students (40%) complained of difficulties in morning awakening; 201 subjects (59%) would like to wake up after 09:45, whereas only 22 (6%) had a morning circadian preference (before 07:45). A high percentage of students could be defined "evening-types": 169 subjects (50%) felt well only in the evening, 131 (39%) would like to always go to bed after 00:30, and 156 (46%) reported problems when forced to get up at 06:00.

Students complained of sleep disturbances: bad sleep was reported by 64 subjects (19%). Symptoms suggesting a sleep disorder (restless leg syndrome [3%], periodic limb movements [12%], hypnagogic hallucinations [19%], sleep paralysis [2%], sleepwalking [2%], sleep terror [2%], and snoring [8%]) were reported, even if the students were not previously informed about sleep disorders. A high percentage of students complained of sleep fragmentation: 152 subjects (45%) woke up at least once during the night with trouble falling asleep again (130 students [38%] needed between 5 and 20 minutes and 13 [3%] more than 20 minutes to return to sleep).

**Table 1**—Driving habits, sleep, sleepiness, and lifestyle habits in students with driving licenses

	Crashes	No crashes	p Value
Driving at least once a week	79	62	0.007 <sup>a</sup>
Driving at night	25	9	< 0.0001 <sup>a</sup>
Sleepiness while driving	56	35	0.001 <sup>a</sup>
Bad sleep	29	16	0.010 <sup>a</sup>
Periodic limb movements	31	28	0.687
Restless legs syndrome	12	5	0.064
Snoring	13	7	0.083
Hypnagogic hallucinations	42	38	0.484
Sleep paralysis	13	8	0.172
Sleepwalking	4	2	0.393
Sleep terror	3	2	0.627
Sleepiness	61	65	0.428
Caffeinated soft drink	32	19	0.021 <sup>a</sup>
Coffee or tea	55	53	0.720
Tobacco	54	27	< 0.0001 <sup>a</sup>
Alcohol	14	9	0.169
Drugs	21	7	< 0.0001 <sup>a</sup>
Men	76	53	< 0.0001 <sup>a</sup>

Data are presented as percentages of students who reported that they had or had not been involved in a motor vehicle crash.  $\chi^2$  statistical test; <sup>a</sup>p value < 0.05.

There was a significant association of daytime sleepiness with the subjective report of bad sleep ( $p = 0.011$ ), sleep paralysis ( $p = 0.008$ ), restless leg syndrome ( $p = 0.020$ ) and periodic limb movements ( $p = 0.001$ ), whereas there was no association between daytime sleepiness and body mass index, snoring, hypnagogic hallucinations, sleepwalking, or sleep terror.

### Driving Habits and Sleepiness While Driving

Two hundred and thirty-four students (66%) used to drive at least 4 to 5 days per week, and 230 (68%) also drove at night once or twice per week.

One hundred and thirty-five (40%) of the students reported that they experienced sleepiness while driving a car; nevertheless, 109 (81%) of them used to keep on driving and adopted the following countermeasures to drowsiness: turning up the radio (39 students, 36%), opening the window (27 students, 25%), singing (14 students, 13%), and moving on the seat (6 students, 5%). Only 26 of the subjects who reported experiencing sleepiness while driving a car (19%) used to stop driving because of sleepiness and tried to fight it by walking (11 subjects, 42%), drinking coffee (8 subjects, 31%), sleeping a few minutes (4 subjects, 15%), or washing their faces (1 subject, 4%). Despite all these countermeasures, 28 subjects out of 339 (8%) reported near-miss crashes that they subjectively ascribed to sleepiness.

Eighty students (24%), 76% of whom were men, had already crashed at least once. Fifteen percent of them considered sleepiness to be the main cause of their car crash; 31% attributed the crash to speed, and 14% to alcohol consumption.

**Table 2**—Regression table showing the final results of the logistic regression model

	Coefficient	Standard Error	z	P >  z	95% CI	
Male sex	1.1968	0.3090	3.87	0.000	0.5912	1.8023
Sleepiness at the wheel	0.7229	0.2791	2.59	0.010	0.1759	1.2699
Bad sleep	0.6423	0.3228	1.99	0.047	0.0096	1.2749
Smoking	1.1597	0.2829	4.10	0.000	0.6052	1.7143
Constant	-2.8826	0.3399	-8.48	0.000	-3.5488	-2.2163

  

	OR	Standard Error	z	P >  z	95% CI	
Male sex	3.3094	1.0225	3.87	0.000	1.8062	6.0639
Sleepiness at the wheel	2.0604	0.5750	2.59	0.010	1.1923	3.5604
Bad sleep	1.9008	0.6135	1.99	0.047	1.0097	3.5784
Smoking	3.1891	0.9024	4.10	0.000	1.8315	5.5530

Table 2 shows the coefficients (upper part) of each covariate (male sex, sleepiness at the wheel, bad sleep, smoking), and the odds ratios (OR) (lower part) in which the dependent outcome variable is self-reported car crash in the final logistic regression model.

Data from students who had crashed at least once were compared with those of other respondents to examine car habits, sleepiness, sleep habits, and lifestyle habits (**Table 1**). Those who had crashed were more frequently to be men; more likely to frequently drive a car, especially during the night; and more likely to report experiencing sleepiness while driving. Moreover, they more often reported bad sleep and the use of caffeinated soft drinks, tobacco, and drugs. Conversely, there was no difference regarding daytime sleepiness or symptoms of specific sleep disorders in the 2 groups.

Logistic regressions analysis confirmed the relationship between the binary dependent variable (presence or absence of self-reported car crashes) and the predictors identified by the forward selection approach: male sex, sleepiness at the wheel, bad sleep, and use of tobacco. There was an increased risk of car accidents in men ( $p < 0.0001$ ; OR = 3.3, CI = 1.8-6.1), those who experienced sleepiness at the wheel ( $p = 0.010$ , OR = 2.1, CI = 1.2-3.6), those who reported having bad sleep ( $p = 0.047$ , OR = 1.9, CI = 1-3.6), and smokers ( $p < 0.0001$ , OR = 3.2, CI = 1.8-5.5). The Hosmer-Lemeshow test showed a good fit of the model ( $\chi^2 = 2.26$ ,  $p = 0.9441$ ) (**Table 2**).

## DISCUSSION

In a cross-sectional setting, we explored sleep habits and their relationships with self-reported car crashes in Italian adolescent students who had a regular driving license. Our key findings are (1) adolescents frequently complained of poor nocturnal sleep and daytime sleepiness; (2) bad sleep and sleepiness at

the wheel, together with male sex and unhealthy lifestyle habits (smoking), significantly increased the risk for car crashes among young drivers.

Our results regarding sleep quality are in line with the current knowledge.<sup>8-12</sup> Adolescence is frequently characterized by insufficient sleep and consequent sleepiness, as final outcomes of intrinsic and extrinsic factors. During puberty, changes occur in hormone and circadian timing systems, leading to a biologic tendency to sleep phase advance, with consequent difficulty in getting up early in the morning and a preference for staying up late in the evening.<sup>19-21</sup> Social and environmental factors also contribute to behaviorally induced insufficient sleep.<sup>12</sup> During weekdays, the required time for school attendance (with early awakening time) and studying, together with social activities (in the afternoon and evening hours), decrease the time for sleep and lead to chronic sleep debt. Young people try to compensate by extending their sleep period during the weekends; nevertheless, the final result is a clear-cut chronic (and frequently not subjectively perceived) sleep deprivation.<sup>23</sup>

Adolescents also suffer from different clinical sleep disorders.<sup>8-16</sup> We did not aim to deeply investigate these diagnostic aspects by means of a self-reported questionnaire, but we still had information through questions addressing symptoms suggestive of sleep disordered breathing, restless legs syndrome, hypnagogic hallucinations, sleep paralysis, sleepwalking, and sleep terror.

The most common counterpart of unrefreshing sleep was daytime sleepiness, reported by 65% of our students. They reported falling asleep while traveling, watching television or listening to music, and reading or studying, and, sometimes, they also used stimulants (caffeinated soft drinks, tea, and tobacco) to maintain alertness.

We explored the associations among sleep quality, daytime sleepiness, and driving. Adolescent drivers crash more often than do experienced middle-aged drivers.<sup>37</sup> Their high crash rate (almost 3 times) has been related to young age, with a propensity for enhanced risk-taking behaviors, and overall driving inexperience.<sup>34</sup> Driving at night, carrying teenage passengers, and traveling faster than posted speed limits or than reasonable for bad weather or road conditions, are the commonly suggested causes of the increased risk of motor vehicle crashes in young and novice drivers.<sup>30,34</sup> The contributing role of sleepiness in car crashes among young people has been poorly explored. Adolescents have a high risk of being involved in a SRC because they drive late at night, and, consequently, they are supposed to be sleep deprived.<sup>15,28-30</sup> The chronic-sleep-deprivation hypothesis has been further confirmed in a recent study that proved the efficacy of a 1-hour delay in high-school start times on extending night-time sleep and reducing the rate of motor vehicle crashes.<sup>35</sup>

Our students recognized that sleepiness was a leading cause of car crashes, showing awareness of the problem; nevertheless, they did not adequately prevent and counteract the occurrence of sleepiness while driving, as has been previously reported.<sup>34</sup> In fact, only a minority of subjects used to stop driving and sleep for some minutes, whereas the most commonly adopted strategies such as singing, listening to music, and opening the window, were certainly inadequate. Moreover, even the students who stopped driving (showing awareness of the problem)

frequently adopted useless or short-lasting countermeasures to fight against drowsiness (e.g., washing their face, drinking coffee, or walking). We also emphasize the differences of sleep and lifestyle habits between students who crashed and those who did not, the former being more frequently male smokers who experienced sleepiness at the wheel and complained of having bad sleep. Consistent with previously reported data, we confirm that men were more likely than women to crash with a higher driving exposure, and other authors have suggested causes that include minor risk perception, speeding, and following to closely.<sup>34</sup> We outline the relationships among poor sleep quality, sleepiness, and self-reported car crashes, underlining the importance of sleepiness as a primary contributing factor for car crash risk among adolescents. Regarding the use of tobacco, we believe that it could be regarded as an indirect estimate of unhealthy lifestyle habits, as well as a behavior to counteract sleepiness.

We acknowledge some limitations to our study. First, our results were based on the students' self-reports, in the absence of confirmatory information such as sleep laboratory recordings, parents' and teachers' ratings, and standardized test batteries, that would have allowed us to perform a more comprehensive and reliable assessment. Nevertheless, previous studies comparing subjective reports to objective measurements have shown that self-reported data well represent sleep habits and sleepiness.<sup>38</sup> Second, we do not know how our sample represents the Italian population of adolescent students having a regular driving license, but the congruence between our findings on sleep and sleepiness and those from other studies suggested that the sample was typical of adolescents.<sup>8-16</sup> We suggest that future studies investigate the contribution of socioeconomic and cultural background in this field. Third, our study had a cross-sectional design. Therefore, the outcome variable (i.e., self-reported car crashes) was collected at the same time as the explanatory factors (e.g., bad sleep), which injected potential biases (e.g., recall bias, reverse causation) that should be addressed by further prospective cohort studies. Fourth, instead of using validated crashes (e.g., police records), we relied on self-reports of car crashes, which could have been overestimated or underestimated. Nevertheless, our questionnaires were anonymous, and students were assured that their answers could not have any influence on their driving licenses or school reports.

In conclusion, our young students frequently complain of symptoms of sleep disorders (insomnia, sleep phase advance, sleep disordered breathing, restless legs syndrome, daytime sleepiness) and suffer from chronic sleep deprivation. Poor sleep quality, together with sleepiness at the wheel, significantly increase the risk of car crashes in our population. Inadequate sleep hygiene could have negative effects on daytime functioning in adolescents; therefore, education programs on sleep issues and on the dangers of sleep deprivation targeted toward young people are warranted. Previous reports of education programs in schools have shown subsequent increased students' perception of sleep as a problem interfering with different aspects of their life. Cortesi and coworkers gave a 2-hour interactive sleep-education course to 540 Italian high-school students, documenting an improvement in knowledge and also a retention of information about sleep at a 3-month follow-up survey, mainly for the sleep need and the sleep debt, that could be considered the most

useful information for improving healthy sleeping habits.<sup>39</sup> Brown and coworkers further evaluated the effectiveness of a sleep treatment and education program for university students, reporting a significant improvement in sleep quality and sleep hygiene after 6 weeks of treatment.<sup>40</sup> Adolescence is a life period characterized by significant changes in biologic rhythms and social activities, in which we highlight the importance of sleep-related factors, to correctly educate young students to achieve a better quality of life.

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## DISCLOSURE STATEMENT

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