The Contributing Role of Sleepiness in Highway Vehicle Accidents

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Study objective: To evaluate the contributing role of sleepiness in Italian highway vehicle accidents during the time span 1993—1997.
Design: We analyzed separately the hourly distribution of accidents ascribed by police officers univocally to sleepiness and the rest.
Patients: N/A
Interventions: N/A
Measurements: Using a polynomial regression, we evaluated the relation between accidents (whether sleep-ascribed or not) and sleepiness as derived from a 24-hour sleep propensity curve. The relation between sleep-influenced and non-sleep influenced accidents was analysed using a linear regression
Results: The rate of non-sleep ascribed accidents is closely related with sleep propensity and bears a strong similarity with the pattern of sleep-ascribed accidents. A close relationship between the curves of non-sleep ascribed accidents and sleep-ascribed accidents is confirmed. The regression coefficient, which can be seen as the ratio between the quota of accidents that can be considered as sleep affected and those actually ascribed to sleepiness, results in a value of 5.83. Considering that the rate of sleep ascribed accidents is 3.2%, we can calculate the quota of sleep influenced accidents out of those not officially ascribed to sleepiness as 18.7% reaching an estimate of accidents related in some way to sleepiness equal to 21.9%.
Conclusions: Our indirect estimate of sleep influenced accidents approaches data reported by other European countries and highlights the importance of sleepiness as a direct and/or contributing factor in vehicle accident rates.
Key words: Sleepiness; vehicle accidents; circadian rhythm

INTRODUCTION

SLEEPINESS IS A MAJOR CONTRIBUTING FACTOR IN THE FREQUENCY OF HIGHWAY VEHICLE CRASHES and has serious consequences as it leads to a far higher fatality rate than other factors.[1,2,3,4]

The available data regarding the incidence of sleepiness vary considerably from country to country according to police methods for gathering data, to the population studied, to the definition of sleepiness adopted, and to the amount of detail available on road accidents.[1,3]

The different estimates of the impact of sleepiness may be due in part to the fact that sleepiness often underlies other, more apparent, factors (e.g., driving speed, weather and road conditions, vehicle condition, driving habits), and weighing up the contributing role of sleepiness is extremely difficult given the multi-factor nature of many road accidents.

On the other hand, the awareness of police officers about sleepiness as a factor contributing to vehicle accidents can vary greatly. This could explain the discrepancies between the low rate of road accidents ascribed to sleepiness obtained from the analy-sis of the databases and the higher percentage reported by field studies conducted by police officers sensitized on the importance of sleepiness as a determinant of vehicle accidents and supplied with a structured interview checklist.[1,3]

On the grounds of this assumption we attempted an evaluation of sleepiness as a factor contributing to the incidence of vehicle accidents by analyzing the database of vehicle accidents on the Italian highway network from 1993 to 1997. We analyzed separately the hourly distribution of accidents univocally ascribed by police officers to sleepiness and we made an attempt to evaluate, by means of a statistical estimation, the role of sleepiness as a contributing factor on vehicle accidents not directly ascribed to sleepiness on the same database.

METHODS

Data regarding vehicle accidents per hour of the day were supplied by the Italian National Institute of Statistics (ISTAT) and by the Italian Automobile Club (ACI).

Data regarding traffic density in the corresponding time span were supplied by the Italian Highways Society.[5]

Analysis of Sleep Ascribed Accidents

The criteria used by police officers to ascribe a given accident to sleepiness are the following:

- Suspicion of sleepiness as the major cause, stated by the policeman called on the accident scene. It is based on the pres-
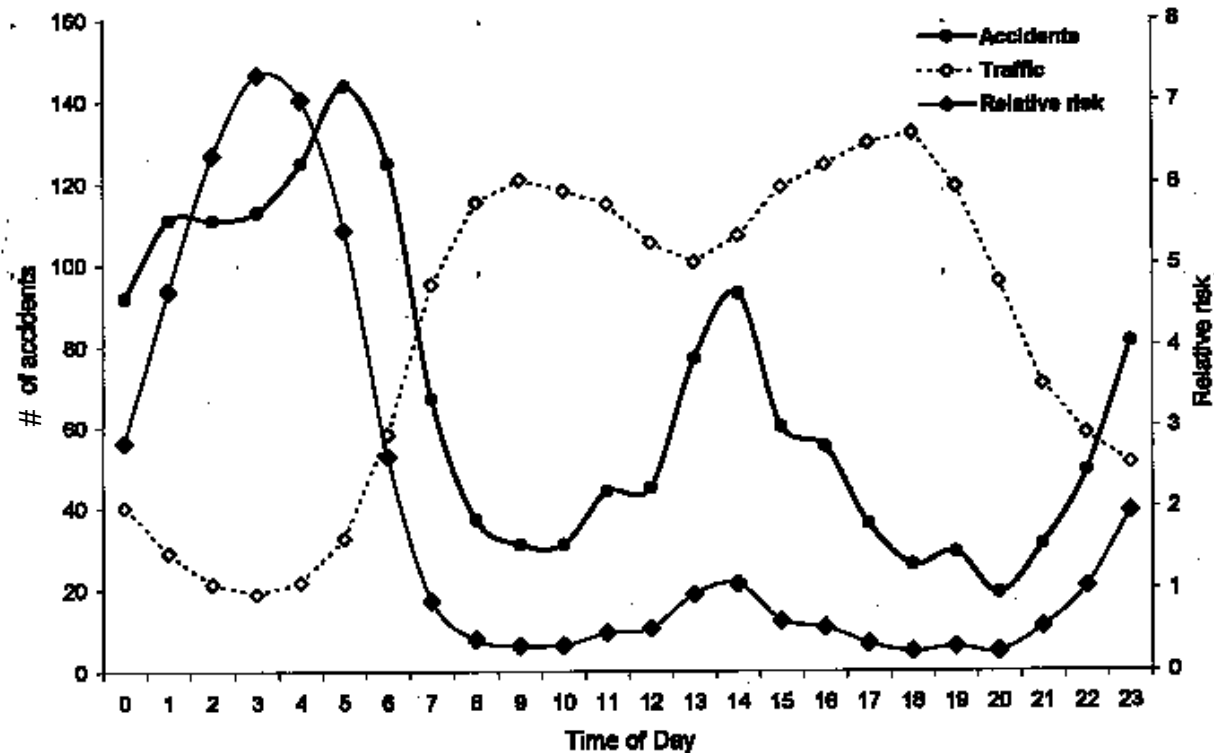

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Figure 1—Time distribution of sleep-related accidents and traffic density during the 24 hours. Heavy line, black circles: hourly distribution of sleep-related accidents. Dotted line, white rhombs: hourly distribution of traffic density. Thin line, gray rhombs: relative risk of sleep-related accidents.

ence of a single car accident without marks of breaking and/or with the car leaving the road on a straight line; the driver admission of having fallen asleep is not necessary for ascribing the accident to sleepiness.

• Exclusion of alcohol or of a neuropsychoactive substance ingestion in the judgement of the policemen and/or after breathalyzer use or blood tests.

• No running defects of the vehicle or defective tires.

• Absence of an intentionally dangerous or illegal driving behavior as speeding, driving too close to the vehicle in front, dangerous overtaking, and so on.

• Good weather conditions, clear visibility, and absence of abnormal road conditions.

• Exclusion of sudden loss of consciousness due to causes not related to sleep.

The hypothesis of significant influences on sleep-related accident distribution exerted by the time of the day has been evaluated by means of ANOVA.

The hypothesis of significant differences between the distribution of sleep-related accidents per hour and the distribution of traffic density were tested applying the Kolmogorov-Smirnoff test on the relative cumulated values. The relative hourly probability of sleep-related accidents was stated after correction for the differential traffic densities over the 24 hours by calculating the percent composition ratio for both sleep-related accidents and the traffic and then the proportionality ratio between them. This ratio expressed either the increase or decrease of the risk of sleep-related accidents with reference to the baseline condition in which accidents were simply proportional to traffic density (ratio = 1).

Analysis of the Role of Sleepiness on the Distribution of Accidents not Directly Ascribed to Sleepiness

We operated separately on vehicle accidents expressly ascribed by police officers to sleepiness and the rest. The number of total accidents per hour was divided by traffic density rates hour by hour, thus obtaining a normalized rate of accident occurrence over the 24-hour period.

Using a polynomial regression, we evaluated the relation between accidents (whether sleep-ascribed or not) and sleepiness as derived from a 24-hour sleep propensity curve. This curve has been obtained from previously published data in a study conducted in bed rest conditions.[6] It represents the hourly distribution of sleep time expressed as the percentage of the mean value of total sleep time during the 24 hours.

The relation between sleep-ascribed and non-sleep-ascribed accidents was analyzed using a linear regression, in the hypothesis that sleep-ascribed accidents could represent a constant quota of all accidents in which sleepiness may have played a role. The estimation of this quota has allowed us to approximate the percentage of accidents that may be considered to be affected by sleepiness.

RESULTS

Sleep-Ascribed Accidents

Sleep ascribed accidents in the explored period were 1,632, i.e., 3.2% of the overall number of accidents occurred (50,859). Death of the driver occurred in 11.4% of sleep-related accidents and contrasts with 5.62% of accidents not related to sleep.

ANOVA showed a highly significant effect of the time of the day (p<0.0001). Two gatherings of sleep-ascribed accidents were evident in night hours and in the mid-afternoon while two low-incidence time spans were present between 8:00 A.M. and 1:00 P.M. and between 6:00 and 9:00 P.M. The hourly distribution of traffic was clearly different, as confirmed by the Kolmogorov-Smirnoff test, and showed a nearly reversed pattern. The relative risk of sleep-related accidents showed peaks and troughs with a dramatic increase of risk during the night when it increased by more than seven times the reference value; the lowest level of the relative risk was detected in the late afternoon when it reached a quarter of the reference value (Fig.1).

The Relationship Between Sleepiness and Total Number of Accidents

The number of non-sleep-ascribed accidents was 49,784. The rate of non-sleep ascribed accidents was closely related with sleep propensity and bears a strong similarity with the pattern of sleep-ascribed accidents (Fig.2). In both cases a third degree polynomial fits the data well (p<0.0001) and accounts for 92% and 93% of total variance respectively. The patterns reveal the rapid increase in accident density in correspondence with high sleep propensity levels occurring at night. The close relationship between the two curves is confirmed by the linear regression of non-sleep ascribed versus sleep-ascribed accidents. The linear regression fits the data and accounts for 94% of variance. Both the regression coefficient and the intercept proved highly significant (p<0.0001). The intercept represents a constant rate of non-sleep influenced accidents: with reference to the mean traffic density it results in a value of 1,618.7 with a standard error of

64.7. The regression coefficient results in a value of 5.83 with a standard error of 0.32 (95% confidence limits: 5.16 – 6.50); it can be seen as the ratio between the quota of accidents that can be considered as sleep affected and those actually ascribed to sleepiness. Considering that the rate of sleep ascribed accidents is 3.2%, we can calculate the quota of sleep influenced accidents out of those not officially ascribed to sleepiness as: 5.83 x 3.2% = 18.7% (95% confidence limits: 16.52 – 20.81%). Adding to this the aforementioned 3.2% of sleep ascribed accidents produces an overall estimate of accidents related in some way to sleepiness equal to 21.9%±2.14 of the total.

CONCLUSIONS

As to temporal distribution of sleep-ascribed accidents, our data describe a situation which is largely superimposable to that of other countries.[1,3,7,8,9] The well known higher dangerousness of sleep-related accidents[2,3] is also confirmed.

Our data highlight clear circadian and circasemidian effects with evidence of high incidence of sleep-related accidents around 2 and 6 A.M. and in the early afternoon and of two zones of lower incidence from 9 to 11 A.M. and from 6 to 9 P.M. Such a distribution pattern is highly correlated with the well-known circadian and circasemidian rhythm of alertness-sleepiness, reported by several laboratories and is highly correlated with the curve of sleep tendency obtained from our previous study.[6] However the percentage of sleep ascribed accidents from our database (3.2%) is close to the percentage of incidence reported in the US databases (1%—3%) but is much lower than that obtained from other field studies on British motorways.[1,3]

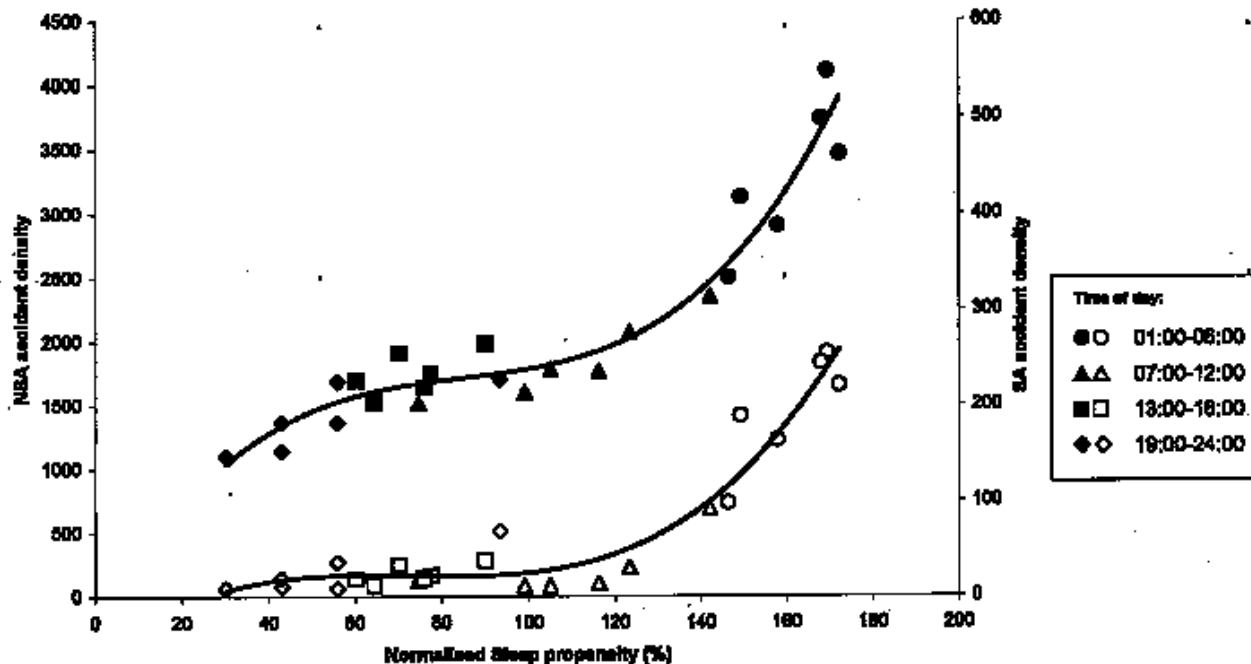Concerning the analysis of accidents not directly ascribed to

Figure 2—The density of accidents occurred on Italian highways (1993-97) is plotted versus the sleep propensity curve for both the sleep-ascribed accidents (SA, empty symbols) and non sleep- ascribed ones (NSA, full symbols). The number of accidents has been divided by the traffic density and then normalized so that the data point sum to the total number of accidents in the five years considered. The sleep propensity has been estimated from a bed rest protocol by evaluating, for every hour, the time spent in sleep as percent of its mean value during the 24 hours.

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sleepiness our findings demonstrate that the distribution of road accidents is actually correlated to the sleep propensity curve. This suggests a percentage of sleep influenced accidents much higher than the current rate of 3.2%. This percentage summed to that of directly sleep-ascribed accidents reaches the value of 21.9%. We can infer that such a difference may be attributed to the excessively limited definition of sleepiness adopted by the Italian police and to the scarce awareness of sleepiness as a contributing factor in road accidents. On the other hand, our data suggest that by altering driver performance and reaction time, sleepiness could increase considerably the risk of accidents in the presence of other contributing factors that ought to be randomly distributed (excessive speed, bad weather and road conditions, poor vehicle conditions, dangerous driving habits, etc.).

Our indirect estimate of sleep influenced accidents approaches the data reported by other European countries[3] (even though performed on reduced samples by police-officers made aware about the role of sleepiness in accidents) and highlights the importance of sleepiness as a direct and/or contributing factor in vehicle accident rates.

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