G Ital Med Lav Erg 2001; 23:4, 430-434

S. Garbarino[1,2,3], L. Nobili[2], M. Beelke[2], F. De Carli[4], V. Balestra[5], F. Ferrillo[2]

Sleep related vehicle accidents on italian highways

[1] Centre of Neurology and Medical Psychology, Health Service of the State Police, Department of the Interior, Italy
[2] Sleep Disorder Center, DISMR, University of Genoa, Italy
[3] Scuola di Specializzazione in Medicina del Lavoro, Università di Pavia, Italy
[4] Center for Cerebral Neurophysiology, National Research Council, Genoa, Italy
[5] Chair of Clinical Epidemiological Methodology, University of Genoa, Italy

RIASSUNTO. La sonnolenza è stata identificata come un importante fattore di rischio d'incidenti stradali, per tale ragione si rendono necessarie indagini specifiche anche in Italia. Obbiettivo dello studio è stato quello di valutare l'incidenza e le caratteristiche degli incidenti stradali dovuti a sonnolenza sulle autostrade italiane. Per questo studio sono stati utilizzati i dati ISTAT (1993-1997), 50859 incidenti stradali di cui 1632 (3,2%) attribuiti dalla Polizia Stradale alla sonnolenza. La distribuzione degli incidenti stradali è stata calcolata mediante l'analisi di varianza considerando come fattori: l'anno, il giorno della settimana, l'età e l'ora del giorno. È stato inoltre valutato il rischio relativo degli incidenti stradali dovuti a sonnolenza (ISDS), in rapporto ai livelli d'intensità di traffico (dati forniti dalla Società Italiana Autostradale). La distribuzione degli ISDS ha mostrato valori massimi e minimi nelle 24 ore in rapporto rispettivamente a livelli di maggiore sonnolenza e vigilanza. Tale distribuzione era ancora più evidente se riferita al rischio relativo. Gli ISDS, erano caratterizzati da una più elevata mortalità (11,4%) rispetto a quelli dovuti a tutte le altre cause (5,6%). La maggior parte degli ISDS sono occorsi agli automobilisti con meno di 35 anni (61,4%), in particolare modo durante le ore notturne con un aumento progressivo del numero nel corso degli anni analizzati. Specialmente prevalevano quelli verificatesi nel weekend. La sonnolenza si rivela un importante fattore di rischio e, a nostro parere, il suo ruolo contributivo come causa e/o concausa negli incidenti autostradali italiani è ancora sottovalutato.

Parole chiave: incidenti, incidenti stradali, ritmi circadiani, sonnolenza, ergonomia.

ABSTRACT. Sleepiness has been identified as a significant risk factor for vehicle accidents, and specific surveys are needed for Italy. The aim of this study was to assess incidence and characteristics of sleep-related vehicle-crashes on Italian highways. The database of the Italian National Institute of Statistics (1993-1997) was the source for the survey (50859 accidents with 1632 (3,2 %) ascribed to sleep by the police). The distribution of accidents was evaluated by means of the analysis of variance considering the year, the day of the week, the age and the time of day and their interactions as main factors. The relative risk of sleep-related accidents was also evaluated with reference to the relative traffic density as estimated by the Italian Highways Society. The counts of sleep-related accidents, and even more the relative risk, revealed the presence of peaks and troughs in zones at a higher level of sleepiness and alertness respectively. Death of the driver occurred in 11.4 % of sleep related accidents versus 5.6 % in general accidents. The great majority of sleep-related accidents occurred to drivers under 35 (61.4 %) mainly during the night with an increasing trend in the yearly number of sleep-related accidents, especially on weekends. Therefore sleepiness appears a remarkable risk factor and, in our opinion, its incidence as sole or contributory cause of accidents on Italian highways is still underestimated.

Key words: *accidents, vehicle accidents, circadian rhythms, sleepiness, ergonomics.*

Introduction

Sleepiness has been identified as a significant risk factor for vehicle accidents (1, 2). Recently investigators have assessed the incidence, time of day influences, and driver morbidity associated with sleep-related vehicle crashes. Data from the United States (3), Israel (4), France (5, 6), Sweden (7), Finland (8) and the United Kingdom (9, 10, 11) state that sleep-related vehicle accidents are largely dependent on the time of day and account for a considerable proportion of total accidents, especially on motorways and other monotonous roads. They cause greater driver morbidity and mortality because of the greater speed on impact (12,10). To date no comparable data are available for Italy. We report in this study on sleep-related vehicle accidents occurred on Italian highways covering all accidents after which the police were called, during the period 1993-1997 inclusive, taking into account their distribution over the time of day, the age of drivers and the day of the week.

Material and Methods

Data regarding vehicle accidents per hour of the day and per day of the week were supplied by the Italian National Institute of Statistics and by the Italian Automobile Club. Data regarding traffic density in the corresponding time span were supplied by the Italian Highways Society. The relationship between the accident and sleepiness was assessed by the policemen involved according to the following criteria.

- Suspicion of sleepiness as the prime cause, expressed by the policeman called on the accident scene and based on the presence of a single car accident without marks of breaking and/or with the car leaving the road on a straight line; the driver's admission of having fallen asleep being not compulsory 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.

Abbrevations:

ANOVA, Analisys of Variance

- No running defects of the vehicle or defective tires.
- Elimination of intentionally dangerous or illegal driving behaviors as speeding, driving too close to the vehicle in front, dangerous overtaking, and so on.
- Good weather conditions, clear visibility and absence of abnormal conditions of the road.
- Exclusion of sudden loss of consciousness due to causes not related to sleep.

No detailed instructions about sleep-related accidents have been given to policemen or have they been supplied with structured interview checklists or sensitized to sleepiness and driving problems either.

The hypothesis of significant influences on sleep-related accident distribution exerted by the time of day, the driver age, the day of the week and the year was explored by means of ANOVA, and two and three factor interactions were also considered. As sleep-related accidents were rare events at the level of detail used in our survey, the factor levels for the analysis of variance were grouped as follows:

- three classes for the day of the week (working day, Saturday and Sunday);
- six age classes (18 - 25, 26 - 35, 36 - 45, 46 - 55, 56 - 65, over 65 years);
- six time intervals within a day;
- five time intervals of one year each in the period 1993-1997.

The counts of accidents were then handled as frequencies of events with a Poisson distribution and hence, as recommended by Freeman and Tukey (13), the following transformation was applied:

$$x^1 = \sqrt{x} + \sqrt{x + 1}$$

The hypothesis of significant differences between the distribution of sleep-related accidents per hour and the distribution of traffic densities was 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 the increase or decrease of the risk of sleep-related accidents with reference to the baseline condition in which the accidents were simply proportional to the traffic density (ratio = 1).

The hypothesis of an increasing trend of sleep-related accidents over time was tested by means of the Poisson regression analysis.

Results

Sleep related accidents in the explored period were 1632 comprising 3.2 percent of the 50859 accidents occurred. Death of the driver occurred in 11.4 percent of sleep-related accidents contrasting with 5.62 percent of accidents not related to sleep.

ANOVA showed a highly significant effect ($p < 0.0001$) of the year, the age and the time of the day, while the effect of the day of the week resulted borderline significant ($p < 0.05$). The analysis of variance also showed a significant interaction between:

– the day of the week and the age;
– the year, the day of the week and the age;
– the day of the week and the time of the day;
– the age and the time of the day.

The year and the age also interacted at a borderline significant level ($p < 0.05$).

Some details concerning the analysis of variance are reported in table I, while patterns associated to significant effects are described in the following.

First of all we considered the effect of the time of the day, by examining the absolute number of hourly sleep-related accidents, the hourly distribution of traffic and the relative risk of sleep-related accidents (figure 1). Three peaks were evident in the heavy line (absolute number of accidents), centered on 2.00 a.m., 6.00 a.m. and 3.00 p.m., 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 nearly in the same position as those of raw data with a dramatic increase during the night and rising to more than sevenfold the reference value. A maximum decrease in the late afternoon, lowering to a quarter of the reference value, was also evident.

Table I. ***Results of the analysis of variance performed by the GLM procedure of the SAS software. The transformed values of sleep-related accident counts acted as dependent variable while the effects considered were the year, the day of the week, the age and the time of the day and their two and three levels interactions. The significance levels are marked by '*' (p < 0.05) or '**' (p < 0.001)***

	Source	Degrees of freedom	F Value	Pr > F
**	Whole model	389	4.11	0.0001
**	Year	4	8.12	0.0001
*	Day	2	3.58	0.0295
	Year * Day	8	1.61	0.1217
**	Age	5	99.95	0.0001
*	Year * Age	20	1.84	0.0177
**	Day * Age	10	4.19	0.0001
**	Year * Day * Age	40	2.21	0.0001
**	Time	6	45.49	0.0001
	Year * Time	24	1.09	0.3581
**	Day * Time	12	2.97	0.0007
	Year * Day * Time	48	1.14	0.2654
**	Age * time	30	9.29	0.0001
	Year * Age * Time	120	1.16	0.1729
	Day * Age * Time	60	1.23	0.1386

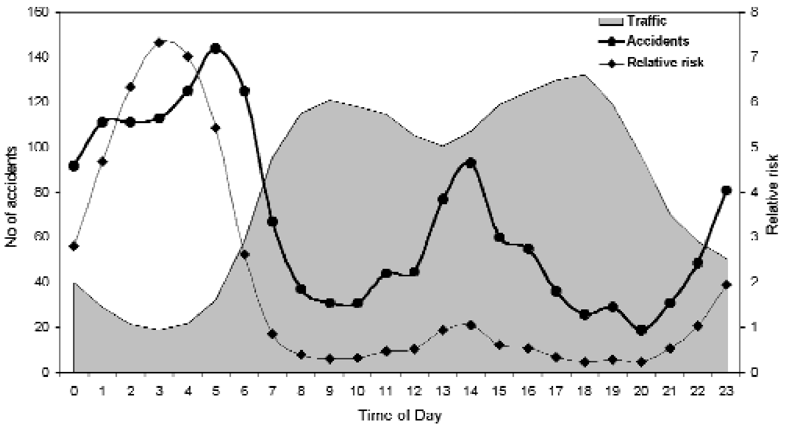

Figure 1. ***Time distribution of sleep-related accidents and traffic during the day. Heavy line: total counts of hourly sleep-related accidents during the five years considered in the study. Gray area: percent traffic distribution of the traffic density during the day. Thin line: relative risk of sleep-related accidents (see the text for the definition)***

As to other effects and interactions, we could analyze only the distributions of the absolute number of accidents, as no detailed norm for road use was available.

Concerning the age, the great majority of sleep-related accidents occurred to drivers under 35 (n = 994, percent = 61.4) contrasting with the 26.8 percent occurred to drivers between 36 and 55 and the 11.8 percent to those over 55. Moreover, looking at data in greater detail, we found the maximum number of sleep related accidents for the age class 21 - 25 (n = 368, 22.7 percent), followed by a nearly exponential decrease with age (figure 2). The interaction between age and time of the day was evident when comparing the time distribution of the accidents for the three main age classes (figure 3A): during night hours (from 9 p.m. to 5 a.m.) most accidents occurred to under 35 drivers (70.1 percent) while during the 13-16 peak the number of accident was more even. Moreover the 13-16-time span is the time of day where the maximum number of accidents was found for the oldest drivers (age > 55).

Concerning the day of the week, the maximum number of sleep-related accidents occurred on Sunday (n = 343) followed by Saturday (n = 277), while 1012 accidents occurred during working days, with a mean number of 202.4 and values within 187 - 214. The day of the week was marked as slightly significant in the statistical analysis, but interacted significantly with other factors, highlighting different time and age patterns. The hourly distributions of accidents for the mean weekday, Saturday and Sunday are compared in figure 3B, where the main differences were evident during the late night hours (0 a.m. - 7 a.m.). The counts of accidents occurred on Sunday nights clearly exceeded the values of Saturday while values for the mean weekday were by far the lowest. On the contrary the three patterns were rather similar during daytime.

Remarkable differences among the mean weekday, Saturday and Sunday were also found concerning the age distribution of accidents (figure 4): the youngest age class was involved in a greater number of accidents, which greatly increased on Saturdays and Sundays. The percent of sleep-related accidents occurred on weekends for this age class was 49.5, compared with values ranging from 30 to 36 percent for the other age classes.

An increasing trend in the yearly number of sleep-related accidents was noticeable and confirmed by the Poisson regression (n = 260, 253, 308, 422, 375; $p < 0.0001$). The significant three factor interaction among the year, the day of the week and the age mainly reflected the marked increase of Sunday accidents involving young people, up to 35 years (figure 5).

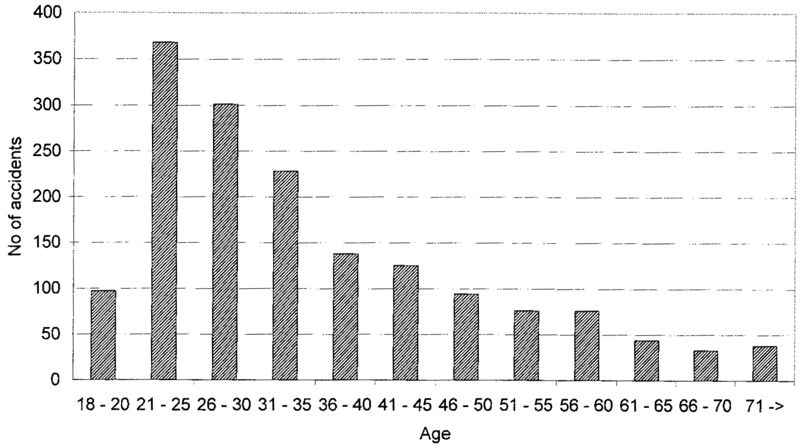

Figure 2. ***Number of sleep-related accidents in each age class during the five years considered in the study***

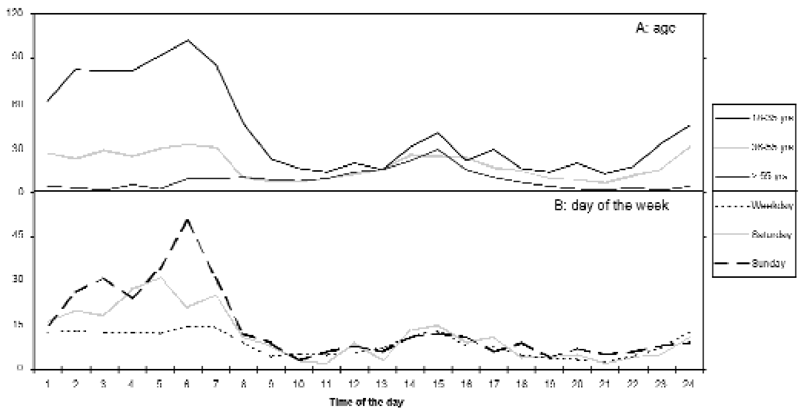

Figure 3. ***Time distribution of sleep-related accidents during the day for the three main age classes (A) and for the three typical days of the week (B). The data for the weekday were computed as the mean counts of accidents for the five working days (from Monday to Friday)***

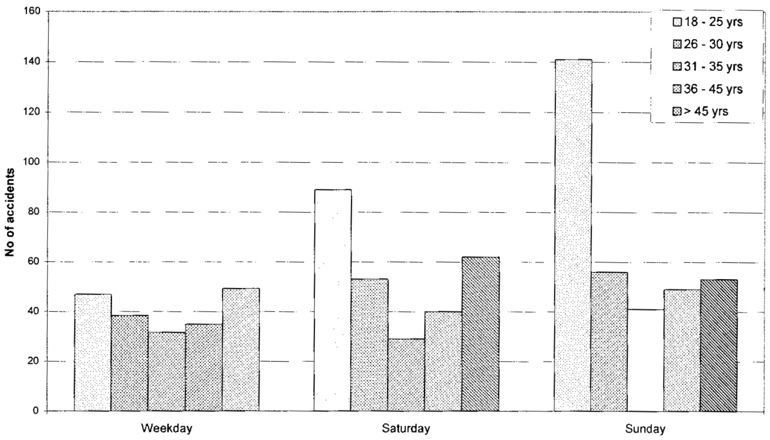

Figure 4. ***Number of sleep-related accidents per age class and day of the week***

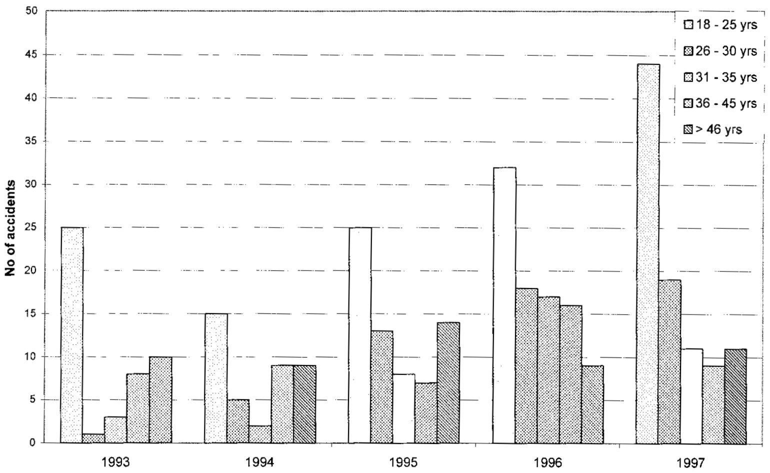

Figure 5. ***Distribution of sleep-related accidents occurring on Sundays per year and age class***

Discussion

All in all our data describe a situation which is largely superimposable to that of other countries (10). As to the influence of time of the day our data put into evidence 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 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 semicircadian rhythm of alertness-sleepiness, reported by several laboratories (14, 15, 16). Similar patterns of distribution of sleep-related accidents were obtained by other investigators (3, 7, 9). Sleepiness is a normal manifestation of the biological need for sleep and increased sleepiness is associated with a decrement in reaction time, psychomotor coordination, information processing and decision making which influence the probability of having accidents (17). In order to evaluate the relative risk of sleep related accidents as a factor independent of traffic rate, we computed the proportionality ratio between the number of accidents and the traffic; we could then quantify the risk increase in the night hours to more than seven-fold the reference value and the decrease in the late afternoon to less than a quarter of the reference value. This normalization clearly strengthened the difference between night and daytime data as the traffic density itself is spontaneously correlated with the mean level of alertness.

Concerning the mortality of the accidents our data seem to be confirmative of the well known higher dangerousness of sleep-related (12). For this purpose it is worth pointing out that our data on drivers mortality include only death occurred within 7 days from the accident while international definition is extended to 30 days and - according to the Italian National Institute of Statistics - the datum of mortality should be multiplied for a 1.08 coefficient (18).

Although the lack of appropriate norms for road use by age, day of the week and time of day do not allow to discriminate between the exposure and the risk of sleep related-accidents at the level of detail used in this study, our results account for a specific risk for drivers under 25 years and chiefly during night hours. Such an increased risk for younger drivers seems to be absent in relation with the early afternoon sleepiness peak. In this time span we found an even distribution of accidents across age span and the maximum number of accidents for the over 50 drivers age group. We can infer that old drivers are less exposed to risk of accidents during the night hours and are more likely to drive during the afternoon, so that - according to Horne (19) - the high incidence of sleep-related accidents for young adults during the night could be interpreted as a mixture of higher risk and higher exposure. This interpretation is corroborated by data on the differences between working days and weekends: the occurrence of late night socializing and poor sleep habits on Saturdays and Sundays are likely to prevent younger drivers from getting sufficient sleep thus augmenting their risk and their exposure at the same time. From these data we can affirm that the combining effect of young age, night hours and weekends strongly increase the risk of sleep-related vehicle accidents.

In the framework of an increasing trend in the number of sleep-related accidents during the five years we considered, the maximum increase was found in accidents occurring on Sunday nights (the night between Saturday and Sunday) and mostly involving young people. These data could be the expression of a strong rise in sleep-related accidents due to the increased number of young people adopting a lifestyle that involves behaviors which put them at risk as to sleep-related accidents, i.e. late night socializing, sleep loss, early morning driving after sleep deprivation, fatigue due to dancing and noisy environments and possible interference of psychotropic substances (3).

On the other hand such an increase could also be influenced by an increased awareness of police officers about the relationship between sleepiness and driving and of their focusing attention on sleep loss side-effects and on young people behavior.

On the grounds of this we think that the high level of subjectivity of police officers in ascribing accidents to sleepiness is a serious shortcoming of this survey. In many cases the ascription of an accident to sleepiness probably occurred after the spontaneous admission of the driver involved but it was impossible to assess the role of sleepiness from the evaluation of objective data gathered by police operators on the accident scene. For example, when sleepiness could have been the main cause of an accident along with other co-factors as illegal behavior of the driver, namely speeding, the accident was attributed to speeding.

Such shortcomings could partially explain the discrepancies concerning the incidence of sleep-related accidents between our result (3,2 percent of all highways accidents) and data reported by Horne (9) for English motorways (23 percent). The data analyzed by Horne were collected by police officers sensitized on sleep-related vehicle accidents and supplied with a short structured interview checklist to be administered to all drivers involved in all accidents, whether they were sleep-related or not. On the other side our data seem to be closer to the 1-3 percent of US highway crashes caused by driver sleepiness (3). Further studies must be performed for an in-depth comparison of data collected in different countries. However, though our data show a certain remarkable trend in the time and age distribution of sleep-related accidents, in our opinion the incidence of sleepiness as sole or contributory cause of accidents on Italian highways is still underestimated.

Acknowledgements

This survey was made possible thanks to the cooperation of:

- The Italian National Institute of Statistics that collected and structured the data base, in particular thanks to Dr. R. Amato and Mrs. M. Patteri;
- The Italian Highways Society that provided the model for the relative traffic density;
- The Italian Traffic Police (Department of the Interior) that gave a lot of useful information for the analysis and interpretation of the data, in particular thanks to Dr. P. Cestra and Dr. G. Zadro.

References

1) Mitler MM, Carskadon MA, Czeisler CA et al. Catastrophies, sleep and public policy - consensus report. Sleep 1988; 11:100-9.
2) Dinges DF. An overview of sleepiness and accidents. J. Sleep Res 1995; 4(suppl.2):4-14.
3) Lyznicki JM, Doege TC, Davis RM, Williams MA. Sleepiness, driving, and motor vehicle crashes. JAMA 1998; 279: 1908-13.
4) Zomer J, Lavie P. Sleep related automobile accidents - when and who? In: Horne JA (ed) Sleep '90 Bochum-Pontenagel Press 448-451.
5) Philip P, Ghorayeb I, Stoohs R, Menny JC, Dabadie P, Bioulac B, Guilleminault C. Determinants of sleepiness in automobile drivers. J Psychosom Res 1996; 41: 279-288.
6) Beslot P, Cabon P, Mollard R. Accidentologie autoroutiere et fatigue [French]. Proceeding of the workshop on "Human factors and safety on highways", 23-24 September 1999, Paris, France.
7) Kecklund G, Akerstedt T. Time of day and Swedish road accidents (Abstract). In: Akerstedt T, Kecklund G, eds. Work hours, sleepiness and accidents. Stockholm, S: Karolinska Institute, (Stress Research Report No 248, Section of Stress Research), 1994: 100.
8) Summala H, Mikkola T. Fatal accidents among car and truck drivers: effects of fatigue, age and alcohol consumption. Human Factors 1994; 36: 315-26.
9) Horne JA and Reyner LA. Sleep related vehicle accidents. Br Med J 1995: 310, 565-67.
10) Maycock G. Sleepiness and driving: the experience of UK car drivers. J Sleep Res 1996; 5: 229-37.
11) Horne JA and Reyner LA. Vehicle accidents related to sleep: a review. Occup Environ Med 1999; 56: 289-94.
12) Pack AI, Pack AM, Rodgman E et al. Characteristics of crashes attributed to the driver having fallen asleep. Accid Anal Prev 1995; 27: 769-75.
13) Freeman MF and Tukey JW. Transformations related to the angular and the square root. Annals of Mathematical Statistics 1950; 21: 607-11.
14) Broughton R, and Mullington J. Circasemidian sleep propensity and the phase amplitude maintenance model of human sleep/wake regulation. J Sleep Res 1992; 1:93-98.
15) Lavie P. Ultrashort sleep-waking schedule. III. 'Gates' and 'forbidden zones' for sleep. Electroencephalogr Clin Neurophysiol 1986; 63: 414-25.
16) Nobili L, Besset A, Ferrillo F et al. Dynamics of slow wave activity in narcoleptic patients under bed rest conditions. Electroenceph Clin Neurophysiol 1995; 95: 414-25.
17) Monk TH. Sleepiness, sleep and performance. Chicherster, UK: J Willey, 1991.
18) Putignano C. Measuring under-reporting of road accidents in Italy (Abstract). Seminar on International Road Traffic and Accident Databases, Helsinki, 11-13 sept 1995, Abstract Book.
19) Horne JA and Reyner LA. Driver sleepiness. J Sleep Res 1995; 4(suppl2): 23-9.

Reprint request: *Dr. Sergio Garbarino - Center for Sleep Medicine (DISMR) - University of Genoa - Ospedale S. Martino - Largo R. Benzi, 10 - I-16132 Genova, Italy - Phone: +39-010-3537465 - Fax: +39-010-3537699 - E-mail: fifi@dism.unige.it*