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A Case-Crossover Study of Sleep and Childhood Injury

Francesca Valent, MD*; Silvio Brusaferrò, MD*; and Fabio Barbone, MD, DrPH†‡

ABSTRACT. *Objective.* To evaluate the association between sleep and wakefulness duration and childhood unintentional injury.

Study Design. Case-crossover study.

Methods. Two hundred ninety-two injured children who presented at the Children's Emergency Center of Udine, Italy, or their parents were interviewed after a structured questionnaire. Information was collected concerning sociodemographic variables, participant's habits, and injury characteristics, including a brief description of the accident dynamics. Sleep or wakefulness status of the child was assessed retrospectively for each of the 48 hours before injury. For each child, we compared the 24 hours immediately before the injury (hours 1–24; case period) with hours 25 to 48 (control period). Nonparametric tests were conducted to compare the difference of sleep duration between case and control periods. In addition, we conducted intrapersonal conditional logistic regression analyses and estimated relative risks (RRs) and 95% confidence intervals (CIs).

Results. Overall, more children had longer hours of sleep during the control period than during the case period. However, this difference was significant for boys only. A direct association between injury risk and sleeping <10 hours was found among boys (RR: 2.33; 95% CI: 1.07–5.09) but not among girls (RR: 1.00; 95% CI: .29–3.45). This association was particularly strong among boys attending nursery school. We also found a direct association between injury occurring between 4 PM and midnight, and being awake for at least 8 hours before injury occurred (both sexes, RR: 4.00; 95% CI: 1.13–14.17).

Conclusions. Our findings show that inadequate sleep duration and lack of daytime naps are transient exposures that may increase the risk of injury among children. These results suggest new prospects for injury prevention in childhood. *Pediatrics* 2001;107(2). URL: <http://www.pediatrics.org/cgi/content/full/107/2/e23>; *children, injury, sleep, case-crossover, epidemiology*.

ABBREVIATIONS. CERP, children's emergency room of the pediatrics department; RR, relative risk; CI, confidence interval.

From the *Cattedra di Igiene ed Epidemiologia, DPMS, University of Udine, Udine, Italy; and the †Department of Epidemiology and International Health, University of Alabama at Birmingham, Birmingham, Alabama.

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Address correspondence to Fabio Barbone, MD, DrPH, Department of Epidemiology and International Health, 220J RPHB, 1665 University Blvd, University of Alabama at Birmingham, Birmingham, AL 35294-0022. E-mail: fbarbone@ms.soph.uab.edu

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In Italy (~56 million inhabitants; 9 million children <15 years of age), ~500 children <15 years of age are killed each year in unintentional injuries.¹ Homicides and suicides are much less frequent, accounting for <10% of all fatal injuries among children.¹ In Northern Italy, in 1995, injury mortality rates (*International Classification of Diseases, Ninth Revision* codes from 800 to 999) were 10 deaths/100 000 inhabitants under 1 year of age, 5/100 000 from 1 to 4 years of age, and 6/100 000 from 5 to 14 years of age. Among infants, injury represented only 2% of overall mortality, whereas in the 2 older age groups injuries accounted for 18% and 33% of all deaths, respectively.² Mortality, however, is just the tip of a pyramid, where for each injury resulting in a death there are many injuries causing hospitalization and treatment in emergency centers, by general practitioners or by paramedics only.³

Sudden events are often caused by complex, concatenated mechanisms whose identification may fail because they are transient in nature.⁴ In particular, traditional case-control studies may not be well suited to investigate relevant risk factors for sudden events. The case-crossover design, in contrast, has proved to be particularly useful when investigating how transient exposures can trigger acute events, such as cardiovascular events,^{5,6} injuries,^{7–10} and death in general.^{11,12} The case-crossover design has also been proposed as a useful method in the study of occupational injuries.¹³ This epidemiologic method has been successfully applied to evaluate the risk of childhood injuries associated with traffic volume and speed on the roads crossed by young pedestrians⁷ and with emotional distress and physical activity.¹⁰ The case-crossover design offers a number of advantages. Cases serve as their own controls and a participant's exposure at the time of the event of interest (case period) is compared with another period when the participant was not a case (control period). Therefore, it is not required to sample additional control participants. In the analysis, each participant is considered a stratum in a case-control study, where cases and controls are times. Comparisons are made within each participant; therefore, this approach controls by design for potential confounding caused by age, sex, personality, and other stable participant-specific covariates.

Because there is evidence that among adults sleepiness may be a factor and a cofactor of vehicle accidents^{14–16} and vigilance deficits have been shown to be related to traffic injuries in children,¹⁷ we conducted a case-crossover study to examine the effects

of sleep and wakefulness duration on the occurrence of unintentional injuries in childhood.

METHODS

Data Collection

This study was conducted at the children's emergency room of the pediatrics department (CERP) of the University of Udine, the only acute pediatric care center in the Province of Udine. Only a few children present to the general emergency room instead of CERP, and the most plausible reasons are being borderline-aged or having suffered a life-threatening injury requiring transportation to the hospital by ambulance or helicopter.

We trained 5 interviewers (2 medical doctors, 2 medical students, and 1 biologist working in the medical field) who staffed CERP between May 10 and July 4, 1999, for a total of 28 seven-hour shifts and 28 eight-hour shifts. Seven-hour shifts were from 9 AM to 4 PM, 8-hour shifts from 4 PM to midnight. Shifts were assigned so that each day of the week was covered 8 times (4 seven-hour and 4 eight-hour shifts), but with no more than 1 shift a day. The interviewer on duty approached patients with acute injury presenting to CERP. We decided to enroll patients who declared unintentional injuries, who were treated and discharged from the emergency department or admitted to any of the hospital services, and who were accompanied by at least 1 parent giving written informed consent. After a structured questionnaire, the interviewers conducted in person interviews with the patient's mother or father or with the child, if the child was old enough to understand and properly answer the questions. The interviews took place while waiting for the pediatrician to see the injured child or immediately after the visit. Complete interviews lasted ~10 to 15 minutes each. Information collected concerned characteristics of the patient, such as sex; age and educational level; acute or chronic use of medication; the child's usual sleeping pattern; the child's sleeping pattern during the last week; date, hour, and characteristics of injury; and a short narrative reconstruction of the accident. The interviewers also investigated the 48 hours before injury, asking whether the patient was asleep or awake, hour-by-hour. *International Classification of Diseases, Ninth Revision* E-codes were assigned to each injury by one medical doctor (F.V.) after reading the description of the injury dynamics.

Statistical Analysis

This was a case-crossover study, in which each participant acted as his or her own control. We compared sleep and wakefulness duration in the 24-hour interval immediately before injury, when the child served as a case, with the 24-hour interval of the previous day, when the child served as a control. The dependent variable was the presence or absence of injury. The exposure categories were obtained dichotomizing daily sleep amount and length of wakefulness periods. Conditional logistic regression was used to estimate relative risks (RRs) and 95% confidence intervals (95% CIs). First, we calculated the RR of injury during a 24-hour period in which the child had slept <10 hours, compared with a period in which he/she had slept at least 10 hours. Second, for injuries occurring between 4 PM and midnight, we calculated the RR for having been awake for at least 8 hours, compared with <8 hours. These cutoffs were chosen according to the methodology developed by Maclure⁵ to minimize nondifferential misclassification of exposure. In brief, we repeated the risk calculations varying the time intervals and chose the cutoffs that maximized the RR. Our selection was also supported by biological reasons. In fact, 10 hours were also the median and the mean duration of sleep in our sample. For sleep duration, we considered as the effect period the whole day, from rising to going to bed, because we assumed that influence exerted by insufficient sleep started immediately after rising in the morning and lasted until going to bed in the evening. Both nighttime sleep and daytime naps were included when considering as exposure a sleep duration <10 hours. In fact, Kaplan et al¹⁸ found among children a tradeoff between nap length and nighttime sleep, which were negatively correlated. In addition, children's sleep distribution has been shown to depend on age.¹⁹ Separate analyses were also conducted using the sleep duration variable as continuous rather than dichotomous. This approach allowed for an evaluation of a possible dose-response relation between duration of sleep and childhood injury. Finally, we eval-

uated differences between usual sleep duration and sleep duration during the 48 hours before injury.

In the analyses regarding wakefulness duration, we chose 8 hours as a cutoff because it is likely that if a child had been awake for such a period, no naps were taken early in the afternoon. For wakefulness duration, we selected as the effect period the part of the day starting from 4 PM until going to bed, because it provided the highest RR estimates among all periods allowing for a previous 8-hour wakefulness.

In stratified analyses, we grouped cases by age and type of school attendance, as follows: <1 year old; 1 to 2 years old; children attending nursery school (3–5 years old); children attending elementary school (6–10 years old); children attending middle school (11–13 years old); children attending high school (≥ 14 years old). In fact, not only age may be associated with injury occurrence, injury nature, and sleep characteristics, but also school type may be an important factor in that it influences the children's habits (eg, bedtime, rise time, and leisure activities).

For the case-crossover analyses, the effect measures were calculated considering all the participants, and after excluding children <1 year of age and participants attending high school. The former group was excluded because their role was unlikely to be active in determining the injury. The latter group was excluded because many risk factors other than intrapersonal variation of sleep are likely to play a much more relevant role. In fact, these children can operate mopeds, their schools are more frequently distant from home, and they are more likely to drink alcohol^{20,21} and to smoke.²² All case-crossover analyses were repeated after excluding children who were injured in circumstances that they probably could not control, that is children bitten by animals and as car passengers.

Because some children could have been awake for a long time in the same day when they slept few hours overall, for injuries taking place after 4 PM, we fit a conditional logistic regression model with both sleep and wakefulness duration, to evaluate the effect of wakefulness after controlling for the other. In addition, day of the week was considered as a potential intrapersonal confounder, because it may be associated with both the risk of injury and lack of sleep. To control for potential confounding by day of the week, we included an indicator variable (weekday vs weekend) in a multivariate conditional logistic regression model. Because injury risk varies with time of day and fatigue increases with time, we evaluated possible effect modification by time of the accident. To evaluate whether the relation between sleep duration and injury varied with type of activity at the time of injury, we performed subgroup analyses according to activity risk level. In particular, we considered activities, such as walking, playing with friends or with toys, bathing and washing hands, and eating meals as relatively safe. In contrast, activities involving a higher level of energy (riding bicycles, playing football, rugby, volley-ball, climbing playground equipment, etc) were considered as risky. We also performed stratified analyses according to place of injury.

RESULTS

During the 420 hours covered by our staff, 340 unintentionally injured children presented to CERP. Among them, 311 (91.5%, 186 boys and 125 girls) participated in the study. Fourteen children were not enrolled because they were accompanied by persons other than their parents and no informed consent form could be signed by them. Seven children could not be interviewed because they had to undergo diagnostic tests in locations not adjacent to the division of pediatrics and the interviewers could not follow them because other cases had arrived at the emergency department. Seven children were not enrolled because their parents refused to sign the consent form; and 1 child was too seriously injured to be interviewed. Most of the 311 children enrolled in the study were treated and discharged from the emergency center; only 10 children required admission to inpatient services: 8 were discharged within 3 days from the division of pediatrics and 1 from the inten-

sive care service; 1 was discharged from pediatrics after >3 days.

For 19 cases, complete information on the exact number of hours of sleep during the 48 hours before injury was not available. The main reason for this was that 12 children had been bitten by ticks and, as is often the case, they did not notice the bite immediately and could not estimate the exact hour it had occurred. Therefore, 292 children remained eligible for the case-crossover analyses.

Injury, as reported to CERP, was more frequent among boys (62.0%) than among girls (38.0%). However, between 1 and 4 and from 10 to 11 years of age, female cases were almost as numerous as males. Falls were the leading cause of injury (42.5%), followed by knocks received for striking against objects or for being struck by objects or persons (16.4%), and by pedal cycle accidents (13.4%). No relevant differences between males and females were found regarding the distribution of external causes, with the exception of falls. In fact, although falls represent the same proportion of injuries among boys as among girls, the 2 sexes differ by characteristics of the fall. Falls from playground equipment, cliffs, chairs, and beds were more frequent among females than among males. Boys more than girls fell on ground level because of slipping, tripping, or stumbling. Falls were the leading cause of injury among children <6 years of age. Children <1 year of age fell from beds and chairs only, toddlers fell mostly on ground level, whereas children from 3 to 5 years of age fell as frequently on ground level as from a higher level. Among children from 6 to 10 years of age, the most frequent external causes were pedal cycle accidents (18.2%), falls (23.9%), and knocks (21.6%). A higher level of dynamic energy was involved in the majority of injuries among children from 11 to 13 years of age

(pedal cycle accidents: 28.2%, knocks: 23.1%) and among children attending high school (knocks: 25.0%, motor vehicle accidents: 17.8%). Injuries occurred more frequently late in the afternoon (36.0% from 4 PM to 7 PM) and during weekend days (35.2%). Only 4 children reported chronic consumption of drugs that could have decreased their vigilance level.

Table 1 shows the sleep characteristics of the injured children admitted to CERP. Almost one half of the children usually slept 10 to 11 hours a day, including both nighttime sleep and daytime naps. Very few children usually slept <8 hours (1.4%) or 14 hours or more (1.7%). As age increased, higher proportions of children usually slept fewer hours; even among the oldest children; however, nobody usually slept <6 hours a day. During the week before injury, most of the children were reported as having slept about the same number of hours as usual. However, the usual sleep duration was generally slightly lower than the sleep duration during both the control and the case period.

The comparison of daily sleep amount during the last day before the injury with the day before last highlighted that, overall, more children had longer hours of sleep during the control period than during the case period (sign test, $P < .046$). However, this difference was significant for boys only and, if considering age groups, for 3- to 5-year-old children only. Among all children, the mean number of daily hours of sleep was slightly lower during the case period than during the control period. Considering age groups, a lower mean duration of sleep during the case period was evident only for children 1 to 5 and 11 to 13 years of age.

The RRs of injury for sleeping <10 hours a day overall are shown in Table 2. Having slept <10 hours

TABLE 1. Sleep Characteristics Among 292 Injured Children Admitted to the Emergency Room, According to the Type of School Attendance

	School Age (Years)										Total			
	Not in School <1		Not in School 1-2		Nursery 3-5		Elementary 6-10		Middle 11-13		High ≥14		n	%
	n	%	n	%	n	%	n	%	n	%	n	%		
Total	14	100.0	55	100.0	64	100.0	93	100.0	38	100.0	28	100.0	292	100.0
Sleep in the 7 d before the injury*														
Much less than usual	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A little less than usual	5	35.7	3	5.4	5	7.8	7	7.5	2	5.3	5	17.9	27	9.2
About the same as usual	8	57.1	48	87.3	55	85.9	81	87.1	30	78.9	21	75.0	243	83.2
A little more than usual	1	7.1	2	3.6	4	6.5	2	2.1	5	13.2	2	7.1	16	5.5
Much more than usual	0	0	1	1.8	0	0	1	1.1	0	0	0	0	2	.7
Undefined	0	0	1	1.8	0	0	2	2.1	1	2.6	0	0	4	1.4
Sleep during case and control period														
Longer in the control period	4	28.6	18	32.7	25	39.1	17	18.3	11	28.9	4	14.3	79	27.0
The same in both periods	7	50.0	26	47.3	28	43.7	57	61.3	22	57.9	18	64.3	158	54.1
Longer in the case period	3	21.4	11	20.0	11	17.2	19	20.4	5	13.2	6	21.4	55	18.8
Sign test P value	1.000		.265		.029		.868		.210		.754		.046	
Hours of sleep in the case period														
Mean \pm standard deviation	12.4 \pm 2.5		11.8 \pm 1.7		10.8 \pm 1.3		9.9 \pm 1.1		9.1 \pm .8		9.2 \pm 1.5		10.4 \pm 1.7	
Median	12.0		12.0		11.0		10.0		9.0		9.5		10.0	
Hours of sleep in the control period														
Mean \pm standard deviation	11.9 \pm 1.6		12.0 \pm 1.5		11.1 \pm 1.4		9.8 \pm 1.1		9.4 \pm 1.2		9.0 \pm 1.4		10.5 \pm 1.7	
Median	12.0		12.0		12.0		10.0		9.0		9.0		10.0	

* As perceived by the child or by his/her parent.

TABLE 2. RR and 95% CI for Sleeping Less Than 10 Hours a Day Overall

Participants	<i>n</i>	<i>f</i> ₁₁ *	<i>f</i> ₁₀ †	<i>f</i> ₀₁ ‡	<i>f</i> ₀₀ §	RR	95% CI
All cases	292	62	26	14	190	1.86	.97–3.55
Boys	181	40	21	9	111	2.33	1.07–5.09
Girls	111	22	5	5	79	1.00	.29–3.45
All cases except children <1 y of age or attending the high school	250	47	26	11	166	2.36	1.17–4.78
Boys	151	29	21	7	94	3.00	1.27–7.06
Girls	99	18	5	4	72	1.25	.34–4.65
Cases from 1 to 2 y of age	55	1	5	1	48	5.00	.58–42.80
Boys	29	0	3	1	25	3.00	.31–28.84
Girls	26	1	2	0	23	∞	.19–∞
Cases attending the nursery school (3–5 y of age)	64	2	8	1	53	8.00	1.00–64.00
Boys	35	1	6	0	28	∞	1.18–∞
Girls	29	1	2	1	25	2.00	.18–22.06
Cases attending the elementary and middle school (6–13 y of age)	131	44	13	9	65	1.44	.62–3.38
Boys	87	28	12	6	41	2.00	.75–5.33
Girls	44	16	1	3	24	.33	.03–3.20

* *f*₁₁ = frequency of concordant pairs with both case and control exposed.

† *f*₁₀ = frequency of discordant matched pairs with exposed case and unexposed control.

‡ *f*₀₁ = frequency of discordant matched pairs with unexposed case and exposed control.

§ *f*₀₀ = frequency of concordant pairs with both case and control unexposed.

on the current day increased the risk of injury by 86%. Using 10 hours of sleep as the reference category, a dose–response analysis showed that the RR was 1.10 (95% CI: .22–5.58) for 7 hours or less, 1.71 (95% CI: .62–4.70) for 8 hours, 1.84 (95% CI: .91–3.70) for 9 hours, .93 (95% CI: .49–1.78) for 11 hours, .67 (95% CI: .29–1.54) for 12 hours, and .87 (95% CI: .31–2.42) for 13 hours or more. In analyses stratified by sex, the excess risk was restricted to boys. After excluding from the analysis children under 1 year of age and children attending high school, the RR was further increased. When we stratified the data by age, the excess risk was still evident in all groups, but 3- to 5-year-old children had the highest RR. Children from 6 to 10 and from 11 to 13 years of age were combined because RR estimates were similar in these 2 groups. The RR among girls was never significantly increased or decreased. The RR among males was

increased in all age groups, but the highest excess risk was detected among boys from 3 to 5 years of age. The relation between sleep duration and injury did not change after adjusting for day of week and was not modified by time of day. The subgroup analysis according to activity risk level showed a RR of 3.33 (95% CI: .92–12.11) for relatively safe activities, whereas for risky activities the RR was 1.45 (95% CI: .67–3.13). In stratified analyses by place of injury, the RR was 2.20 (95% CI: .76–6.33) for home injuries, .67 (95% CI: .11–3.99) for school injuries, 3.67 (95% CI: 1.02–13.14) for recreational injuries, and .67 (95% CI: .11–3.99) for road accidents.

Table 3 refers to injuries that took place from 4 PM to midnight and shows the RR of injury for being awake for at least 8 hours. Being awake for at least 8 hours was associated with a RR of 4.00 (95% CI: 1.13–14.17). After stratifying by sex, the risk was still

TABLE 3. RR and 95% CI for Having Been Awake for at Least 8 Hours (Only for Injuries That Occurred From Four PM to Midnight)

Participants	<i>n</i>	<i>f</i> ₁₁ *	<i>f</i> ₁₀ †	<i>f</i> ₀₁ ‡	<i>f</i> ₀₀ §	RR	95% CI
All cases	156	103	12	3	38	4.00	1.13–14.17
Boys	101	68	10	2	21	5.00	1.10–22.82
Girls	55	35	2	1	17	2.00	.18–22.06
All cases except children <1 y of age or attending the high school	135	89	11	3	32	3.67	1.02–13.14
Boys	84	56	9	2	17	4.50	.97–20.83
Girls	51	33	2	1	15	2.00	.18–22.06
Cases from 1 to 2 y of age	27	2	4	2	19	2.00	.37–10.92
Boys	13	1	3	1	8	3.00	.31–28.84
Girls	14	1	1	1	11	1.00	.06–16.00
Cases attending the nursery school (3–5 y of age)	32	18	3	0	11	∞	.41–∞
Boys	17	7	3	0	7	∞	.41–∞
Girls	15	11	0	0	4	—	—
Cases attending the elementary and middle school (6–13 y of age)	76	69	4	1	2	4.00	.45–35.79
Boys	54	48	3	1	2	3.00	.31–28.84
Girls	22	21	1	0	0	∞	.02–∞

* *f*₁₁ = frequency of concordant pairs with both case and control exposed.

† *f*₁₀ = frequency of discordant matched pairs with exposed case and unexposed control.

‡ *f*₀₁ = frequency of discordant matched pairs with unexposed case and exposed control.

§ *f*₀₀ = frequency of concordant pairs with both case and control unexposed.

strongly increased among boys (RR: 5.00; 95% CI: 1.10–22.82), whereas it was not significantly increased among girls. When we excluded from the analysis children younger than 1 year of age and children attending high school, the RR was 3.67 (95% CI: 1.02–13.14). When we stratified the data by both school type and sex, very imprecise estimates resulted, because of the small number of discordant pairs in each group. The RR estimates did not change after adjustment for day of week and after including in the model a term for sleep duration. In the subgroup analysis according to activity risk level the RR was 6.00 (95% CI: .72–49.84) for relatively safe activities and 3.00 (95% CI: .61–14.86) for risky activities. In the analysis stratified by place of injury, the RR was 4.50 (95% CI: .97–20.83) for home injuries, and 2.00 (95% CI: .18–22.06) for recreational injuries.

We also repeated all our analyses excluding children who were car passengers or who were bitten by animals, because they were probably injured in circumstances they could not control; however, the results did not change (data not shown).

DISCUSSION

In our study, sleeping <10 hours a day was associated with an 86% increase in injury risk. A significantly increased risk did not emerge in all subgroups of patients but it was evident among children from 3 to 5 years of age, boys in particular, even if precision of estimates was low. A fourfold increase in injury risk was also associated with being awake for at least 8 hours. The risk increase seemed to be significant among males only. Age-stratified analyses provided very imprecise estimates because of the small number of discordant pairs in each subgroup. In case-crossover analyses, only discordant matched pairs are informative in the RR calculations.

A major methodologic problem of studies of acute events such as unintentional injuries is the selection of an appropriate control group. We bypassed this problem using a case-crossover design for this study. Cases acted as their own self-matched controls; therefore, control selection bias was eliminated. Our study had, however, several potential limitations that must be addressed. Case selection bias would be an issue if nonparticipation was associated with a differential pattern of sleep duration in the case period. Although our study had a very high participation rate, our surveillance system could not detect all injured children who required emergency care during the study. Some children could have been treated at the general emergency room as opposed to CERP because they were teenagers or because they were more seriously injured. In addition, we did not include in the study children who were seen at CERP with life-threatening injuries and those who presented at CERP from midnight to 8 AM. We did not cover nighttime hours because we assumed that in this period most children would be sleeping. We also missed children between 2 consecutive interviewing shifts. However, there is no reason to assume that those patients differed from those included in the study, because all days of the week were equally

surveyed with the same pattern. Therefore, our enrollment restrictions are not likely to have determined case selection bias in our study. However, because of possible incomplete enrolment of teenagers and severe injuries, our results should not be generalized to older children and to life-threatening injuries.

In our study, we assumed that patients had comparable possibilities to be injured on both days we investigated. Yet, we did not focus on injuries occurring while performing a particular action; therefore, children might have carried on a great number of different potentially risky activities, both at school and during leisure-time. Our RRs could be overestimated or underestimated as well, depending on the type and duration of activities on the day of injury compared with the previous day. We did not control for this factor; however, it should not have affected the strength of our results because most accidents happened while children were carrying on ordinary actions, such as playing at home (26% of all accidents), instead of unusual or dangerous activities and the highest RR was found in the safe activities subgroup.

The case-crossover design allowed us to control for variables that may differ between individuals and that may affect the validity of case-control studies. In fact, children's personality, recklessness, liveliness, and absent-mindedness were not an issue in our study. In addition, we controlled for intrapersonal confounders, such as day of the week and duration of night sleep as well as nap time. Medication use was not an issue in our study, because nobody reported new or intermittent consumption of medicinal drugs in the 48 hours before the injury and only 4 children reported chronic medication use. We can put forward a number of hypotheses, however, concerning other potential confounders that may still be present and affect our findings. A disease, stressful events, sport activities, or trips starting very early in the morning are examples of factors that might have caused lack of sleep and increased the risk of injury.

Recall bias is a relevant potential source of bias in case-crossover studies. In our study, information bias could stem from the fact that reporting sleep duration the night before the injury was less difficult than the night before that. A comparison between the 2 days before the injury showed an overall lower mean in the 24 hours immediately before the accident, but a clear tendency to underreport sleep on the day of injury could not be claimed because in some age categories an opposite direction was detected. A deliberate overreporting or underreporting of sleep duration could have occurred if children or their parents were aware of the special importance we gave to this factor, but this seems unlikely because our questionnaire collected information about many other factors. Nevertheless, an overestimate of sleep duration may exist for children who were not interviewed in person. In fact, parents who answered our questions instead of their children might have reported times for going to bed and for rising, rather than true times for falling asleep and waking. This possible

exposure misclassification, however, is nondifferential, because it is likely to have characterized both the case and the control day. Therefore, such a misclassification might have biased risk estimates toward the null. A comparison between information on usual sleep duration and data on sleep collected hour-by-hour during the 48 hours before the injury showed that usual sleep duration was somewhat lower than sleep duration during both the case and the control period. These results support our choice of using as control period hours 25 to 48 before injury and suggest that using a single question such as, "What is the child's usual sleep duration?" might be invalid for estimating the background sleep duration of the child.

If we had chosen different effect periods, our results would have changed. We believe that our choices were the most appropriate because the selected periods were chosen according to a methodology that minimizes nondifferential exposure misclassification and because we adopted definitions that were based on the distribution of sleep duration in our sample. The stratified analysis suggested a different effect of sleep characteristics on injury risk, depending on child's sex and age. The risk among girls seemed to be increased by reduced sleep amount or by prolonged wakefulness duration only in certain age subgroups and never significantly. In contrast, among all males, the risk increase was significant and boys attending the nursery school seemed to be those who suffered the most from sleep deprivation. Because participants attending elementary and middle school usually slept less than younger children, for them we repeated the analyses using shorter sleep duration as exposure cutoff, but no significant risk increase was seen. The sex difference might be attributable to chance, or there might be other causes accounting for it. Males might have been injured while carrying on activities in which being rested could make the difference, whereas in injuries involving females factors other than fatigue might have been more relevant. Analogous considerations apply also to the age difference. Possibly, sleepiness plays a relevant role in some activities and is less important in others. Because of the small size of the study, we could not bear out this hypothesis. In fact, when considering only selected activities, such as riding a bicycle or playing football, calculated RR estimates were very imprecise (data not shown).

Menchini et al²³ found that childhood accidents occurred more frequently during the spring and the summer; therefore, our surveillance took place in late spring and early summer to increase the efficiency of data collection. Our findings cannot be generalized to all injured children because seasonal differences may exist.

CONCLUSION

The finding that sleep and wakefulness duration are associated with the risk of injury in children suggests new opportunity for injury prevention in childhood. A tendency of Italian children up to 6 years of age to sleep less than children of the same

age living in other countries was found by Ottaviano et al,¹⁹ who interpreted it as a possible result of sociocultural and climate differences. Our findings suggest that such a tendency should be opposed and, even if children of the same age may need a different number of hours of sleep, as pointed out by Klackenberg,²⁴ the benefit of adequate nighttime sleep and daytime naps should not be neglected. Because the differences in sleep duration between the case and the control periods were relatively small (eg, an average of 20 minutes among 3- to 5-year-old children) and risk estimates were imprecise because of the small number of participants in our study, it might be premature to quantify the exact duration of sleep required to minimize injury risk in childhood. Further research is desirable to confirm and strengthen our results.

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REFERENCES

1. Istituto Nazionale di Statistica. Cause di morte—Anno 1994. Roma, Italy: Annuari, ISTAT; 1997
2. Istituto Nazionale di Statistica. Cause di morte—Anno 1995. Roma, Italy: Annuari, ISTAT; 1998
3. Kraus JF, Peek-Asa C, Blander B. Injury control: the public health approach. In: Detels R, Holland WW, McEwen J, Omenn J, eds. *Oxford Textbook of Public Health*. 3rd ed. New York, NY: Oxford University Press; 1997;1291–1306
4. Rothman KJ, Greenland S. *Modern Epidemiology*. 2nd ed. Philadelphia, PA: Lippincott-Raven; 1998
5. Maclure M. The case-crossover design: a method for studying transient effects on the risk of acute events. *Am J Epidemiol*. 1991;133:144–153
6. Mittelman MA, Mintzer D, Maclure M, Tofler GH, Sherwood JB, Muller JE. Triggering of myocardial infarction by cocaine. *Circulation*. 1999;99:2737–2741
7. Roberts I, Marshall R, Lee-Joe T. The urban traffic environment and the risk of child pedestrian injury: a case-crossover approach. *Epidemiology*. 1995;6:169–171
8. Vinson DC, Mabe N, Leonard LL, Alexander J, Becker J, Boyer J, Moll J. Alcohol and injury: a case-crossover study. *Arch Fam Med*. 1995;4:505–511
9. Barbone F, Mc Mahon AD, Davey PG, et al. Association of road-traffic accidents with benzodiazepine use. *Lancet*. 1998;352:1331–1336
10. Petridou E, Mittleman MA, Trohanis D, Dessypris N, Karpathios T, Trichopoulos D. Transient exposures and the risk of childhood injury: a case-crossover study in Greece. *Epidemiology*. 1998;9:622–625
11. Neas LM, Schwartz J, Dockery D. A case-crossover analysis of air pollution and mortality in Philadelphia. *Environ Health Perspect*. 1999;107:629–631
12. Lee J, Schwartz J. Reanalysis of the effect of air pollution on daily mortality in Seoul, Korea: a case-crossover design. *Environ Health Perspect*. 1999;107:633–636
13. Mittelman MA, Maldonado G, Gerberich SG, Smith GS, Sorock GS. Alternative approaches to analytical designs in occupational injury epidemiology. *Am J Ind Med*. 1997;32:129–141
14. Horne JA, Reyner LA. Sleep related vehicle accidents. *Br Med J*. 1995;310:565–567
15. Sharpley A. Impact of daytime sleepiness underrated. *Lancet*. 1996;348:71
16. Sagberg F. Road accidents caused by drivers falling asleep. *Accid Anal Prev*. 1999;31:639–649
17. Pless IB, Taylor HG, Arsenaull L. The relationship between vigilance deficits and traffic injuries involving children. *Pediatrics*. 1995;95:219–224
18. Kaplan BJ, McNicol J, Conte RA, Moghadam HK. Sleep disturbance in preschool-aged hyperactive and nonhyperactive children. *Pediatrics*. 1987;80:839–844
19. Ottaviano S, Giannotti F, Cortesi F, Bruni O, Ottaviano C. Sleep char-

- acteristics in healthy children from birth to 6 years of age in the urban area of Rome. *Sleep*. 1996;19:1-3
20. Daris F, Barbone F, Romano R, Mislei M, Modonutti GB, Gasparini V. Assessment of alcohol consumption among the secondary school population of Trieste. *Minerva Med*. 1985;76:2011-2017
 21. Schwartz RH, Hayden GF, Getson PR, DiPaola A. Drinking patterns and social consequences: a study of middle-class adolescents in two private pediatrics practices. *Pediatrics*. 1986;77:139-143
 22. Centers for Disease Control and Prevention. Tobacco use among middle and high school students—United States, 1999. *MMWR Morb Mortal Wkly Rep*. 2000;49:49-53
 23. Menchini M, Cappuccino M, Paperini F, Formica U. Epidemiology of accidents in childhood. *Pediatr Med Chir*. 1985;7:107-110
 24. Klackenberg G. Sleep behaviour studied longitudinally: data from 4-16 years on duration, night-awakening and bed-sharing. *Acta Paediatr Scand*. 1982;71:501-506

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Francesca Valent, Silvio Brusaferrero and Fabio Barbone

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