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Circadian preference, sleep and daytime behaviour in adolescence

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SUMMARY The aim of this study was to determine the relationship between circadian preferences, regularity of sleep patterns, sleep problems, daytime sleepiness and daytime behaviour. As a part of an epidemiological survey on sleep in a representative sample of Italian high-school students, a total of 6631 adolescents, aged 14.1–18.6 years, completed the *School Sleep Habits Survey,* a comprehensive questionnaire including items regarding sleep, sleepiness, substance use, anxiety and depressed mood, use of sleeping pills, school attendance and a morningness/eveningness scale. The sample consisted of 742 evening-types (315 males and 427 females; mean age 17.1 years) and 1005 morning-types (451 males and 554 females; mean age 16.8 years). No significant sex differences were found for morningness/eveningness score. Eveningness was associated with later bedtime and wake-up time, especially on weekends, shorter time in bed during the week, longer weekend time in bed, irregular sleep–wake schedule, subjective poor sleep. Moreover, evening types used to nap more frequently during school days, complained of daytime sleepiness, referred more attention problems, poor school achievement, more injuries and were more emotionally upset than the other chronotype. They referred also greater caffeine-containing beverages and substances to promote sleep consumption. Our results suggest that circadian preference might be related not only to sleep pattern, but also to other adolescent behaviours.

KEYWORDS chronotype, sleep, daytime behaviour, adolescence, epidemiology

INTRODUCTION

Several studies carried out on adult populations have pointed out interindividual differences in preferred timing of behaviour. The endogenous circadian pacemaker has been shown to contribute to daily variations in a number of physiological and behavioural/psychological rhythms.

The so-called M-types are phase advanced, showing a marked preference for waking at an early hour and find it difficult to remain awake beyond their usual bedtime, compared with E-types, who show a preference for sleeping at later hours and often find it difficult to get up in the morning. Furthermore, they have different endogenous circadian phases, differing in daily rhythms of many physiological variables, such as subjective alertness, core body temperature, heart rate, blood pressure and hormones secretion (Baehr *et al.* 2000; Bailey and Heitkemper 1991; Monk *et al.* 1997; Smyth *et al.* 1997). Moreover, also the rhythm of plasma melatonin secretion occurs later in E-types than in M-types (Hall *et al.* 1997; Duffy *et al.* 1999). In addition, the timing and daily patterns of behavioural and performance rhythms have also been shown to differ between M- and E-types (Carrier & Monk 2000). Morning/evening types describe the fact that the former prefer day activity while the latter night activity. Therefore, these circadian types differ in their sleep–wake patterns as well as in their performances at different times of the day. The impact of these individual differences in circadian phase positions on daytime functioning has recently received increasing interest.

Furthermore, morningness/eveningness can vary with age. In a polysomnographic study, Carrier *et al.* (1997) pointed out

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that age and morningness were both important predictors of the habitual sleep pattern in the middle years of life. Furthermore, increasing age was associated with a greater tendency toward morningness. Older people are likely to rate themselves as more morning-like than younger people (Taillard *et al.* 1999).

Studies carried out on adolescent populations showed an age-related increase in eveningness, indicating that adolescence is a stage in which the sleep–wake cycle tends to become delayed compared with the circadian phase position of the sleep–wake cycle of children. Adolescents tend to stay up progressively later and to sleep later in the morning than preadolescents. Moreover, there is a tendency to extend sleep during weekends. Valdez *et al.* (1996), in a study on 52 students with different school schedules, suggested that the 'prolonged sleep during weekends may be the result of reduction of sleep during schooldays, whereas the delay of bedtime seems to be associated with a tendency of circadian system to maintain a delayed phase with respect to the solar daylight period.' This circadian phase delay is more important on weekends than on schooldays. This was usually attributed to psychosocial factors, but involvement of biological factors was pointed out by Carskadon *et al.* (1993) who hyphothesized a biologically mediated phase delay linked to puberty. A link between the brain mechanisms controlling circadian rhythms and pubertal timing has been suggested because of the inverse relationship of melatonin and gonadotropine secretion across puberty development. Furthermore, the timing of melatonin secretion was significantly correlated to maturation and adolescents with higher Tanner stage show later melatonin secretion (Carskadon *et al.* 1997; Laberge *et al.* 2000). The phase delay of melatonin secretion, recently reported in adolescence, indicated the contribution of biological factors, in addition to social incentives, to the frequent phase delays of the sleep–wake cycle seen in this age group.

In adolescence, this sleep pattern may be related to insufficient sleep, daytime sleepiness, poor self-rated sleep quality, increased vulnerability to accidents and poor school achievement (Carskadon 1990; Dahl *et al.* 1992; Laberge *et al.* 2001). Furthermore, many adolescents may experience sleep phase delay syndrome with insufficient sleep.

Although morningness/eveningness scales were usually designed for adult populations, some years ago, Carskadon *et al.* (1993) developed a morningness/eveningness scale for adolescents (derived from Smith *et al.* 1989) with a good full-scale reliability for this age group.

Andrade *et al.* (1992), studying 62 adolescents on three different occasions at 6-month intervals, found that the E-types had less sleep on school nights, but noted that they slept longer on weekends than M-type adolescents.

As a part of an epidemiological survey on sleep in a representative sample of Italian high-school students, we studied the relationship between circadian phase preference and sleep patterns, the impact of these rhythms on daytime functioning, self-reported school achievement and some emotional aspects in a very large population of healthy adolescents.

METHODS

Subjects

Research data were collected from a sample representative of public high-school population in Italy. The sample was drawn from 349 schools across the state, according to a two-stage sample procedure involving the selection of a stratified sample of high schools according to geographical regions, and a sample of students stratified to represent the different grades within a high school. The questionnaires were mailed to schools in March and the last school responded in May. The response rate was 87%. All students suffering from chronic illness or referring stressful experiences, such as accidents or death among the subject's family or friends, serious current illness and family changes in the last year were excluded.

Questionnaire

Data were collected through a slightly modified version of *School Sleep Habits Survey* by Carskadon (1991a, b). The questionnaire is a comprehensive instrument including items about sleep habits during the previous 2 weeks as well as daytime functioning and self-rated school achievement. It includes also the following scales that obtained, in our sample, a moderate to good reliability. The Sleepiness Scale consisted of 10 items asking whether the students had struggled to stay awake in different situations (Cronbach's α 0.63). The Sleep–Wake Problems Behaviour Scale included 10 items regarding irregular sleep habits, prolonged sleep latency and difficulties in getting up in the morning (Cronbach's α 0.71). The Substance Use Scale consisted of five items regarding the use of caffeine, tobacco, alcohol and cannabis (Cronbach's α 0.51). Also, the scales assessing emotional aspects, in the last 6 months, showed a good reliability in our sample: the 24-item Rutter Anxiety (Cronbach's α 0.80) and six-item Kandel and Davies Depressed Mood (Cronbach's α 0.75). In order to reduce the number of variables, we evaluated these two scales together, deriving a composite score of emotional adjustment by summing up the total scores of Rutter Anxiety and Depressed Mood scales.

Furthermore, the questionnaire includes a morningness/eveningness scale (M/E) to determine circadian preference, which in our sample showed a Cronbach's α of 0.73. The score can range from 43 (extreme morning) to 10 (extreme evening). In our sample, the median scale score was 27 (SD: 4.46). Thus, given the differentiation on the external criteria obtained with the 10–90 percentile split of the scale, we decided to establish raw score cut-off at these points in the distribution. The intervals formed by these points are provided as follows: E-type 10–21 and M-type from above 32.

The questionnaire also includes a self-administered rating scale for pubertal developmental (Carskadon *et al.* 1993). Students responded anonymously during a class period with a teacher overseeing them. Participants were evenly distributed between the upper-middle and lower-middle socio-economic classes.

Data analysis

The variables were first tested for normality. Therefore, natural log transform was used to produce normal distributions. Because of the known effect of age, we split the sample into two groups: younger aged 14.1–16 years and older aged 16.1–18.6 years.

Given the number of the dependent variables in this study to limit analysis and to reduce the possibility of Type I errors, we first tested for group differences on our entire set of dependent measures, using a one-way multivariate analysis of covariance (MANOVA) with circadian type (evening and morning) as independent variable. Analysis of variance was used to evaluate the impact of circadian preference on the dependent continuous measures of sleep and emotional adjustment. Therefore, the analysis of covariance (ANCOVA) model included circadian typology and gender as between-subjects factors, and age as covariate.

Sleep categorical variables were compared using the Cochran–Mantel–Haenszel test (CHM) controlled for sex, to test general association with circadian typology (morning/evening × sleep variable × sex). Separate analyses were performed for each age group.

Separate hierarchical multiple-regression analyses were performed to assess the relative influence of variables in predicting daytime sleepiness and emotional adjustment. The ordering of the 12 independent variables, significantly correlated with the outcome variables, was based on the logically causal relationship among variables. In the regression model with sleepiness as dependent measure, background variables (age, sex, socio-economic status and pubertal development) were entered into the analyses in the first step. Variables related to emotional aspects and substance use were entered in the second step. Then, variables related to sleep (sleep length, sleep debt, Sleep–Wake Problems Behaviour Scale) were entered in the third step and the evening preference, converted to a dummy variable, was entered in the last step. The ordering of variables in the analysis with emotional composite score as outcome variable was: set of background variables (age, sex, socio-economic status and pubertal development) entered into the analysis in the first step, variables related to substance use entered in the second step, variables related to sleep (sleep length, sleep debt, Sleep–Wake Problems Behaviour Scale, Sleepiness Scale) entered in the third step and the evening preference entered in the last step.

Furthermore, logistic regression analysis was performed to compute the odd ratios of risk factors of the same set of 12 variables for poor school performance.

All data were coded and computerized with statistical analysis performed using STATISTICA 5.5 package for Windows (StatSoft Inc., Tulsa, OK, USA). The *P*-level was set at <0.01 for statistical significance.

RESULTS

The final cleaned sample population consisted of 6631 students [3986 females and 2645 males; aged 14.1–18.6; mean age 16.7 (SD: 1.7)]. Each grade was equally represented. A widespread slight prevalence of females among students attending the secondary schools in Italy has already been reported (ISTAT 1994). In general, all girls were postmenarchal and all boys showed evident or marked pubertal changes.

The sample considered for this study consisted of 742 E-types (315 males and 427 females; mean age 17.1 years) and 1005 M-types (451 males and 554 females; mean age 16.8 years). No significant sex differences were found for M/E scores. As expected, our results confirmed significant changes in sleep preference with chronological age. There was a slight, but significant correlation between M/E score and age and, in both sexes, increasing age was associated with a tendency toward eveningness (Spearman's $\rho = -0.15$, $P < 0.001$).

The multivariate tests indicated significant differences between circadian types (Wilks's λ 0.85; Rao $R(24, 13) = 45.73$; $P < 0001$). Next, we performed subsequent two-factor ANCOVAS to analyse differences on each sleep variable and scale.

Sleep habits

Tables 1 and 2 show sleep characteristics in the different chronotypes according to sex in the two age groups.

Regarding subjective measurements of sleep variables, E-types reported significant later bedtimes on weekdays and weekends, as well as later rising times, more evident (about 2 h later) on weekends than M-types in both age groups. During weekends, all students slept more, went to bed and woke up later; however, E-types showed a weekend oversleep of about 1 h more than M-types. Although E-types subjectively expressed a significantly greater need for sleep than M-types (about 1 h per night), they usually slept significantly less than others on weeknights (about 30 min less). Consequently, E-types showed a significant *daily sleep debt* (ideal sleep need *minus* week night sleep time) illustrated in Fig. 1, of about 2 h compared with the 30 min of M-types.

Regarding the main effect of gender, the inspection of sleep variables presented in Tables 1 and 2 indicated slightly significant sex differences in almost all sleep variables. Males in particular reported later bedtimes and risetimes both on weekdays and at weekends and shorter sleep length at weekends in both age groups. No significant interaction effect was found between circadian groups and gender.

As expected, our results also confirmed significant changes in sleep patterns with chronological age, a reduction of sleep time and a tendency to go to bed later with age, both during school nights and particularly at weekends (Tables 1 and 2).

Furthermore, we found that E-types used to nap during weekdays more frequently than M-types. This habit regarded either the young group (46% of E-types vs. 25% of M-types; relative risk Mantel Haenszel (RRMH) = 0.39, chi square $(1) = 47.3$, $P < 0.001$) or the old one (70% of E-types vs. 45% of M-types; RRMH = 0.29, chi square $(1) = 73.2$, $P < 0.0001$). It must be noted that while in the youngest no significant sex differences were found, in the oldest a high, but not significant, prevalence of males, who referred napping

Table 1 Sleep characteristics according to chronotypes (age 14.1–16.0 years)

Sleep variables	E-type means All	E-type means M	E-type means F	M-type means All	M-type means M	M-type means F	F-value for group effect	F-value for sex effect	F-value for interaction	Age betas
Weeknights										
Bedtime (hh.min)	23.05	23.09	23.00	22.30	22.35	22.25	$F_{1.94} = 178$**	$F_{1,94} = 4.73$*	NS	0.13*
Risetime (hh.min)	7.10	7.20	7.00	6.40	6.50	6.30	$F_{1.94} = 97$**	$F_{1,94} = 28$**	NS	NS
Sleep duration (min)	460	460	460	490	490	490	$F_{1.94} = 45$**	NS	NS	−0.11**
Weekend nights										
Bedtime (hh.min)	01.15	01.25	01.10	23.40	23.50	23.30	$F_{1.94} = 265$**	$F_{1,94} = 9.3$*	NS	0.21**
Risetime (hh.min)	10.55	10.50	11.00	08.55	08.50	09.00	$F_{1.94} = 476$**	NS	NS	NS
Sleep duration (min)	545	535	555	565	555	575	$F_{1.94} = 15.3$*	$F_{1.94} = 15.7$*	NS	−0.16**
Others										
Sleep need (min)	585	580	590	535	530	540	$F_{1.94} = 80.5$**	NS	NS	−0.07*
W-end oversleep (min)	115	90	120	65	40	70	$F_{1.94} = 64.4$**	$F_{1.94} = 20.7$**	NS	−0.08*

*$P < 0.01$; **$P < 0.001$; NS = not significant.

Table 2 Sleep characteristics according to chronotypes (age 16.1–18.6 years)

Sleep variables	E-type means All	E-type means M	E-type means F	M-type means All	M-type means M	M-type means F	F-value for group effect	F-value for sex effect	F-value for interaction	Age betas
Weeknights										
Bedtime (hh.min)	23.30	23.40	23.20	22.30	22.40	22.20	$F_{1.79} = 228$**	$F_{1.79} = 23$**	NS	NS
Risetime (hh.min)	7.10	7.20	7.00	6.25	6.10	6.40	$F_{1.79} = 137$*	$F_{1.79} = 18.8$**	NS	NS
Sleep duration (min)	440	440	440	480	475	485	$F_{1.79} = 84$**	NS	NS	−0.07*
Weekend nights										
Bedtime (hh.min)	02.25	03.00	02.10	00.25	01.00	00.10	$F_{1.79} = 212$**	$F_{1.79} = 15.5$**	NS	0.16**
Risetime (hh.min)	11.25	11.20	11.30	09.10	09.15	09.00	$F_{1.79} = 504$**	NS	NS	0.11**
Sleep duration (min)	530	520	540	500	490	495	$F_{1.79} = 21.6$*	$F_{1.79} = 12.5$**	NS	−0.08*
Others										
Sleep need (min)	515	510	520	575	570	580	$F_{1.79} = 93.5$**	NS	NS	NS
W-end oversleep (min)	90	80	100	20	15	25	$F_{1.79} = 97.2$**	NS	NS	NS

*$P < 0.01$; **$P < 0.001$; NS = not significant.

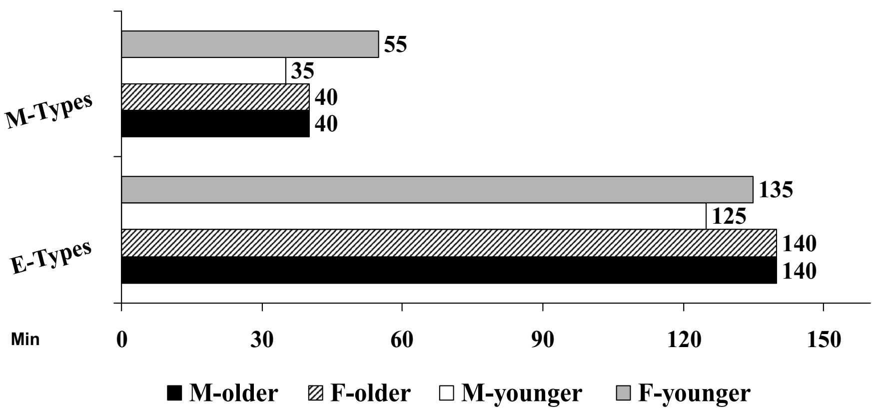

Figure 1. Sleep debt between chronotypes. Two factors ANOVA: Younger *F*-value for group effect (1.94) = 367.6**; *F*-value for sex effect (1.94) = 6.56*; Older *F*-value for group effect (1.79) = 205.1**; No sex effect. No age effect for both groups – **$P < 0.001$; *$P < 0.01$.

during weekdays, was reported in both circadian groups (oldest E-types: males 75%, females 64%; M-types males 47%, females 34%).

Consequently, E-types showed a more irregular sleep schedule, referring a weekend delay, considered as the difference between weekend and weeknight bedtime higher than 3 h, in 32% of cases compared with 10% of M-types in the youngest group (RRMH = 0.25, chi square (1) = 68.7, $P < 0.0001$) and in 47% of older E-types compared with 25% of older M-types (RRMH = 0.39, chi square (1) = 41.7, $P < 0.001$). In both groups, this habit is slightly more frequently reported by males than females (younger E-types: males 34% and females 28%, M-types males 11% and females 9%; older group E-types: males 50% and females

44%, M-types males 27% and females 23%). It must be noted that this habit becomes more frequent with age in both circadian types.

Sleep problems

Regarding the presence of sleep problems, E-types reported a higher score in the Sleep/Wake Behaviour Scale, indicative of more problems [*younger* E-types: males 36 and females 37; M-types: males 28, and females 28; *F*-value for group effect (1.94) = 242, $P < 0.0001$; *older* E-types: males 37 and females 35; M-types: males 30 and females 28; *F*-value for group effect (1.79) = 141, $P < 0.0001$]. Neither significant gender differences nor interaction between circadian groups and gender were found. Age as covariate failed to show a significant effect in both age groups.

Although almost one-third of E-types of both age groups described themselves as 'poor sleepers' compared with 15% of M-types; significant differences were found between circadian groups only regarding the complaint of difficulties in falling asleep (Table 3). Furthermore, only in the older group E-types showed a significantly higher rate of multiple nightwakings. No significant differences were found regarding early morning awakening and night wakings lasting more than 30 min.

Moreover, almost 10% of older E-types (7% males and 12% females) reported the consumption of sleeping pills compared with about 3% of older M-types (1.2% males and 5.1% females) [RRMH = 0.33, chi square (1) = 15.3, $P < 0.001$]. It must be noted that a slight, but not significant, prevalence of females using sleeping pills was found in both circadian types. In contrast, no significant differences in sleeping pill consumption between chronotypes were found in the younger group was found. In this latter group, luckily, this habit is less common, with only 4% of students with a significant higher prevalence of females (1.4% males, 5.3% females; Pearson's χ^2 10.45, d.f. = 1, $P < 0.01$).

Daytime functioning and emotional aspects

Self-rated sleepiness was assessed either by the sleepiness scale or by a single question that asked: During the daytime activities, how much of a problem do you have with sleepiness (feeling sleepy, struggling to stay awake)? Response choices were: 'no problem at all; a little problem; more than a little problem; a big problem; a very big problem.' The latter three responses were combined to derive a measure of perceived sleepiness, in contrast to the first two.

Figure 2 shows the percentages of subjective sleepiness between chronotypes in the two age groups. Thus, in both groups E-types reported more subjective daytime sleepiness. It must be noted that in both circadian types this complaint is more frequently reported by females. As with other variables, subjective daytime sleepiness became a more frequent complaint with age.

These results were confirmed also by the sleepiness scale, where E-types obtained a higher score (see Table 4) in both age groups. Moreover, E-types tended to use more frequently alcohol, tobacco and other caffeine-containing beverages, as shown by the Substance Use Scale, than M-types (Table 4). This tendency became more frequent with age. While in the younger adolescents no sex effect was found, in the older ones, males were more prone to use psychoactive substances than females. Furthermore, E-types presented more emotional problems, showing a higher score in the Emotional Adjustment Composite Score (Table 4) in both age groups. Moreover, in this latter scale females of both circadian types and both age groups obtained higher scores than males. A significant increase of emotional problems with age was found only in the younger teens.

Furthermore, in both age groups E-types reported poor school achievement more frequently than M-types, they complained of more attention problems and reported the

Table 3 Sleep problems

	E-types (353)		*M-types (593)*		
	M (%)	*F (%)*	*M (%)*	*F (%)*	*Cochran–Mantel–Haenszel test*
Age 14.1–16.0 (946 students)					
Sleep onset insomnia	35	24	15	21	RRMH 58 χ^2 (1) = 15.82, $P < 0.001$
Night wakings (2–3 per night)	14.5	14.8	8.1	12.4	NS
Night wakings (>3 per night)	1.3	2.9	0.4	2.1	NS
Early morning awakings	31.1	27.7	22.8	26	NS
Night waking longer than 30 min	4.6	2.2	5	7.8	NS
Subjective poor sleep quality	26.4	36.6	9.9	14.0	RRMH 29 χ^2 (1) = 58.4, $P < 0.001$
	E-types (389)		*M-types (414)*		
	M (%)	*F (%)*	*M (%)*	*F (%)*	
Age 16.1–18.6 (801 students)					
Sleep onset insomnia	29	29	18	18	RRMH 52 χ^2 (1) = 16.1, $P < 0.001$
Night wakings (2–3 per night)	11.0	8.8	6.1	12.0	NS
Night wakings (>3 per night)	2.4	4.9	1.1	2.1	RRMH 43 χ^2 (1) = 5.2, $P < 0.01$
Early morning awakings	23.1	22.2	23.5	25	NS
Night waking longer than 30 min	4.6	2.2	5	7.8	NS
Subjective poor sleep quality	30.4	29.7	11	18.4	RRMH 42 χ^2 (1) = 26.6, $P < 0.001$

RRMH = relative risk Mantel Haenszel.

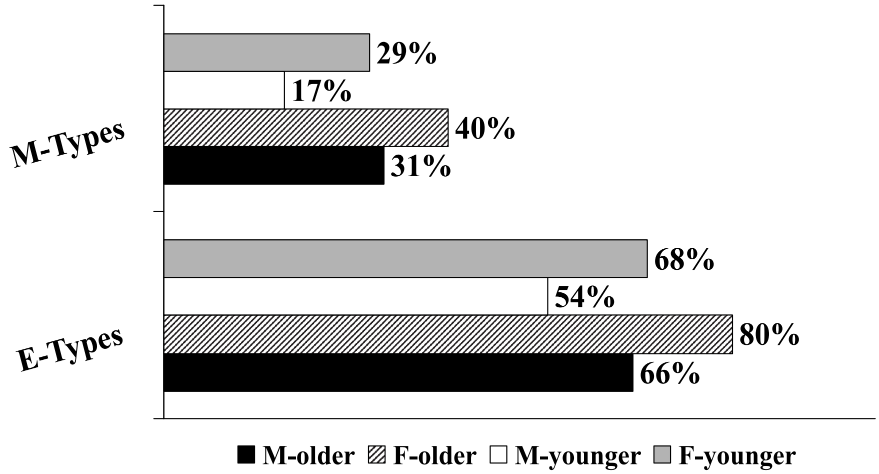

Figure 2. Subjective sleepiness between chronotypes. Cochran–Mantel–Haenszel: Older age group (14–16 years): Relative risk Mantel Haenszel (RRMH) = 0.18, $\chi^2 = 143.9$, $P < 0.001$. Younger age group (16.1–18.6): RRMH = 0.19, $\chi^2 = 119.73$, $P < 0.001$.

Table 4 Scales' scores according to chronotypes. Results of two factors ANCOVAS (circadian type by sex), controlled for age

	E-type means			*M-type means*						
Scales scores	*All*	*M*	*F*	*All*	*M*	*F*	*F-value for group effect*	*F-value for sex effect*	*F-value for interaction*	*Age as covariate betas*
Age 14.1–16.0										
Emotional composite	26.5	24	29.2	21.5	19	24	$F_{1.94} = 93$**	F (1.94) = 100**	NS	0.13**
Sleepiness	16.3	15.9	16.5	13.7	13.6	13.8	$F_{1.94} = 112.2$**	NS	NS	NS
Substance use	8.9	8.9	8.9	7	7	7	$F_{1.94} = 203.7$**	NS	NS	0.12**
Age 16.1–18.6										
Emotional composite	26.5	24	29	22.5	20	25	$F_{1.94} = 56$**	$F_{1.94} = 82$**	NS	NS
Sleepiness	16.6	16.4	16.8	13.8	13.6	14.1	$F_{1.94} = 124.8$**	NS	NS	NS
Substance use	9.7	10	9.3	7.2	7.4	6.9	$F_{1.94} = 207$**	$F_{1.94} = 12$**	NS	0.09*

Higher scores are indicative of more problems. *$P < 0.01$; **$P < 0.001$; NS = not significant.

Table 5 Daytime functioning at school

	E-types (353)		*M-types (593)*		
	M (%)	*F (%)*	*M (%)*	*F (%)*	*Cochran–Mantel–Haenszel test*
Age 14.1–16.0 (946 students)					
Poor school performance	20	14	6	5.3	RRMH 0.30, χ^2 (1) = 33.09, $P < 0.001$
Attention problems at school	46.3	40.1	10.6	10.9	RRMH 0.43, χ^2 (1) = 31.15, $P < 0.001$
Tendency to fall asleep at school	17.2	15.8	6.6	3.7	RRMH 0.27, χ^2 (1) = 37.1, $P < 0.001$
	E-types (389)		*M-types (414)*		
	M (%)	*F (%)*	*M (%)*	*F (%)*	
Age 16.1–18.6 (801 students)					
Poor school performance	17	5.3	4.5	3.4	RRMH 0.35, χ^2 (1) = 15.16, $P < 0.001$
Attention problems at school	50.6	40.3	16.7	13.3	RRMH 0.21, χ^2 (1) = 90.03, $P < 0.001$
Tendency to fall asleep at school	30	17	13.4	5.1	RRMH 0.32, χ^2 (1) = 31.8, $P < 0.001$

RRMH = relative risk Mantel Haenszel.

tendency to fall asleep at school more often (Table 5). The higher prevalence of males reporting all these problems in both circadian groups at all ages must be noted.

More injuries were reported by E-types in both age groups, on average about three injuries in the last 6 months, compared with the average of two of M-types [*F*-value for group effect: younger (1.94) = 18, $P < 0.001$; and older (1.79) = 12.8, $P < 0.01$]. Only in the older group males reported more frequent injuries than females [*F*-value for sex effect (1.79) = 13, $P = 0.01$].

Regression results

The 12 variables entered in four steps accounted for a substantial amount of 24% of the variation in Sleepiness Scale score ($r^2 = 24$; $F_{12,15}) = 40.7$, $P < 0.001$). After a negligible effect of background variables, measures of emotional problems and substance use added 16.5% to the explained variation, variables related to sleep accounted for 4% of the variation, and finally evening preference added about 3% of the variation. In particular, a high consumption of caffeine-containing beverages or tobacco use (Substance Use Scale β: 0.16, $P < 0.001$), a problematic sleep (Sleep–Wake Problems Behaviour Scale β: 0.15, $P < 0.001$), a high level of emotional problems [Emotional Adjustment composite score (β: 0.15, $P < 0.001$), evening preference (E-type β: 0.14, $P < 0.001$) and irregularity of sleep–wake pattern (β: 0.07, $P < 0.01$)] were significantly associated with daytime sleepiness.

Regarding emotional aspects, hierarchical regression results with the emotional adjustment composite score (Depressed Mood Scale plus Rutter Anxiety Scale total scores) as outcome variable showed that the entire set of independent variables, entered in four steps, accounted for 29% of the variation ($r^2 = 0.29$; $F_{12,15} = 54.18$, $P < 0.001$). Background variables explained 11% of the total variance. After the effect of substance use that accounted for 5%, sleep variables added 12% of the variation and evening preference added a small increment (1%) of the explained variation. In particular, female sex (β: 0.28, $P < 0.001$), a problematic sleep (Sleep–wake Problems Behaviour Scale β: 0.25, $P < 0.001$), high level of daytime sleepiness (Sleepiness Scale β: 0.14, $P < 0.001$), less nighttime sleep (β: −0.09, $P < 0. = 01$), and evening preference (E-type β: 0.06, $P < 0.001$) were significantly associated with emotional problems.

The results of the logistic regression model [maximum likelihood chi square (10) = 77.57, $P < 0.001$] showed that among the 12 variables considered, evening preference (OR 1.6, 95% CI 1.02–2.56), more emotional problems (OR 1.04, 95% CI 1.01–1.07) and higher substance consumption (OR 1.1, 95% CI 1.03–1.21) increase the risk of poor school performance, whereas female sex significantly decreases it (OR 0.47, 95% CI 0.26–0.84).

DISCUSSION

The principal aim of this report was to assess the relationship between circadian preference, adolescents' sleep–wake habits and their daytime functioning in a large sample of over 6600 students, representative of the Italian high-school student population.

As expected, our study emphasizes once more the results of other investigators who pointed out the tendency of an age-related increase in eveningness. Our data are consistent with previous studies on sleep habits of different chronotypes (Ishihara *et al.* 1988; Taillard *et al.* 1999), confirming the presence of irregularity of sleep–wake schedules in E-types (Monk *et al.* 1994) and their tendency to extend sleep duration (Violani *et al.* 1997). In fact, as already pointed out by Carskadon *et al.* (1993), in our study, E-types used to go to bed and wake up later, especially on weekends, on average 2 h later than M-types, to sleep more at weekends than on school nights and to complain of a sleep debt of more than 1 h compared with the other chronotype. On the contrary, as one would expect, E-types stated, in our study as well as in other reports, a greater need for sleep than other groups and tried to reduce their sleep debt by not only extending weekend sleep duration, but also by napping on school days. This irregularity of sleep–wake schedules may produce, as already stated by Manber *et al.* (1996), insufficient sleep and excessive daytime sleepiness. In contrast, Taillard *et al.* (1999), in his study on adult population, found that E-types, although reporting a reduction of sleep duration on weekdays, a higher sleep debt and irregularity of sleep–wake schedules, did not suffer from daytime sleepiness. Furthermore, Rosenthal *et al.* (2001) found an overall higher level of sleepiness, evaluated not only subjectively with the Sleep–Wake Activity Inventory but also objectively by means of multiple sleep latency tests in a morning group of young adults. In contrast, in our study, we found that E-types complained of more subjective sleepiness and obtained higher scores in Sleepiness Scale than the M-types, indicative of sleepiness problems. Regression results pointed out that evening preference, as well as a problematic sleep, irregularity of sleep–wake pattern and high level of emotional problems was significantly related to daytime sleepiness in our sample. It is quite difficult to explain why our adolescent E-types complained of more subjective daytime sleepiness than older ones. On the basis of these results, older E-types appear to adapt better to sleep irregularity and sleep restriction than adolescents. However, further studies are needed to better understand these differences.

This insufficient sleep may interfere negatively on daytime functions with increasing risk of accidents, injuries and poor school attendance. In our study, E-types, who reported sleep restriction and irregularity of sleep–wake schedules, referred more frequently the occurrence of injuries and almost 13% of them reported poor school achievement. The relationship between sleep–wake irregularity and poor school performance was already reported by other studies (Carskadon *et al.* 1995; Link *et al.* 1995; Wolfson *et al.* 1998). These studies, however, did not consider the circadian preference, which seems to play an important role in the sleep patterns of adolescents, facilitating the irregularity of the sleep–wake schedule in the E-types. Our logistic regression results showed that evening preference significantly increase the risk of poor school performance. As expected, E-types showed more difficulty adjusting to school life and accommodating to early sleep schedule. In our study, E-types reported attention problems also at school and a tendency to fall asleep in the morning at school significantly more frequently than M-types, probably because of a higher sleep propensity, as already stated by Volk *et al.* (1994), during the morning hours. On the other hand, as already reported by Monk *et al.* (1994), who found a greater regularity in life-style in M-types, also our 'larks' showed a more regular sleep–wake schedule, highly regular school attendance, better subjective sleep, higher morning alertness and higher school achievement than 'owls'.

As already reported by other studies (Rosenthal *et al.* 1991), to counteract effect of daytime sleepiness, our group of E-types used more frequently psychoactive substances such as caffeine, caffeine-containing beverages and tobacco.

Although it has already been pointed out that repeated sleep restriction might also cause behavioural and emotional problems, few studies focused attention on the correlation between circadian types, personality and mood. Larsen *et al.* (1985) reported, in general, that people with self-reported E-type circadian activity tend to be more extraverted, while M-types were associated with introversion. In contrast, a study carried out in healthy young adults found only slight personality differences between circadian typologies (Violani *et al.* 1997). Other studies reported a significant variation of mood with circadian phase, suggesting an underlying circadian rhythm of mood so that the position of sleep in the circadian cycle seems to be important for the control of mood (Boivin *et al.* 1997). Moreover, a significant deterioration of mood has been noted during sleep deprivation suggesting a link between subjective mood and variation in levels of alertness. On the other hand, when sleep is displaced, the phase relationship between the sleep–wake cycle and the endogenous circadian pacemaker changes and this may affect mood. In fact, a high prevalence of anxious/depressive symptoms has been reported in the shift-worker population (Healy *et al.* 1993). Moreover, circadian sleep disorders, mainly delayed sleep phase syndrome, showing daytime irritability and mood disorders, may be mistaken for depression, in which the sleep–wake cycle may be delayed or advanced. A higher prevalence of personality disorders among circadian rhythm sleep disorder patients has already been reported (Dagan *et al.* 1996). In our study, we found that E-types were more emotionally upset. Regression results showed that not only female sex, a problematic sleep, high level of daytime sleepiness, less night sleep but also evening preference were significantly related to emotional problems. Although further studies will be necessary to clarify the complex interaction between circadian processes and affective states, we can hypothesize that the higher emotional vulnerability found in our E-types may be because of many factors. In particular, chronic sleep deprivation, sleep displacement, difficulty adjusting to social constraints and less life-style regularity may negatively interfere with emotional adjustment.

Our study also pointed out a slight, but significant, prevalence of sleep problems in the E-types, who reported difficulty in falling asleep. Moreover, E-types complained frequently of poor sleep quality and were prone to use more substances to promote sleep. Probably in the E-types, who tend towards a phase delay syndrome, a temporal disalignment between the sleep–wake cycle, the endogenous circadian rhythms and the environmental constraints exist, which can lead to sleep onset insomnia. As previously reported, one of the most common causes of insomnia in this age group derives from sleep–wake schedule problems. Adolescents, and especially E-types, may experience extraordinary difficulty adjusting to the early demands of school schedule. Their optimal bedtime may coincide with the so-called 'forbidden zone' of the circadian system making it quite impossible to fall asleep at the desired bedtime. This can lead to difficulty in falling asleep, adolescents experience anxiety about getting sufficient sleep and consequently perceive a poor sleep quality.

There are some obvious limitations to the current study. One observation must be considered about the accuracy and validity of retrospective subjective reports. Although objective data would be useful and desirable, self-questionnaire reports remain the most widely used measures in community survey. The recall period of sleep variables of the present study investigated only the last 2 weeks; therefore, considering how difficult it is to report and estimate some variables such as usual sleep–wake schedules, which can vary, or subjective daytime sleepiness, some data may be overlooked. Another limitation is that our sample, whilst representative of a student population, excludes adolescent workers, potentially at high risk for sleep problems and sleep–wake schedule disorders. Furthermore, some caution is warranted with respect to the conclusions about the direction of influence and casual nature of study findings. Despite its limitations, the current study has the advantage of being based on a very large nationally representative population of high-school students. Moreover, to our knowledge, this investigation is the first study carried out in healthy young subjects including a large age span that examines the phase preference and its association with many aspects of adolescent life.

Although future studies will be necessary to better clarify the complex interaction between circadian preference, sleep, sleepiness, personality disorders and other behaviours, the results of our study suggested that circadian preference might be related not only to different sleep–wake schedules but also to different life-styles. Adolescent E-types showed more irregular life habits and sleep–wake patterns, more sleep problems, less adaptiveness to environmental demands, more daytime sleepiness and vulnerability to injuries and emotional problems. Therefore, circadian preference may need to be taken into account in the assessment of sleep and daytime behaviour in this age group.

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