Morningness–eveningness and sleep patterns of adolescents attending school in two rotating shifts

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School system in which classes are scheduled 1 week in the morning and the other in the afternoon, and in which students rotate schedule every week, fosters sleep irregularity. In this study, we examined morningness–eveningness of adolescents who were involved in such schedule of school time and explored relationship between their circadian preferences and sleep characteristics. A large sample of 2287 students between the ages 11 and 18 years (52% girls) from 24 schools in Croatia was studied. The School Sleep Habits Survey was modified to enable differentiation of sleep patterns between the two school schedules and weekends. Two measures of ME were used: the Morningness–Eveningness Scale for Children (MESC) and mid-sleep time on weekends (MSFsc). Both measures showed a shift to eveningness starting between the ages 12 and 13 (MESC), or 13 and 14 (MSFsc). However, MESC demonstrated a plateau in the shift in older adolescent whereas MSFsc indicated further progress of phase delay. Significant differences in sleep timing and duration were found between three chronotype groups (Morning, Intermediate, and Evening). Generally, Evening types went to bed and woke up the latest in all situations. Their sleep duration was the shortest on school week with morning schedule. On weekends Morning types slept shorter than other two chronotype groups. On school week with afternoon schedule all chronotype groups slept close to the recommended 9 h. All three chronotype groups delayed their bedtimes and wake-up times, and extended their sleep in situations with fewer constraints on sleep timing (i.e. afternoon school schedule, and weekends versus morning school schedule). Expectedly, the evening types showed the greatest sleep irregularity. The findings of this study suggest that the Croatian school system fosters sleep irregularity, but provides more opportunity for fulfilling sleep need of all chronotype groups of adolescents. Age effects on morningness–eveningness observed in Croatian adolescent do not seem to be different from those observed in adolescents from other countries involved in a regular morning school schedule. Further studies are necessary to explore differences in the trend of shift towards eveningness found between the two measures of morningness–eveningness in this, as well as in other studies.

Keywords: Adolescence, chronotype, school schedule, sleep patterns, sleep regularity

INTRODUCTION

The majority of questionnaire studies which examined morningness–eveningness preferences or chronotypes in adolescents used one of the four well-known morningness–eveningness questionnaires. The first is the Morningness–Eveningness Questionnaire (MEQ) designed by Horne and Ostberg (Andrade et al., 1992; Ishihara et al., 1990; Kim et al., 2002; Laberge et al., 2000; Megdal & Schernhammer, 2007; Natale et al., 2005; Park et al., 1999; Randler, 2008c; Shinkoda et al., 2000; Tonetti et al., 2008). The second is the Diurnal Type Scale (DTS) designed by Torsvall and co-workers (Gaina et al., 2005a, 2006; Harada et al., 2007; Takeuchi et al., 2001). The third is the Composite Scale of Morningness (CSM), designed by Smith and co-workers (Diaz-Morales & Randler, 2008; Randler, 2008a, 2008b, 2008c, 2008d, 2009; Randler et al., 2009; Randler & Schaal, 2010; Schneider & Randler, 2009). The fourth scale is the Morningness–Eveningness Scale for Children (MESC), which was designed from selected items of the previous three scales by Carskadon and co-workers (Carskadon et al., 1993, 2002; Chung & Cheung, 2008; Collado Mateo et al., 2012; Diaz-Morales et al., 2007; Diaz-Morales & Gutierrez Sorroche, 2008; Gau et al., 2004; Gau & Soong, 2003; Gelbmann et al., 2012; Giannotti et al., 2002; Goldstein et al., 2007; Kim et al., 2002; LeBourgeois et al., 2005; Natale et al., 2005; Russo et al., 2007; Yang et al., 2005).

Various age groups of adolescents were studied and the delay in their phase preference, both with increasing
age and when compared to prepubertal children was documented (e.g. Carskadon et al., 1993; Díaz-Morales et al., 2007; Gaina et al., 2005b; Gau & Soong, 2003; Giannotti et al., 2002; Kim et al., 2002; Park et al., 1999). The phase shift in the preferred sleep pattern of adolescents towards later hours, i.e. towards eveningness, was considered to be an exclusive result of changes in their social life and opportunities for sleep (e.g. less parental control over bedtimes, increased peer influences and interactions). However, the publication of Carskadon et al. (1993) study put emphasis on biological factors influencing delay of circadian preferences in adolescents. The authors have shown that the preferences for later phase in adolescent girls were related to self-rated pubertal maturity rather than to psychosocial influences of peers and older siblings. Further studies have shown that the phase delay reflects intrinsic biological changes in both homeostatic and circadian mechanisms regulating sleep and wakefulness (Carskadon et al., 1997, 1998, 1999; Gau & Soong, 2003; Gaudreau et al., 2001; Jenni & Carskadon, 2004; Jenni et al., 2005; Kim et al., 2002; Park et al., 1999; Taylor et al., 2005).

Biological factors influencing the phase delay in adolescents have been well documented, but the influence of social factors on morningness–eveningness remains an important issue. Several studies have shown that the parental control over adolescents’ bedtimes and wake-up times was less frequent in older adolescents than in children (e.g. Carskadon, 2002; Gau & Soong, 1995; Giannotti & Cortesi, 2002; Radosevic-Vidacek & Koscec, 2004; Randler et al., 2009; Takeuchi et al., 2001). Some authors examined the relationship between parental control over bedtime and morningness–eveningness in adolescents. Takeuchi et al. (2001) found that parental control over bedtime during childhood was associated with somewhat less pronounced evening preferences in urban adolescent boys than in comparable group of adolescents whose parents did not set their bedtimes. Similarly, Randler et al. (2009) showed that the adolescents whose parents set their bedtimes were earlier chronotypes (measured by mid-time in bed) than the adolescents who were free to set their own bedtimes on weekdays.

Several questionnaire studies have shown that the pronounced phase shift towards eveningness starts around the age of 12 or 13, corresponding with the timing of pubertal changes (e.g. Díaz-Morales & Gutiérrez Sorroche, 2008; Ishihara et al., 1990; Kim et al., 2002; Randler, 2008c, 2008d; Russo et al., 2007; Shinkoda et al., 2000). While there are some similarities in the findings regarding the beginning of the phase shift towards eveningness, it is not clear at what age the phase delay stops. One of the reasons why the end of phase delay has not been established may lie in different age ranges of the studied adolescents. In addition, the studies did not focus on the end of phase delay but on the issues such as onset of the delay, gender differences in chronotype, and various behavioral characteristics of different chronotypes. In the latter context, the sleep behavior in adolescents of different phase preferences has extensively been explored. The results showed that, like in adult population, evening preferences in adolescents were associated with tendency for later bedtimes, later wake-up times, shorter sleep duration (or time in bed) during week and greater difference in sleep duration between school days and weekends (e.g. Andrade et al., 1992; Gau & Soong, 2003; Giannotti et al., 2002; Park et al., 1999; Russo et al., 2007).

The study of Roenneberg et al. (2004) explored the age differences in chronotype using “mid-sleep on free days” as an index of morningness–eveningness, which was estimated by means of the Munich Chronotype Questionnaire. Their study showed that mid-sleep on free days continued to delay gradually until the age of 19.5 years in girls and 20.9 years in boys, after which a significant, and again gradual, shift towards morningness was observed. The authors concluded that the switch in circadian phase towards morningness could be considered a marker of the end of adolescence. Studies that used the same or similar measure of morningness (Borisenkov, 2010; Borisenkov et al., 2010; Tonetti et al., 2008) indicated that the beginning of phase advance started around the age of 20, supporting the finding of Roenneberg et al. (2004). In several recent studies dealing with sleep patterns and morningness–eveningness in adolescents, Randler (2008d, 2009) further elaborated on the measure of mid-sleep demonstrating its significant correlation with the scores on the CSM.

School start time is another social factor influencing the adolescents’ sleep patterns to a significant degree. Preferences for later bedtimes combined with early school start time may result in insufficient sleep and impaired daytime functioning (e.g. as summarized by Fisher et al., 2008). All of the aforementioned studies have examined adolescents in countries where classes are scheduled in the morning (Canada, China, England, Germany, Italy, Japan, Korea, Portugal, Spain, Taiwan and US). The morning start of school is considered to be a general fact and the exact time when classes start in the morning has not been reported in the majority of studies. In several studies which have reported the exact time, it varies in a narrow range between 07:30 and 08:30 (Andrade et al., 1992; Chung & Cheiung, 2008; Díaz-Morales & Gutiérrez Sorroche, 2008; Díaz-Morales & Randler, 2008; Díaz-Morales et al., 2007; Randler, 2008b; Schneider & Randler, 2009). Therefore, all these studies have reported information about chronotypes and sleep behavior in adolescents whose major social zeitgeber of the school time is constant over the school term.

However, there are some countries in which classes do not necessarily start in the morning because of the insufficient capacities of schools, or – in some cases – because of adolescents’ work during the day (Fisher et al., 2008). The majority of elementary and high
schools in Croatia organize classes both in the morning and in the afternoon, with weekends off, due to the lack of school space to accommodate all students at the same time. Students change schedule every week, attending classes 1 week in the morning and the other in the afternoon. The question is what happens with morningness–eveningness preferences of adolescents and their relationship with sleep behavior when the major social zeitgeber promotes sleep irregularity between school weeks. So far only few studies examined sleep of adolescents who attended double shift schools (Bakotic et al., 2009; Louzada & Menna-Barreto, 2004; Lazaratou et al., 2005; Natal et al., 2009; Peixoto et al., 2009; Radosevic-Vidacek & Koscec, 2004; Valdez et al., 1996, 2003). Out of them only the study of Valdez et al. (1996) report data on morningness–eveningness measured by means of MEQ. The study examined students on a fixed shift schedule, one group attending school in the morning and the other in the afternoon, and found no difference in the MEQ scores between the two groups.

The aim of this study was to examine the morningness–eveningness of adolescents of different age who change school time every week and to explore the relationship between phase preferences and sleep characteristics in different situations within the two-shift cycle of school time (morning schedule, afternoon schedule and weekends).

METHOD
Participants
Research data were collected during an extensive survey study on adolescents’ sleep habits. The sample was composed of 2363 elementary and high school students from the city of Zagreb. All students attended school 1 week in the morning and the other in the afternoon, with weekends off. In the school week with morning schedule their classes typically started at 08:00 and ended at 13:00, while in the school week with afternoon schedule the classes started at 14:00 and ended at 19:00. In the city of Zagreb, 69% of elementary schools (giving 8-year basic education) and 82% of high schools (giving up to 4-year upper secondary education) organize classes in two shifts, while 4% of elementary and none of the high schools organize classes even in three shifts. That is somewhat greater percentage of two-shift schools than in the whole Croatia, since the most recent analyses performed for the Ministry of Science, Education and Sport for the school year 2012/2013 indicate that altogether there are 57% of elementary and 64% of high schools that organize classes in two shifts, and 2% of elementary and 3% of high schools that organize classes in three shifts (The Ministry of Science, Education and Sport, personal communication).

Multistage sampling was used to select participants from 102 public elementary and 50 public high schools in Zagreb. Public elementary schools were selected taking into account their geographical position (north, south, east, west) and location with respect to the city center (center, wider city area, suburb). In the first stage of sampling, 4 elementary schools were selected from each of the 3 city areas, which resulted in 12 selected schools. In the next stage, 4 classes from each of these 12 schools were randomly selected, one class per each grade from 5th to 8th (final) grade. That resulted in a final sample of 48 classes with 1261 potential participants from elementary schools. The selection of high schools was performed to cover all types of educational programs (grammar schools, vocational schools in the area of engineering and vocational schools of other types). In the first stage of sampling, 4 high schools were randomly selected from each of the 3 types of schools, making it a total of 12 schools. Next, 4 classes from each of these 12 schools were randomly selected, 1 class per each grade from 1st to 4th (final) grade, resulting in a total of 48 classes with 1426 potential participants from high schools.

Out of 2687 potential participants from elementary and high schools, 324 (12%) students did not participate in the study for the following reasons: because they were absent from school on the day of the testing; they did not have parents’ approval for participation; or they did not want to participate. Of the 2363 participants, we excluded the data on the students who were below 11 years (N= 65) or above 18 years (N= 11) of age, which resulted in the final sample of 2287 participants whose mean age was 14.43 years (SD=2.18). In this sample, there were 1194 females (52%) and 1093 males (48%).

Ethical considerations
The Ethics Committee of the Institute for Medical Research and Occupational Health approved the study, which was conducted in a way to conform to the standards of good research practice such as declared in Portaluppi et al. (2010). An approval from the Education and Teacher Training Agency was also obtained, as well as the written consent of the school headmasters. For the minors, consent was obtained from their parents/guardians by their class masters. An assent was also obtained from participants themselves. Participants and their parents/guardians were informed about the purpose and the nature of the study in writing. The study was conducted anonymously and the participants were granted confidentiality of the data. The use of data for scientific purposes only was guaranteed.

Instruments
Data on sleep patterns and circadian preferences of adolescents were collected using the School Sleep Habits Survey (SSHS – Wolfson & Carskadon, 1998), which was translated into Croatian and adapted for the two-shift school system. Two authors of this article independently translated the survey into Croatian and then decided on the final version by consensus method.
The SSHS is an extensive instrument collecting data on socio-demographic characteristics, general health, sleep environment and conditions, sleep patterns, extracurricular activities, and physical injuries. It also includes five scales, one of which is the Morningness–Eveningness Scale for Children (MESC, Carskadon et al., 1993). The MESC comprises a total of 10 questions among which five questions refer to the actual behavior and mood at different times of day, three questions refer to the preferred timing of various activities, and two questions refer to the functioning in hypothetical situations. The total score is calculated as the sum of points for each scale item and can range from 10 to 43, with higher score indicating more pronounced morningness. The Cronbach’s alpha coefficient of the Croatian translation of MESC was \( \alpha = 0.76 \) (N = 1723), indicating good internal consistency for this scale. Previous studies in other countries yielded similar reliability indexes for the MESC: \( \alpha = 0.73 \) (Carskadon et al., 1993), \( \alpha = 0.77 \) (Giannotti et al., 2002), \( \alpha = 0.82 \) (Díaz-Morales et al., 2007), and \( r_{1-2} = 0.78 \) (Kim et al., 2002). Temporal stability of the Croatian translation of MESC was also acceptable with one-month test–retest stability index \( r_{1-2} = 0.83 \) (N = 807).

The Croatian version of SSHS contains more items than the original, because it includes separate sleep-related questions for the school week with morning schedule and the school week with afternoon schedule. The participants were asked to report their usual sleep patterns during previous 2 weeks for three situations: school week with morning schedule, school week with afternoon schedule, and weekends. We did not ask separate sleep reports for the weekend following the morning schedule and the weekend following the afternoon schedule because we considered that in a 2-week period, for which reports were collected, there was not enough days to get reliable separate estimates. The students answered the survey during one school class (45 min).

**Data analysis**

Sleep patterns were assessed from the students’ answers about bedtime, sleep latency and wake-up time for the morning schedule, afternoon schedule and weekends. Sleep onset for each situation was calculated by adding the time it took to fall asleep (sleep latency) to bedtime. Sleep duration for each situation was calculated as a difference between wake-up time and sleep onset.

Variables regarding bedtime, sleep latency, wake-up time and sleep duration were checked for the presence of outliers. For the normally distributed variables (bedtime, wake-up time and sleep duration), outliers were defined as the values with z-score greater than +3 or lower than −3. For sleep latency, outliers were detected by a box plot method and they were defined as the values at a distance which is greater than 3*interquartile range \( (Q3–Q1) \) from the lower quartile values \( (Q1) \) or from the upper quartile values \( (Q3) \). In addition, values of the wake-up time on the morning shift which were greater than 08:00 h (class start time) were also considered outliers. We detected a total of 353 participants with outliers and our sample for the analyses was reduced to 1934 participants. There were 1049 females (54%) and 885 males (46%) in this sample.

The need for sleep was assessed in two ways. One was through students’ self-reports on the amount of sleep they think they should obtain each night in order to maintain adequate daytime functioning (ideal sleep need). The other was adopted from Roenneberg et al. (2004), who defined sleep need as the average weekly sleep duration. In this study, the average sleep duration was calculated from sleep durations on school days with morning and afternoon schedules and weekend days. The average sleep duration was defined as follows: \( 5 \times \text{sleep duration on the school days with morning schedule} + 5 \times \text{sleep duration on the school days with afternoon schedule} + 4 \times \text{sleep duration on weekends} / 14 \).

Sleep debt was calculated as the difference between sleep duration on weekends and averaged sleep duration, as proposed by Roenneberg et al. (2004).

Mid-sleep time on weekends (MSF) was calculated by adding a half of the weekend sleep duration to the weekend sleep onset time. In accordance with a suggestion given by Roenneberg et al. (2004), MSF was corrected (MSF\(_{sc}\)) by subtracting a half of the sleep debt from MSF.

The differences in bedtime, wake-up time and sleep duration were calculated between weekends and schooldays of the morning schedule, as well as between schooldays of the afternoon and morning schedule.

The total score on the MESC was calculated if minimally 8 of 10 questions were answered (N = 1837). In the cases where answers to 1 or 2 items were missing, the missing values were replaced by the individual mean on the scale. To check the assumption that the MESC scores follow normal distribution, we used the normal Q–Q plot coupled with histogram of the scale data. Both methods did not indicate any significant deviations of MESC scores from normality. Additionally, the measures of skewness and kurtosis \( \text{skewness} = -0.06, \text{SE} = 0.06, \text{kurtosis} = -0.09, \text{SE} = 0.11 \) also indicated the normal distribution of the data. In our sample, MESC scores ranged from 10 to 42, with the group mean \( M = 27.11 \) (SD = 5.05). We divided the sample into three groups according to the scores on MESC: Morning types, Intermediate types, and Evening types. The cut-off score for the evening types was 10th percentile (21.00), and for the morning types the 90th percentile (34.00). This categorization resulted in 190 morning types, 1420 intermediate types, and 227 evening types.

All data analyses were performed using IBM® SPSS® Statistics 20.
RESULTS

Age differences in the morningness–eveningness

To answer the question whether the morningness–eveningness preferences differ with respect to age, we analyzed the MESC scores of eight groups of adolescents (aged 11–18 years) by univariate ANOVA in which the between-subject factors were Age and Gender. There was a significant main effect of Age, $F_{(7/1821)} = 22.95, p<0.001$, partial $\eta^2 = 0.08$. The observed partial $\eta^2$ indicates that 8% of the variance in the MESC scores can be predicted from age of adolescents. Mean MESC scores in different age groups of adolescents are presented in Figure 1. Pairwise comparisons between the groups, using the Bonferroni correction, revealed that there were no differences in the average MESC scores between 11- and 12-year-old adolescents ($M_{11y} = 29.77$, $SD = 5.00$, $N = 187$; $M_{12y} = 29.40$, $SD = 4.88$, $N = 222$).

However, adolescents aged 13–18 reported on average more pronounced eveningness preferences ($M_{13y} = 27.65$, $SD = 5.15$, $N = 233$; $M_{14y} = 26.93$, $SD = 4.83$, $N = 262$; $M_{15y} = 25.95$, $SD = 5.05$, $N = 262$; $M_{16y} = 25.62$, $SD = 4.59$, $N = 258$; $M_{17y} = 26.30$, $SD = 4.74$, $N = 276$; $M_{18y} = 25.89$, $SD = 4.34$, $N = 137$) in comparison to 11- and 12-year-olds (all $p<0.01$). Furthermore, adolescents aged 15, 16 and 18 reported on average more pronounced eveningness preferences in comparison to 13-year-olds (all $p<0.05$). Starting from the age of 14 there were no further differences in the average MESC scores between the age groups. Girls reported on average slightly greater preference for eveningness than boys ($M_{girls} = 26.87$, $SD = 4.86$, $N = 998$; $M_{boys} = 27.41$, $SD = 5.25$, $N = 839$). The difference was statistically significant, $F_{(1/1821)} = 4.20, p<0.05$, but the partial $\eta^2$ of 0.002 indicated a negligible effect size. There was no significant interaction between Age and Gender, $F_{(7/1821)} = 1.41, p = 0.197$.

The mid-sleep time on weekends (MSF$_{sc}$) was used as a measure of morningness–eveningness based on the participants’ self-reported sleep patterns in the previous 2 weeks. Univariate ANOVA with Age and Gender as between-subject factors showed a significant effect of Age, $F_{(7/1918)} = 80.18, p<0.001$, of large size, partial $\eta^2 = 0.23$. Mean MSF$_{sc}$ in different age groups of adolescents are presented in Figure 2. Pairwise comparisons between the age groups, using the Bonferroni correction, revealed that there were no differences in the average weekend mid-sleep among adolescents aged 11–13 years ($M_{11y} = 4.40$, $SD = 1.12$, $N = 241$; $M_{12y} = 4.46$, $SD = 1.11$, $N = 236$; $M_{13y} = 4.64$, $SD = 1.09$, $N = 241$).

However, adolescents aged 14–18 years reported on average later mid-sleep ($M_{14y} = 4.87$, $SD = 1.24$, $N = 269$; $M_{15y} = 5.16$, $SD = 1.21$, $N = 269$; $M_{16y} = 5.66$, $SD = 1.34$, $N = 261$; $M_{17y} = 6.09$, $SD = 1.61$, $N = 279$; $M_{18y} = 6.67$, $SD = 1.71$, $N = 138$) than 11- and 12-year-old adolescents (all $p<0.01$). Additionally, later mid-sleep was observed on average in adolescents aged 15–18 years in comparison with 13-year-olds (all $p<0.001$), 16–18 years in comparison with adolescents aged 14 and 15 (all $p<0.001$), 17–18 years in comparison with those aged 16 (all $p<0.001$), and 18 years in comparison with 17-year-olds ($p<0.001$). A significant effect of Gender revealed that weekend mid-sleep fell on average somewhat later in boys ($M = 5.33$, $SD = 1.52$, $N = 885$) than in girls ($M = 5.06$, $SD = 1.45$, $N = 1049$), $F_{(1/1918)} = 29.90, p<0.001$, partial $\eta^2 = 0.02$, while their interaction was not significant, $F_{(7/1918)} = 2.10, p = 0.273$.

FIGURE 1. Mean scores (±SE) on the morningness–eveningness scale (MESC) for adolescents aged 11–18 years.
The MESC scores and MSF sc were moderately correlated in 11- to 17-year-old adolescents (11 years: $r = -0.48$, $p < 0.001$, $N = 187$; 12 years: $r = -0.43$, $p < 0.001$, $N = 222$; 13 years: $r = -0.40$, $p < 0.001$, $N = 233$; 14 years: $r = -0.44$, $p < 0.001$, $N = 262$; 15 years: $r = -0.41$, $p < 0.001$, $N = 262$; 16 years: $r = -0.41$, $p < 0.001$, $N = 258$; 17 years: $r = -0.42$, $p < 0.001$, $N = 276$), while their correlation in 18-year-olds was small and not significant ($r = -0.16$, $p > 0.05$, $N = 137$).

Circadian phase preferences and sleep characteristics

We conducted univariate ANCOVAs with Chronotype based on the MESC scores (three levels: Morning, Intermediate and Evening types) and Gender as between-subject factors, and Age (eight levels) as a covariate. We examined the effects of these factors on sleep patterns (bedtime; wake-up time and sleep duration) on days of morning and afternoon schedule and weekends. In addition, we analyzed two measures of sleep need (average sleep duration over the 2-week period with different school schedules and ideal sleep need) and sleep debt (difference between sleep duration on weekends and average sleep duration). Finally, we examined the measures of sleep irregularity in the system with alternating school schedule: bedtime delay on weekends and days with the afternoon school schedule with respect to the morning schedule, wake-up time delay on weekends and days with the afternoon school schedule with respect to the morning schedule and sleep extension on weekends and days with the afternoon school schedule with respect to the morning schedule. The results for the main effects of Chronotype and Gender are presented in Table 1. The interactions between Chronotype and Gender were not significant for any of the dependent variables, and therefore were not presented.

Chronotypes differed significantly in all analyzed sleep characteristics. We observed consistent differences in bedtimes over different situations which were in accordance with preferences of the chronotypes. Evening types went to bed on average 41 to 60 min later than Intermediate types, and 79 to 97 min later than Morning types. Differences in the wake-up times on days with the afternoon school schedule and weekends were also consistent with circadian preferences of the three chronotypes. On days with the afternoon schedule Evening types woke up on average 42 min later than Intermediate types and 85 min later than Morning types. On weekends Evening type woke up on average 70 min later than Intermediate types and 139 min later than Morning types. However, on days with the morning schedule, the differences in the wake-up times between Evening, Intermediate and Morning types were of much smaller magnitude. Evening types woke up 13 min later than Morning types but their wake-up time did not differ from the wake-up time of Intermediate types, indicating that the early start of classes limited most severely the wake up time of Evening types.

Regarding sleep duration, on days with the morning schedule, Evening types slept the shortest (6 h and 50 min on average) and Morning types slept the longest (8 h and 2 min on average), whereas on weekends both Evening types and Intermediate types slept around half an hour longer than Morning types. On days with the afternoon schedule the differences in sleep duration were small, and of negligible size effect.

The differences between Evening, Intermediate and Morning types were of opposite direction in the two measures of sleep need. When sleep need was defined as the average sleep duration in a 2-week period, the need
TABLE 1. Estimated marginal means, standard errors in parenthesis, and ANCOVA results for the effects of chronotype and gender on eighteen sleep variables.

<table>
<thead>
<tr>
<th>Sleep variables</th>
<th>Morning types (M)</th>
<th>Intermediate types (I)</th>
<th>Evening types (E)</th>
<th>F-value</th>
<th>Partial $\eta^2$</th>
<th>Pairwise comparisons</th>
<th>Females</th>
<th>Males</th>
<th>F-value</th>
<th>Partial $\eta^2$</th>
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<tbody>
<tr>
<td>Bedtime, h:min</td>
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<tr>
<td>MS</td>
<td>22:12 (0:04)</td>
<td>22:50 (0:01)</td>
<td>23:31 (0:04)</td>
<td>121.84***</td>
<td>0.118</td>
<td>M &lt; I &lt; E</td>
<td>22:46 (0:02)</td>
<td>22:56 (0:02)</td>
<td>9.91**</td>
<td>0.005</td>
</tr>
<tr>
<td>AS</td>
<td>22:44 (0:04)</td>
<td>23:28 (0:01)</td>
<td>00:17 (0:04)</td>
<td>140.24**</td>
<td>0.133</td>
<td>M &lt; I &lt; E</td>
<td>23:20 (0:02)</td>
<td>23:40 (0:02)</td>
<td>29.19**</td>
<td>0.016</td>
</tr>
<tr>
<td>W</td>
<td>23:59 (0:06)</td>
<td>00:36 (0:02)</td>
<td>01:36 (0:06)</td>
<td>75.65***</td>
<td>0.076</td>
<td>M &lt; I &lt; E</td>
<td>00:38 (0:04)</td>
<td>00:57 (0:04)</td>
<td>10.39**</td>
<td>0.006</td>
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<tr>
<td>Wake-up time, h:min</td>
<td></td>
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<tr>
<td>MS</td>
<td>06:30 (0:02)</td>
<td>06:39 (0:01)</td>
<td>06:43 (0:02)</td>
<td>10.48***</td>
<td>0.011</td>
<td>M &lt; I = E</td>
<td>06:41 (0:01)</td>
<td>06:38 (0:01)</td>
<td>ns</td>
<td>0.001</td>
</tr>
<tr>
<td>AS</td>
<td>07:55 (0:04)</td>
<td>08:38 (0:02)</td>
<td>09:20 (0:04)</td>
<td>107.38***</td>
<td>0.105</td>
<td>M &lt; I &lt; E</td>
<td>08:32 (0:03)</td>
<td>08:43 (0:03)</td>
<td>7.56**</td>
<td>0.004</td>
</tr>
<tr>
<td>W</td>
<td>09:04 (0:06)</td>
<td>10:13 (0:02)</td>
<td>11:23 (0:05)</td>
<td>154.12***</td>
<td>0.144</td>
<td>M &lt; I &lt; E</td>
<td>10:19 (0:04)</td>
<td>10:08 (0:04)</td>
<td>ns</td>
<td>0.002</td>
</tr>
<tr>
<td>Sleep duration, h:min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>8:02 (0:04)</td>
<td>7:31 (0:01)</td>
<td>6:50 (0:04)</td>
<td>84.70***</td>
<td>0.085</td>
<td>M &gt; I &gt; E</td>
<td>7:32 (0:06)</td>
<td>7:23 (0:06)</td>
<td>6.56*</td>
<td>0.004</td>
</tr>
<tr>
<td>AS</td>
<td>8:53 (0:05)</td>
<td>8:52 (0:02)</td>
<td>8:39 (0:05)</td>
<td>3.37*</td>
<td>0.004</td>
<td>I &gt; E</td>
<td>8:53 (0:04)</td>
<td>8:43 (0:04)</td>
<td>4.73*</td>
<td>0.003</td>
</tr>
<tr>
<td>W</td>
<td>8:53 (0:06)</td>
<td>9:17 (0:02)</td>
<td>9:25 (0:05)</td>
<td>8.25***</td>
<td>0.009</td>
<td>M &lt; I = E</td>
<td>9:26 (0:04)</td>
<td>8:57 (0:04)</td>
<td>25.14***</td>
<td>0.014</td>
</tr>
<tr>
<td>Sleep need, h:min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Average sleep duration</td>
<td>8:35 (0:04)</td>
<td>8:30 (0:01)</td>
<td>8:13 (0:04)</td>
<td>11.13***</td>
<td>0.012</td>
<td>M = I &gt; E</td>
<td>8:34 (0:02)</td>
<td>8:18 (0:02)</td>
<td>18.84***</td>
<td>0.010</td>
</tr>
<tr>
<td>Ideal sleep need</td>
<td>9:13 (0:07)</td>
<td>9:41 (0:02)</td>
<td>10:35 (0:06)</td>
<td>51.36***</td>
<td>0.055</td>
<td>M &lt; I &lt; E</td>
<td>9:59 (0:05)</td>
<td>9:40 (0:05)</td>
<td>9.98**</td>
<td>0.006</td>
</tr>
<tr>
<td>Sleep debt, h:min</td>
<td>0:18 (0:04)</td>
<td>0:47 (0:02)</td>
<td>1:12 (0:04)</td>
<td>42.58***</td>
<td>0.044</td>
<td>M &lt; I &lt; E</td>
<td>0:52 (0:02)</td>
<td>0:38 (0:02)</td>
<td>11.73*</td>
<td>0.006</td>
</tr>
<tr>
<td>Bedtime delay, h:min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>W-MS</td>
<td>1:47 (0:06)</td>
<td>1:52 (0:02)</td>
<td>2:11 (0:05)</td>
<td>6.30**</td>
<td>0.007</td>
<td>M = I &lt; E</td>
<td>1:52 (0:01)</td>
<td>2:01 (0:01)</td>
<td>ns</td>
<td>0.001</td>
</tr>
<tr>
<td>AS-MS</td>
<td>0:32 (0:03)</td>
<td>0:38 (0:01)</td>
<td>0:46 (0:03)</td>
<td>5.19**</td>
<td>0.006</td>
<td>M = I &lt; E</td>
<td>0:34 (0:02)</td>
<td>0:43 (0:02)</td>
<td>10.24**</td>
<td>0.006</td>
</tr>
<tr>
<td>Wake-up time delay, h:min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>W-MS</td>
<td>2:35 (0:06)</td>
<td>3:35 (0:02)</td>
<td>4:40 (0:05)</td>
<td>117.23***</td>
<td>0.114</td>
<td>M &lt; I &lt; E</td>
<td>3:43 (0:04)</td>
<td>3:29 (0:04)</td>
<td>5.63*</td>
<td>0.003</td>
</tr>
<tr>
<td>AS-MS</td>
<td>1:25 (0:04)</td>
<td>2:00 (0:02)</td>
<td>2:37 (0:01)</td>
<td>78.14***</td>
<td>0.079</td>
<td>M &lt; I &lt; E</td>
<td>1:56 (0:03)</td>
<td>2:04 (0:03)</td>
<td>3.94*</td>
<td>0.002</td>
</tr>
<tr>
<td>Sleep extension, h:min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>W-MS</td>
<td>0:51 (0:07)</td>
<td>1:46 (0:02)</td>
<td>2:35 (0:06)</td>
<td>65.74***</td>
<td>0.067</td>
<td>M &lt; I &lt; E</td>
<td>1:53 (0:04)</td>
<td>1:34 (0:04)</td>
<td>9.85**</td>
<td>0.005</td>
</tr>
<tr>
<td>AS-MS</td>
<td>0:52 (0:05)</td>
<td>1:20 (0:02)</td>
<td>1:48 (0:04)</td>
<td>35.05***</td>
<td>0.037</td>
<td>M &lt; I &lt; E</td>
<td>1:20 (0:03)</td>
<td>1:20 (0:03)</td>
<td>ns</td>
<td>0.000</td>
</tr>
</tbody>
</table>

***p<0.001; **p<0.01; *p<0.05.

MS, morning schedule; AS, afternoon schedule; W, weekend; W-MS, weekend with respect to morning schedule; AS-MS, afternoon schedule with respect to morning schedule.
of Evening types was smaller than the need of Intermediate or Morning types, although the differences were of rather small magnitude (17 and 22 min, respectively). On the other hand, when sleep need was defined as the estimated ideal sleep duration needed for appropriate daytime functioning, Evening types had a greater average need than either Morning types (82 min) or Intermediate types (54 min). Sleep debt, defined as the difference between weekend sleep and average sleep duration (Roenneberg et al., 2004) was the greatest in Evening types (on average 72 min) and smallest in Morning types (only 18 min on average).

There were consistent differences in sleep regularity between three chronotype groups. Evening types delayed their bedtime on weekends and days with the afternoon schedule more than Intermediate types and Morning types did. Furthermore, the wake-up time delay was the greatest in Evening types and the smallest in Morning types, and the differences between chronotypes in the wake-up delay were even more pronounced than the differences in their bedtime. Regarding the sleep extension, both on weekends and on days with the afternoon schedule Evening types extended their sleep the most and Morning types the least.

**DISCUSSION**

The findings of our study give the first insight into morningness–eveningness and its associations with characteristics of sleep of adolescents whose main social zeitgeber – school time – promotes irregularity of sleep between weeks.

The study focused on two measures of morningness–eveningness. One is the Morningness–Eveningness Scale for Children (MESC) (Carskadon et al., 1993) that requires adolescents to describe various preferred, actual and hypothetical behaviors within a 24-h day: preferred times of getting up, going to bed and taking a test; physical performance and attitude towards having to get up at hypothetical morning hours; ease of awakening, alertness after getting up and time necessary to become fully functional after rising; a period of day when having the most energy for favorite things and a time of day when feeling a need for sleep. The other measure is a version of mid-sleep time on free days (Roenneberg et al., 2003) that is based only on reports about sleep behavior. Similarly as the original measure of mid-sleep on free days, it was calculated as a half-way point between sleep onset and offset, and corrected for sleep debt. Our measure differed from the original mid-sleep measure in the reference period for which sleep reports were collected and the calculation of sleep debt. Because the main social zeitgeber of Croatian adolescents, i.e. school time, significantly differs from 1 week to another and affects sleep timing and duration, sleep reports were collected for a 2-week period prior to the study, whereas the original measure requires reports about sleep in an unspecified week that is characteristic for the respondent’s most current living conditions. Consequently, the sleep debt that is necessary for correction of mid-sleep time on free days was also calculated for the 2-week period.

The both measures of morningness–eveningness generally showed an increase of tendency towards eveningness over the ages 11–18. However, some differences in the trend across the age groups were observed between the two measures. The MESC scores indicated a start of the phase delay between ages 12 and 13, a stop of delay at age 14, and no further change up to age 18. In comparison to the MESC scores the mid-sleep time on weekend indicated a start of delay one year later – between ages 13 and 14 – and no sign of a plateau but progressive delay till the age of 18.

Although the number of studies on morningness–eveningness of adolescents has been growing, it is possible to compare our data on the MESC with results of only five studies (Díaz-Morales & Gutiérrez Sorroche, 2008; Gelbmann et al., 2012; Goldstein et al., 2007; Kim et al., 2002; Russo et al., 2007). The comparisons are limited because different MEQs have been used. The other reason lays in different age range of adolescents studied. In addition, results have often been summarized for all age groups together or for subgroups of different age interval. Further difficulty sometimes stem from data reporting for grades instead of age groups. In the case of the five aforementioned studies, we are able to compare our results with results for Spanish adolescents aged 12–16 years (Díaz-Morales & Gutiérrez Sorroche, 2008); Austrian adolescents aged 11–17 (Gelbmann et al., 2012), Canadian adolescents aged 11–14 (Goldstein et al., 2007); US adolescents aged 11–16 (Kim et al., 2002), and Italian adolescents aged 11–14 (Russo et al., 2007). All five studies found a significant effect of age on the MESC scores, but differed in the age when shift towards evening started. Similarly as in our study the shift towards eveningness was found between ages 12 and 13 in Italian adolescents (Russo et al., 2007). In US adolescents, the shift was observed between ages 13 and 14 (Kim et al., 2002). In Spanish adolescents the differences were found at age 12 versus 15 and 16 (Díaz-Morales & Gutiérrez Sorroche, 2008). Goldstein et al. (2007) did not compare individual age groups of Canadian adolescents, but the inspection of average MESC scores shows the largest difference between ages 11 and 12. The largest difference was observed between ages 11 and 12 also in the study by Gelbmann et al. (2012), but it was not statistically significant.

The relationship of morningness–eveningness with regularity of lifestyle, bedtime and rise time was documented in studies on adults (e.g. Monk et al., 2004; Soehner et al., 2011). The results indicated that more pronounced eveningness was associated with irregularity of sleep and lifestyle. The system of school time in Croatia promotes irregularity of sleep and lifestyle.
et al. (2005) found a correlation coefficient of between the two measures in 18 years old. Zavada MESC scores and mid-time of sleep on free days in study, we found moderate correlations between the rise times, (the correlations were around congruent with actigraphically measured bed-times and on seven different MEQs of college students were all phase (Martin & Eastman, 2002). On the other hand, the timing of sleep, and possibly better reflects circadian where mid-time of sleep on free days is based only on possibly partly measures the entrainment to social time, whereas mid-time of sleep on free days is based only on timing of sleep, and to estimate convergent validity of the latter measure of morningness. We can only speculate how much timing of weekend sleep, although not restricted by imposed school schedule, is restricted by a schedule of late night socializing that is very common for adolescents, and therefore reflects opposite social jet lag than the sleep on school days.

The majority of questionnaire studies on adolescent population report no difference in morningness–eveningness preferences between adolescent girls and boys (e.g. Carskadon et al., 1993; Díaz-Morales & Gutiérrez Sorroche, 2008a; Gau & Soong, 2003; Giannotti et al., 2002; Kim et al., 2002; Park et al., 1999; Randler, 2008a; Russo et al., 2007). In our study, we found a slightly more pronounced eveningness preference in adolescent girls when compared to the boys. A similar finding was reported by Gaina et al. (2006) who found that the adolescent girls showed more evening preferences measured by the MEQ than the adolescent boys. Still, authors using the MESC generally reported no sex differences in the total scores (Díaz-Morales & Gutiérrez Sorroche 2008; Kim et al., 2002; Russo et al., 2007). A recent study by Collado Mateo et al. (2012), reported higher eveningness in adolescent girls, but only at the ages 13 and 14. Analyses of sex differences in responses to individual items of the MESC questionnaire (Díaz-Morales & Gutiérrez Sorroche, 2008) showed the more pronounced morning preferences in boys regarding the preferred wake-up time, exercise time and bedtime.

In adult population the questionnaire studies usually show somewhat more pronounced morning tendencies in females (Adan et al., 2012). Tonetti et al. (2008) showed no sex differences in the ideal midpoint of sleep in a subsample from 10 to 17 years of age. However, the phase advance in the ideal midpoint of sleep was observed in females of older subsamples, with the most pronounced sex differences in the group from 18 to 44 years of age. The authors also found that the girls reached the peak in eveningness at the age of 17, whereas the boys reached the peak at the age of 21, which was similar to Roenneberg et al. (2004). In this light, Tonetti et al. (2008) argued the possible modulatory influence of the sex hormones to the circadian system, which is supported by several other studies as summarized by Adan et al. (2012). Our sample comprised the adolescents age 11 to 18, and the girls showed only slightly more pronounced evening preferences (0.50 point of negligible effect size). Considering that, we can conclude that our results do not differ from previous findings regarding the gender differences in total MESC scores. On the other hand, the other measure of morningness–eveningness that we used – the mid-sleep time on weekends – demonstrated somewhat more pronounced eveningness in boys, which is consistent with the results of other studies using that.
A significant need for even longer sleep than they are peers who attend school only in the morning still have who have more flexible sleep opportunities than their longest). This finding indicates that even the adolescents estimation of ideal sleep need – Evening types the between the chronotypes (Morning types the shortest in all chronotype groups, with the expected differences still longer than the actual sleep duration on weekend debt of the adolescents in our study was fully paid off. get close to the recommended 9 h of sleep (Carskadon et al., 2001; Carskadon & Soong, 2003; Park et al., 1999; Russo et al., 2007). Carskadon et al. (2002) demonstrated that the adolescents with pronounced evening preferences had higher level of morning sleepiness after insufficient sleep than the adolescents with pronounced morning preferences. Sleepiness levels of those with pronounced evening preferences continuously declined through four sleep latency tests, while sleepiness of the adolescents with more pronounced morning preferences stayed relatively stable until the early afternoon when it significantly increased. Bearing in mind this neurobehavioral vulnerability of adolescents, who as a population demonstrate the inclination towards eveningness and function under heightened pressure of the accumulated sleep debt, the results of our study point to the relative advantage of a double-shift school system regarding the sleep duration and greater opportunities for paying off the sleep debt accumulated on the school week with morning schedule for all chronotypes.

On a two-shift school schedule such as the one in Croatia, the adolescents are quite free to organize their sleep schedules according to their intrinsic needs and societal demands on most days of a 2-week cycle (i.e. 9). In our study, there was an evident tendency of all chronotypes to delay their bedtimes and wake-up times, and prolong their sleep as the opportunities for greater sleep irregularity and longer sleep duration progressively increased from morning schedule week through the afternoon schedule week to the weekend. On a school week with morning schedule such behavioral tendencies result in inadequate sleep duration (from less than 7 h in Evening types to around 8 h in Morning types). On the other hand, on school days with afternoon schedule, when they are more free to set their wake up times, all three chronotype groups managed to get close to the recommended 9 h of sleep (Carskadon et al., 2001; Carskadon & Dement, 1982).

It can be questioned whether the accumulated sleep debt of the adolescents in our study was fully paid off. Namely, the estimations of the ideal sleep duration were still longer than the actual sleep duration on weekend in all chronotype groups, with the expected differences between the chronotypes (Morning types the shortest estimation of ideal sleep need – Evening types the longest). This finding indicates that even the adolescents who have more flexible sleep opportunities than their peers who attend school only in the morning still have a significant need for even longer sleep than they are able to get considering their phase preferences, lifestyle and societal demands.

The mismatch between the estimated sleep need and actual sleep duration was evident also in the measure of sleep extension which indicates the paying off of the accumulated sleep debt. All chronotype groups extended their sleep both on afternoon school week and on weekends when compared to the morning school week. Again the differences were in the expected direction with the Morning types demonstrating the smallest and the Evening types the longest sleep extension in both situations. The examination of two different measures of sleep debt revealed that the calculations of average sleep durations for the 2-week period gave values of sleep debt ranging from 18 min for the Morning types to 72 min for the Evening types, which were several times smaller than the values of sleep extension on weekend (ranging from around 50 min for the Morning types to 155 min for the Evening types). It seems that calculating sleep debt as a difference between average sleep duration and sleep duration on weekends may not be appropriate for the samples with irregular work or school schedules. Averaging the sleep duration across three different situations over a 2-week period – morning school week, afternoon school week and weekends – can mask the naturally occurring variability of the phenomenon, resulting with the underestimated value of the accumulated sleep debt. The question can also be raised whether it would be better to compute separate mid-sleep measures for free days after each school schedule and correct each of them for sleep debt accumulated on a respective week. The nature of the relationship between such two mid-sleep measures should be examined in future studies.

Rotating school schedules on weekly basis inevitably foster greater sleep irregularity in adolescents, but on the other hand provide additional opportunities for paying off the sleep debt as well as organizing sleep timing in more synchrony with the phase of their endogenous circadian rhythms. The question is what should be prioritized in this particular population – more sleep regularity or more sleep? As many studies have shown, the adolescents who do not get enough sleep may show poorer academic performance, have problems keeping awake during daytime, have higher scores on anxiety and depression scales, are more prone to substance abuse, have lower self-esteem and less achievement motivation (Carskadon, 2002). In this light fostering longer sleep at the cost of some degree of sleep irregularity seems like a reasonable option, especially in a population which is by itself skewed towards the later phase, and therefore more flexible in the adaptation to changes in sleep schedule. On the other hand, even on such a flexible school schedule the adolescents still seem to lack the needed amount of sleep when classes are scheduled in the morning. As the results of some studies suggest (Randler et al., 2009; Takeuchi et al., 2001), one possible direction in preventing...
skewness towards eveningness in adolescent population (which is associated with inadequate sleep duration on schooldays) might be supporting the parental control of sleep timing in early adolescence.

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DECLARATION OF INTEREST

The authors declare no conflict of interest. The authors alone are responsible for the content and writing of this article. This study was funded by the Croatian Ministry of Science, Education and Sports, Grant no. 022-0222411-2659 to B. Radosevic-Vidacek.

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