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Sleep and Academic Performance in Undergraduates: A Multi-measure, Multi-predictor Approach

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The present study examined the associations of sleep patterns with multiple measures of academic achievement of undergraduate university students and tested whether sleep variables emerged as significant predictors of subsequent academic performance when other potential predictors, such as class attendance, time devoted to study, and substance use are considered. A sample of 1654 (55% female) full-time undergraduates 17 to 25 yrs of age responded to a self-response questionnaire on sleep, academics, lifestyle, and well-being that was administered at the middle of the semester. In addition to self-reported measures of academic performance, a final grade for each student was collected at the end of the semester. Univariate analyses found that sleep phase, morningness/eveningness preference, sleep deprivation, sleep quality, and sleep irregularity were significantly associated with at least two academic performance measures. Among 15 potential predictors, stepwise multiple regression analysis identified 5 significant predictors of end-of-semester marks: previous academic achievement, class attendance, sufficient sleep, night outings, and sleep quality ($R^2 = 0.14$ and adjusted $R^2 = 0.14$, $F(5,\ 1234) = 40.99$, $p < .0001$). Associations between academic achievement and the remaining sleep variables as well as the academic, well-being, and lifestyle variables lost significance in stepwise regression. Together with class attendance, night outings, and previous academic achievement, self-reported sleep quality and self-reported frequency of sufficient sleep were among the main predictors of academic performance, adding an independent and significant contribution, regardless of academic variables and lifestyles of the students. (Author correspondence: ana.allen@ua.pt)

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INTRODUCTION

Controlled studies that manipulated sleep in healthy adults through a variety of methods, e.g., post-training sleep and total, partial, or selective-stage sleep deprivation, have found that sleep is associated with a range of cognitive activities, such as attention (Fafrowicz et al., 2010; Lim & Dinges, 2010; Van Dongen et al., 2003a; Wimmer et al., 1992), insight (Wagner et al., 2004), divergent thinking (Horne, 1988; Wimmer et al., 1992), decision-making (Harrison & Horne, 1999, 2000), speech (Harrison & Horne, 1997), and most notably learning and memory (Diekelmann, 2009; Dotto, 1996; Ficca & Salzarulo, 2004; Fogel et al., 2007; Li et al., 1991; Maquet, 2001; Roehrs & Roth, 2000; Smith, 1995, 2001; Stickgold & Walker, 2007; Stickgold et al., 2001; Walker & Stickgold, 2004, 2006). Both total (Lim & Dinges, 2010) and partial (chronic) (Banks & Dinges, 2007; Van Dongen et al., 2003) sleep deprivation may impair daytime neurobehavioral functions in adults. However, the exact mechanisms underlying the associations are still unclear. A concise, up-to-date, discussion about the main theoretical viewpoints on the effects of sleep deprivation on cognitive functions may be found elsewhere (Lim & Dinges, 2010).

A considerable amount of research has focused on the role of sleep on memory. The role of sleep on memory is not merely a passive one (interference reduction); rather, research indicates that sleep actively facilitates memory (Diekelmann et al., 2009; Ficca, 2010). Sleep appears to be related to (i) distinct memory types such as working memory (Kopasz et al., 2010; Lim & Dinges, 2010; Van Dongen et al., 2003a) and long-term memory; (ii) several kinds of materials, namely, memory for procedural/nondeclarative and declarative knowledge (Dotto, 1996; Fogel et al., 2007; Smith, 1995, 2001); and (iii) different memorization stages, such as encoding,

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consolidation, and reconsolidation (Walker & Stickgold, 2006). A full discussion of the role of sleep on memory, and its underlying mechanisms, is beyond the scope of the present study, but may be found in other works (e.g., Diekelmann et al., 2009; Fica & Salzarulo, 2004; Maquet, 2001; Stickgold & Walker, 2007; Walker & Stickgold, 2004, 2006).

Although findings based on standardized cognitive tasks of controlled studies cannot directly be generalized to community samples in natural environments, the above-mentioned cognitive activities seem intuitively important for academic performance; therefore, it is reasonable to suppose that sleeping behaviors and patterns might also influence academic achievement in real-life circumstances. In line with experimental research, ecological studies have found significant associations between sleep patterns and academic achievement measures, such as grade point averages (GPAs; for an overview see Curcio et al., 2006; Dewald et al., 2010; Gomes et al., 2002; Wolfson & Carskadon, 2003). Although the focus of the present paper is on undergraduates, it is worth mentioning that the relationships between sleep parameters and school performance have been more regularly investigated in children and adolescents of several age and educational levels (Bruni et al., 1995; Buckhalt et al., 2009; Dewald et al., 2010; Giannotti & Cortesi, 2002; Hofman & Steenhof, 1997; Meijer & Wittenboer, 2004; Pagel & Kwiatkowski, 2010; Pagel et al., 2007; Ravid et al., 2009; Roberts et al., 2001; Wolfson & Carskadon, 1998). In addition, a growing number of experimental studies on younger children and adolescents show, for instance, that sleep facilitates memory (Kopasz et al., 2010), and that sleep restriction or extension in school-aged children by only 1 h during consecutive nights leads to differential impact on neurobehavioral measures (Sadeh et al., 2003). However, it cannot be assumed that the effects of sleep on cognition or academic performance are the same in all ages or at all stages of human development (Dewald et al., 2010). For example, academic outcome measures seem to be differentially influenced by sleep, depending on student educational level and age (Pagel et al., 2010), and recent reviews (Diekelmann et al., 2009; Kopasz et al., 2010) report that procedural memory consolidation in children may not benefit from sleep to the same extent as it does in adults.

Our focus is sleep and academic performance of university undergraduate students. University students are required to perform at demanding levels. In addition, sleep patterns are likely to change from high school to university due to alterations in zeitgebers, such as class schedules and lifestyle preferences (Urner et al., 2009). Specifically, in samples of university students observed in their natural environment, poorer academic results have been consistently associated with shorter sleep duration (Borisenkov et al., 2010; Jean-Louis et al., 1996; Kelly et al., 2001; Medeiros et al., 2001; Trockel et al., 2000), with later sleep-wake schedules (Elliason et al., 2010; Johns et al., 1976; Medeiros et al., 2001, 1996; Smith et al., 1989; Trockel et al., 2000), and/or with related variables, such as delayed sleep phase (Lack, 1986) and eveningness orientation (Beşoluk et al., 2011; Borisenkov et al., 2010; Medeiros et al., 2001; Randler & French, 2006; Smith et al., 1989). Eveningness preference has also been found to be associated with other variables apparently related to academic achievement, such as procrastination (Digdon & Howell, 2008; Hess et al., 2001). In a study on personality, conscientiousness was associated with earlier class schedules, which in turn were associated with academic performance (Gray & Watson, 2002). Lower academic grades in college were also found to be associated with other sleep variables, such as irregular sleep-wake cycle (Medeiros et al., 2001), poor sleep quality (Gilbert & Weaver, 2010; Howel et al., 2004; Johns et al., 1976), complaints of onset and maintenance insomnia (Pagel & Kwiatkowski, 2010), excessive daytime sleepiness (Rodrigues et al., 2002), and frequent snoring (Ficker et al., 1999).

Summarizing the vast literature on sleep and chronobiology, we may assume that four fundamental sleep patterns are expected to be associated with academic achievement: sleep *quantity*, sleep *quality*, sleep *regularity*, and sleep *phase* schedules. Specifically, sleep restriction, poor sleep quality, and irregular and late sleep schedules are expected to be associated with poorer school performance.

As to *sleep amount*, given the vast research on sleep deprivation (both partial and total) and on hypothetical sleep functions (e.g., restoration theory), especially in relation to the impact of these sleep functions on cognitive/neuropsychological functioning as already reviewed, it is reasonable to expect students with greater sleep debt to demonstrate worse academic performance. In fact, both rapid eye movement (REM) and non-REM sleep stages appear to play a role in memory and learning consolidation. Therefore, it is also expected that poor *sleep quality*, which may manifest itself through difficulties with sleep onset, and/or light sleep, and/or fragmented sleep, might also have an impact on academic performance. As to *sleep irregularity*, shiftwork and jetlag research shows that abrupt changes in the sleep-wake schedule lead to internal dissociation of circadian rhythms, which may result in a variety of undesirable effects, including performance decrements (AASM, 2005). As jetlag symptoms may arise when three or more time zones are rapidly traversed, it is reasonable to suppose that university students showing comparable irregularities in their sleep-wake schedule will suffer undesirable consequences, such as higher fatigue, mood deterioration, reduced performance (Taub & Berger, 1973, 1976), and excessive daytime somnolence (Manber et al., 1996). Finally, studies on student samples have consistently reported poorer school performance to be associated with a *later* sleep-wake schedule and/or chronotype preference towards eveningness. In this case, it is worth mentioning that morningness-eveningness is a continuum of *normal* interindividual differences. That is, along this continuum, sleep should be normal in quantity (Roenneberg et al., 2004) and quality, providing the individual is able to adapt to her/his preferred schedule (AASM, 2005). Therefore, in contrast to sleep restriction, sleep irregularity, or poor sleep quality, it seems that later sleep-wake schedule and eveningness are not per se problematic in the sense that there is no alteration of sleep duration or architecture. Thus, the hypothesized associations between later sleep-wake schedule and academic performance are not direct, but are most probably mediated by other variables, such as sleep restriction and sleep irregularity, both being higher in evening types (Giannotti et al., 2002; Gomes et al., 2008; Taillard et al., 1999), and/or lower class attendance, which may occur as a consequence of conflict between late sleep-wake schedule/eveningness tendencies and externally imposed morning class schedules.

Despite the numerous publications on sleep and academic performance among university students, to date very few studies have examined the relative impact of sleep variables on academic results in real-life circumstances and when other potential predictors are considered, such as well-being, lifestyle, and academic variables. Jean-Louis et al. (1996) considered several psychosocial factors, such as personal, medical, social, sleep habits, academic, mood, and substance abuse, that could be related to the academic performance of college students. Multiple regression analysis identified six significant predictors, three of which were sleep variables (weekend sleep amount, sleep latency, and falling asleep at school). Trockel et al. (2000) analyzed the associations of first-year undergraduate academic performance with health-related variables relative to exercise, nutrition, sleep habits, mood states, perceived stress, time management, social support, religious or spiritual habits, extra number of hours worked per week, sex, and age. Multiple regression analyses selected five significant predictors, two of which were sleep variables (weekday and weekend wake-up times), that accounted for the highest proportion of explained variance in GPA. In a study focused on links between alcohol use, sleep, and academic performance in college students, Singleton and Wolfson (2009) found Scholastic Aptitude Test scores were the strongest predictor of GPA, with the other significant predictors being sex, alcohol consumption, sleep duration, and daytime sleepiness. By considering the multiple variables that might explain academic performance, these types of studies provide valuable data and help to better assess the relative effect of the various aspects of sleep.

In a relatively recent literature review, Curcio et al. (2006) state that the first step in the research agenda on sleep and academic performance should be to find reliable measures of academic performance or, alternatively, adopt the recommendation of Wolfson and Carskadon's (2003) of using a multimeasure approach (e.g., grades, tests, teacher reports). In addition, Wolfson and Carskadon stress the need to gather longitudinal data (see also Dewald et al., 2010) and emphasize that future studies should assess a variety of other variables, besides sleep, that influence academic performance. In spite of these recommendations, to date very few published studies have adopted such a multimeasure, multipredictor approach. Moreover, research aimed at studying the associations between sleep and academic performance has rarely measured neuroticism, the one exception being the study of Gray and Watson (2002), apparently overlooking the literature that has emphasized neuroticism to be one of the most important individual predictors of intolerance to shiftwork, as neurotic individuals are more prone to experience undesirable consequences following abrupt changes in their sleep-wake schedule (e.g., Costa et al., 2001; Härma, 1993; Saksvik et al., 2011). In addition, there appears to be interindividual variability in the susceptibility to sleep restriction (Banks & Dinges, 2007; Van Dongen et al., 2003b) as well as to desynchronization of circadian rhythms (Reinberg et al., 1989), and neuroticism is likely related to this greater vulnerability, at least with respect to sleep debt (Blagrove & Akehurst, 2001; Taylor & McFatter, 2003). For these reasons, it seemed important to consider neuroticism in the present study.

The present study had two major aims: (i) to analyze associations between sleep patterns and multiple measures of academic performance of university students (self-reported retention, previous GPA, subjective impact of sleep patterns on academic results, and end-of-semester marks as indicated by university records); and (ii) to examine longitudinally whether sleep variables emerge as significant predictors of subsequent academic performance when other potential predictors, such as class attendance, time devoted to study, substance use, and neuroticism, are considered. Included in the second aim was determination of whether neuroticism plays a moderating role in the associations between sleep patterns and subsequent end-of-semester marks. Indeed, it may be that inadequate sleep, such as sleep curtailment, has a greater detrimental effect on daytime functioning in neurotic subjects than in stable subjects. In this study, we focus on four fundamental sleep variables: sleep amount, sleep quality, sleep regularity, and sleep phase schedule. Specifically, we hypothesize that sleep restriction, poor sleep quality, and irregular and late sleep schedules are associated with poorer academic performance.

METHODS

Sample

Participants were 1654 full-time students, 55% female and 45% male, aged 17 to 25 yrs (M = 19.98, SD = 1.65), from a public Portuguese University, located in a city at the littoral, center-north region of Portugal. They were distributed across the 1st (31.3%), 2nd (39.5%), and 3rd (29.2%) yrs of university study of 18 undergraduate degree programs, representative of 50% of the existing undergraduate degree programs of the university grouped into five academic fields: engineering (40%), sciences (30%), pre/primary-school education (12%), management (10%), and languages (9%). Inclusion criteria were ≤25 yrs of age, full-time student status, nonworking, nonpregnant, and nonparent (no children). Exclusion criteria were age >25 yrs of age, part-time student status, working, elite athlete, significant university extracurricular activities, having children, and being pregnant. Based on the students' residency status on school days versus weekends/holidays, three groups were formed and labeled as "moved students" (66%), those presumably studying outside their home and living in the university city during the week; "nonresidents" (23.7%), students that presumably travel daily from their home town to the university to attend classes; and "residents" (10.3%), students whose family home is presumably located in the university city.

Instruments and Measures

Sleep-Wake Questionnaire

A sleep-wake questionnaire covering demographic, sleep, academic, lifestyle, and well-being variables was developed for a large research project on sleep, well-being, and academic success of university students that was to be completed during the school semester. Based on existing sleep-wake questionnaires, and lacking a specific Portuguese instrument to access sleep-wake patterns in undergraduates, the questionnaire was principally constructed by the first and third authors, both of whom had at least 5 yrs of clinical practice at a sleep clinic at the University Hospital of Coimbra and research experience in the adaptation, development, and validation of psychological and psychiatric assessment tools. The second author contributed with his experience in supervising research projects about the diagnosis and intervention strategies for the promotion of academic success at the university level. The questionnaire was also built upon the experience of all authors having served as university teachers. The first version was tested with 103 undergraduates using "think aloud" procedures. After this pilot study, several improvements were made. The resulting version was then examined by a group of five teachers. Again, minor improvements were introduced based on their feedback. After these steps, the authors agreed on a definitive version of the questionnaire. The entire questionnaire is shown in Appendix, and items used in the present work are identified with an asterisk. The psychometric properties are further addressed below.

Composite Morningness Questionnaire

The Composite Morningness Questionnaire (CMQ; Smith et al., 1989), Portuguese version (Silva et al., 1995), was used to measure chronotype. In our sample, the internal consistency of the CMQ, assessed through Cronbach α, was 0.81.

Eysenck Personality Inventory

The Eysenck Personality Inventory (EPI), the 12-item version, from the Standard Shiftwork Index (SSI) (Barton et al., 1995) (Portuguese version: Silva et al., 1995), was used to measure neuroticism and extroversion. Two main reasons led us to prefer this tool instead of other measures of these constructs. First, the small number of items is advantageous when researchers need to collect large amounts of data in an already big booklet (as in our study). Second, this version was chosen to integrate the SSI, a battery of tests utilized by leading researchers to investigate shiftwork through the adoption of standardized measures (Barton et al., 1995). A two-factor structure was found in our study (principal components analysis with varimax rotation) in accordance with the expected, with the exception of two items that did not load in any dimension and were, therefore, excluded from further analyses. Five items loaded on the extraversion factor (22.21% of the explained variance; Cronbach α = 0.68), and an additional five items loaded on the neuroticism factor (22.07% of the explained variance; Cronbach α = 0.66).

Variables derived from the self-response questionnaires that are relevant for the analyses of the present study covered several domains. (Except when otherwise specified, the described variables are taken from the sleep-wake questionnaire; further details about the respective items may be found in Appendix.)

- *Demographics* variables included sex, age, residential status, curricular year, academic field (cf. initial questions in Appendix).
- *Academic antecedents* variables included past academic achievement (as measured by self-reported previous GPA, rated on a 6-point scale), vocational preferences (mis)match (1st, 2nd, 3rd, or other), and academic failure in most courses of the previous curricular year. As regards prior GPA, in Portugal marks are expressed on a 0- to 20-point scale (at the university level) or, similarly, on a 0- to 200-point scale (admission to university classification as the result of a weighted mean between high-school GPA and admission tests). In the sleep-wake questionnaire, the participant was asked to report his/her prior GPA on a 6-point scale such that ≤10 (coded as 1), 10–11 (coded as 2), 12–13 (coded as 3), 14–15 (coded as 4), 16–17 (coded as 5), ≥18 (coded as 6) for university classification or as similar options formulated in terms of the to 0- to 200-point scale (rather than 0 to 20) for admission to the university (cf. item 35 in Appendix). As to vocational preference match, student admission to majors in public universities in Portugal occurs once a year throughout the country. Each student must complete a form indicating his/her preference for an undergraduate degree program and university. Candidates/

applicants to each undergraduate degree program are sorted by the Portuguese Ministry of Science and Higher Education according to their grades. Depending on the applicant's position on each list and on the limit of admissions defined for each degree program, students may or may not be admitted to their first preference, and, alternatively, they may be admitted to their second, third, or other choice. In the present study, we have assumed that the student's choice (assessed in the "Demographics/Academics" section of the questionnaire) reflects his/her vocational preference. As to the previous year academic failure in most courses (7th question on the "Demographics/ Academics" part of the questionnaire), in many Portuguese faculties and universities, students may pass or fail a curricular year (or grade) at the university level, just as they can at the high-school level. Undergraduate programs are structured in academic years (two semesters) in such a way that each course is matched to a given curricular year. To obtain approval (pass) in any single course, the student must attain a final mark of ≥10 points on a 20-point scale (<10 points, the student fails that course). Each individual course corresponds to a certain number of credits. Universities and faculties establish a minimum number of credits/ curricular year that students must obtain by passing courses in order to proceed (pass) to the subsequent curricular year. When a student fails more than half the courses in a given academic year, he/she does not obtain enough credits. Consequently, he/she remains, technically, in the same curricular year and must repeat the failed courses. Herein, we term this situation "previous year failure in most courses."

- *Current academic engagement* variables include class attendance (rated on a 5-point scale, cf. item 34 in Appendix), and study time (h/wk, cf. item 32 in Appendix).
- *Lifestyle and substance usage* variables include (cf. items 26–31 and 33 in Appendix) exercise (h/wk), other extracurricular activities (h/wk), night outings (frequency), cigarette use (weighted mean = [units/ week day × 5 + units/weekend day × 2]/7 days), alcohol consumption (weighted mean = [units/week day × 5 + units/weekend day × 2]/7 days), coffee consumption (weighted mean = [units/week day × 5 + units/ weekend day × 2]/7 days), and consumption of other substances (frequency).
- *Daytime subjective well-being* variables include vigor, mood/anxiety complaints, cognitive functioning, and daytime somnolence (Manber et al., 1996). The first three indices resulted from a factor analysis of 14 items asking how the student felt during the day, with each item rated from 0 to 4 or 4 to 0, as appropriate (cf. items 19a to 19n in Appendix). The selected method was a principal component analysis with varimax rotation for components with eigenvalues ≥1.0. A three-factor solution was found, explaining 55.99% of the total variance. Factor 1 items (active, energetic, efficient, alert, happy, relaxed) corresponded to vigor and accounted for 23.01% of the variance. Factor 2 items (tired, irritable, depressed, nervous) corresponded to mood/anxiety complaints and accounted for 17.63% of the variance. Factor 3 items (productive, attentive, motivated, difficulty concentrating) corresponded to cognitive functioning and accounted for 15.35% of the variance. The Cronbach α values were 0.77, 0.74, and 0.73, respectively, indicating good internal consistency of each factor. The daytime somnolence index consisted of 5 items adapted from Manber et al. (1996), plus 1 item about somnolence during class (items 18a to 18e and 18f in Appendix). Cronbach α was 0.84.
- *Neuroticism* was measured by our neuroticism factor of the EPI-12 item version.
- *Sleep quantity* variables include perceived (in)sufficient sleep using a frequency scale (cf. item 14 in Appendix).
- *Sleep quality* variables include 7 items, each rated from 0 to 4 or 4 to 0, as appropriate, covering sleep-onset, early and night awakenings, perceived sleep depth, and quality of sleep (cf. items 4–8 plus 15a and 15b in Appendix). A sleep quality index was obtained through summation of these items. Higher scores equate to poorer sleep quality. The internal consistency was good as indicated by the Cronbach α = 0.73.
- *Sleep phase/chronotype* variables include sleep phase during weeknights, sleep phase during weekend nights, and morningness-eveningness as expressed by the CMQ total score. Each sleep phase variable was determined as a mid-sleep point expressed in hours and minutes, according to the specified formulas [weeknights mid-sleep = bedtime on weeknights + (time in bed on weeknights/2) and weekend nights mid-sleep = bedtime on weekends + (time in bed on weekends/2)], where time in bed was the time interval between bedtime and rise time (either on weeknights or on weekends, as appropriate).
- *Sleep irregularity* variables include bedtime irregularity during the school week, rise-time irregularity during the school week (cf. items 9 and 13 in Appendix), and week/weekend sleep-phase irregularity (difference between week and weekend night sleep phases, expressed in hours and minutes).

Academic Performance Measures

a. *Self-report measures*: Three academic achievement items were included in the sleep-wake questionnaire. Previous GPA and academic failure of most courses during the previous curricular year were previously described. In addition, we also considered it important to assess the subjective impact of sleep on academic performance as perceived by each student through the following question: "Do you feel your sleep patterns have been negatively influencing your academic performance at the university?" (cf. item 36 in Appendix).

b. *Objective prospective measure*: This measure consisted of the final mark obtained by each student at the end of the semester as shown in the university records. Specifically, for each undergraduate degree program, we selected one course per year (the most representative and relevant). For instance, for all participants in the 1st year of the mathematics degree program (n = 43), we collected the final marks received in the Mathematical Analysis II course; for all participants studying in the 3rd year of the biology degree program (n = 72), the end-of-semester marks obtained in the Genetics course were collected. The end-of-semester classification of the student in a given course, on a 0- to 20-point scale, represents a weighted mean score of a certain number of tasks, i.e., assignments and written examinations. The assessment tasks are defined by each professor in agreement with university rules. To enable combination and comparison among marks between different courses, within each given course raw classifications were transformed into standardized z values.

Procedures

The research project was approved by the department and university scientific councils, which were the local sanctioning boards of the university, and conformed to international ethical standards as described in Portaluppi et al. (2010) for biological rhythm research.

A teacher from each university year and selected degree program was approached, and the voluntary nature and the general format of the research were explained. With the approval of the teachers and the consent of the students, the questionnaires were completed at the end of the class sessions. It was emphasized that participation was voluntary, and confidentiality was assured. The aims of the study were briefly explained in the beginning of the questionnaire and were also orally explained to the students by the principal researcher, who was present in all sessions.

To assess the typical sleep-wake patterns of the students when they must attend classes, the survey was conducted in the middle of the semesters, at least 1 mo after the beginning of the classes. Data collection was carefully planned so events that could potentially influence sleep-wake patterns, e.g., holidays and student festivities, were excluded. All questionnaires were collected after 12:00 h to avert underrepresentation of evening-type students in the sample. Participation rate, determined by the difference between the number of questionnaires distributed (2018) and number of questionnaires returned (1819), was 90.1%. From the questionnaires collected, a total of 165 were excluded due to missing answers on key questions, i.e., sleep-wake schedules and sleep durations (33 participants); atypical cases or circumstances, e.g., pregnancy (4 participants); age >25 years (61 participants); having children (5 participants); non-full-time student, i.e., students with part- or full-time jobs, elite athlete students, and those involved in University Student Union activities (62 participants). A final classification for each participant was obtained through university records at the end of the semester.

Data Analyses

First, associations between each sleep pattern and academic performance measures were examined. t tests for independent samples were used to compare mean values on sleep patterns between students who passed versus students who failed the previous curricular year. Mean values for each variable were compared between sleep groups for the remaining academic achievement measures, previous GPA, subjective detrimental effect of sleep on academic performance, and end-of-semester marks. First, following Neale and Libert's (1986) recommendations, for each sleep variable three to four (as appropriate) nonextreme groups of similar size were formed based on quartiles or frequencies. Then, academic performance mean values were determined for each sleep group and compared by analysis of variance (ANOVA). End-of-semester raw classifications in all analyses were converted to standardized z scores to enable combination and comparability among marks from different courses.

Second, considering the entire set of potential predictors of academic performance, the main predictors for end-of-semester marks were identified through multiple regression analysis using the stepwise method to select the most relevant variables:

1. The normality assumption was checked for numeric variables. For variables not showing normal distribution, data were transformed to approximate a Gaussian curve ($\log_{10}$ transformations were used to correct for skewed distributions).
2. A correlation matrix was examined to select potential predictors and avoid multicollinearity; whenever nominal variables were involved, we used other magnitude of association measures instead of correlation coefficients, e.g., η.
   - Variables showing nonsignificant associations with z scores were excluded.
   - Among variables significantly associated with z scores, redundant variables were also removed; for each set of interrelated variables, the rule was to retain the variable showing the highest correlation coefficient with z scores. In addition, a collinearity diagnosis of the model was made, and independence was assumed if the following criteria were met: variance inflation factor [VIF] <2, tolerance values distant from 0, Durbin Watson statistic $\sim$2, condition index <15.
3. The stepwise regression analysis was conducted, entering as potential predictors only those variables showing significant associations with marks in univariate analyses and with minimal redundancy

among each other. The criterion variable was the *z* scores. The rule to enter or remove a variable was $p \leq .05$ and $p \geq .10$ (SPSS default option). As to missing values, listwise deletion was used (Afifi et al., 2004). Eight outliers were detected and excluded from the database for the regression analysis. An additional multiple regression analysis was conducted to test for neuroticism moderator effects. To represent the relevant interactions, variables were first centered and then multiplied together.

A total of 1240 participants were included in the regression analysis, i.e., 75% of the initial sample (n = 1654). These 1240 were comparable to the total sample with respect to sex, age, curricular year, academic domain, and residency status. A total of 406 subjects were excluded from the analysis due to missing data in any of the potential predictors or in the criterion variable. These 406 students were similar to the remaining 1240 for academic field and residency situation, but were older (M = 20.47, SD = 1.77 vs. M = 19.82, SD = 1.59; *t* test, $p < .05$) and men were overrepresented (49.8% in the excluded group vs. 43.2% in the sample group; χ^2 test, $p < .05$).

RESULTS

Sleep and Multi-measures of Academic Achievement

Sleep and Previous Academic Failure (Failed Most Courses in the Last Year)

Compared to those who passed (88.9%, n = 1457), students who failed most of their courses in the preceding curricular year (11.1%, n = 182) displayed current later phases of the sleep-wake cycle, both on weeknights ($t_{1637} = 7.12$, $p < .0001$) and on weekends ($t_{1637} = 3.45$, $p < .0001$), higher eveningness orientation (i.e., lower morningness scores on the CMQ, $t_{1637} = 3.92$, $p < .0001$), and greater rise-time variation during the week ($t_{1607} = 3.01$, $p < .01$). This pattern of results was also evident when examining per sleep group the percentage of students who had failed most courses (Table 1).

Prior GPA by Sleep Group

From eveningness to morningness chronotype tendency groups ($F = 5.511$, $p < .001$) and across groups of students showing progressively lower rise-time oscillations during the week ($F = 3.185$, $p < .05$), there was increased improvement in past academic achievement grades. Previous GPAs were also found to be higher in groups with earlier sleep-wake phases during the school week ($F = 14.760$, $p < .0001$), and in groups reporting better sleep quality ($F = 2.710$, $p < .05$), as shown in Table 1.

Perceived Impact of Sleep on Academic Performance

Across groups showing progressively later sleep-wake phases on weeknights ($F = 17.115$, $p < .0001$) and on weekends ($F = 4.247$, $p < .01$), lower morningness scores ($F = 23.284$, $p < .0001$), lower frequency of enough sleep ($F = 91.141$, $p < .0001$), poorer sleep quality ($F = 19.699$, $p < .0001$), and greater bedtime ($F = 11.936$, $p < .0001$) and rise-time ($F = 10.853$, $p < .0001$) oscillations during the week, there was an increase in mean values for the perception that sleep patterns have had a negative impact on university academic performance (Table 1).

End-of-Semester Marks by Sleep Group

Students of sleep groups who achieved higher marks (mean *z* scores) at the end of the semester (Table 1) were those who reported earlier sleep phases during the week ($F = 5.335$, $p < .001$) and on weekends ($F = 4.649$, $p < .01$), higher morningness scores ($F = 3.486$, $p < .05$), more stable bedtime schedules during the week ($F = 3.240$, $p < 0.05$), better sleep quality ($F = 3.722$, $p < .05$), and higher frequency of enough sleep ($F = 3.689$, $p < .05$).

Main Predictors of End-of-Semester Marks: Stepwise Multiple Regression

After identifying through ANOVA those sleep variables significantly associated with end-of-semester marks, we then sought to determine whether or not any sleep pattern would be selected as a main predictor of academic performance when considered concurrently with other potential predictors of academic performance in a stepwise multiple regression analysis. From a total of 30 variables initially considered to possibly be associated with university marks (covering demographic, neuroticism, lifestyle, well-being, academic, and sleep domains), a preliminary univariate analysis found 19 significantly related to *z* scores ($p < .05$). Nonsignificant associations were found for 11 variables (sex, residential status, curricular year, academic field, passing or failing most courses the previous year, exercise, other extracurricular activities, mood/anxiety complaints, neuroticism, and, as already reported, rise-time irregularity during the school week and week/weekend sleep-phase irregularity). From these 19 variables significantly associated with *z* scores, 4 (vigor, daytime somnolence, sleep phase on weeknights, QCM total score) were removed from the analysis to avert multicollinearity with similar variables, thus assuring independence among potential predictors. The intent was to identify, within each group of interrelated variables, the variable with the strongest association with *z* scores. Thus, 15 potential predictors were entered in the stepwise regression analysis. Descriptive statistics for the potential predictors and for *z* scores (criterion variable) are shown in Table 2. From the 15 variables included in the model, stepwise regression yielded 5 that were significant predictors of marks, explaining 14% of the variance of the *z* scores ($R^2 = 0.14$, adjusted $R^2 = 0.14$; $F(5, 1234) = 40.99$, $p < .0001$; Table 3). The most important predictor of *z* scores was previous academic achievement, followed by class attendance. The third predictor was the frequency of enough sleep. Night outings and sleep quality were the last of the five significant predictors. Moreover, the selected predictors showed associations

TABLE 1. Academic achievement measures across sleep groups

		Failed most courses (%)	Previous GPA[a](M)	Negative impact of sleep over performance[b](M)	End-of-semester marks[c](M)
Sleep Quality Index	Very Good	10.4	3.43	1.55	0.13
	Good	9.8	3.28	1.74	−0.05
	Poor	13.2	3.30	1.70	−0.04
	Very Poor	11.0	3.29	2.10	−0.08
		NS	<0.05	<0.0001	<0.05
Enough sleep (frequency)	Never + Rarely	11.2	3.27	2.28	−0.05
	1–2 nights/wk	10.5	3.34	2.02	−0.09
	3–4 nights/wk	12.4	3.27	1.71	−0.02
	Almost all nights/always	10.3	3.42	1.15	0.14
		NS	NS	<0.0001	<0.05
CMQ	Morningness tendency	7.6	3.49	1.50	0.14
	Intermediate—toward morning	9.4	3.34	1.62	0.00
	Intermediate—toward evening	13.1	3.27	1.83	−0.06
	Eveningness tendency	14.3	3.24	2.07	−0.08
		<0.0001	<0.001	<0.0001	<0.05
Sleep phase on week nights	<03:56 h	5.3	3.51	1.61	0.11
	03:56 to 04:25 h	9.2	3.46	1.62	0.09
	04:26 to 05:00 h	9.3	3.16	1.74	−0.13
	>05:00 h	21.7	3.20	2.09	−0.09
		<0.0001	<0.0001	<0.0001	<0.001
Sleep phase on weekend nights	<05:15 h	7.9	3.44	1.68	0.13
	05:15 to 06:00 h	9.1	3.30	1.68	0.05
	06:01 to 07:00 h	12.2	3.30	1.79	−0.10
	>07:00 h	16.4	3.29	1.92	−0.11
		<0.0001	NS	<0.01	<0.01
Week-weekend sleep-phase displacement	<1h	12.7	3.33	1.81	0.09
	1h–1h30	11.2	3.30	1.76	0.02
	1h31–2h15	10.3	3.33	1.71	−0.01
	>2h15	10.3	3.37	1.75	−0.09
		NS	NS	NS	NS
Bedtime oscillation along the school week	≤1h	10.8	3.34	1.58	0.09
	1h01–2h	10.6	3.32	1.85	−0.03
	>2h	12.3	3.33	1.86	−0.07
		NS	NS	<0.0001	<0.05
Rise-time oscillation along the school week	<1h	8.5	3.41	1.62	0.07
	1h–1h59	9.4	3.32	1.74	−0.01
	≥2h	15.8	3.26	1.92	−0.07
		<0.01	<0.05	<0.0001	NS

[a]Expressed in a 6-point scale: ≤10 points [coded as 1]; >10–11 points [coded as 2]; 12–13 points [coded as 3]; 14–15 points [coded as 4]; 16–17 points [coded as 5]; ≥18 points [coded as 6].
[b]Assessed through a 5-point scale, coded from 0 = "strongly disagree" to 4 = "strongly agree."[c]Transformed into standardized z scores. M = mean values. NS = not significant ($p > 0.05$).

with z scores in the expected directions. Thus, higher (lower) previous GPA, higher (lower) class attendance, higher (lower) frequency of enough sleep, lower (higher) frequency of night outings, and better (worse) sleep quality during the semester were associated with an increase (decrease) in end-of-semester marks as expressed by z scores.

Associations of the remaining sleep, academic, well-being, and lifestyle variables e.g., (time devoted to study, alcohol consumption, cognitive functioning) with academic achievement lost significance in the stepwise regression. Of the four sleep variables entered in the analysis, two—sleep quality and enough sleep—remained significantly associated with end-of-semester grades in the presence of other significant predictors, thus adding an independent contribution to grades. The other two sleep variables introduced in the analysis, sleep phase and regularity of sleep schedules, lost significance in a stepwise regression after controlling for the influence of previous academic results, class attendance, night outings, sleep amount, and sleep quality.

Finally, to ascertain whether neuroticism interacts with the two selected sleep variables in predicting end-of-semester marks, another multiple regression

TABLE 2. Descriptive statistics for the variables in the regression analyses—*z* scores (criterion variable) and potential predictors (n = 1240*)

Variable	M	SD	Min	Max
z scores	0.03	0.97	−2.73	3.06
Age	19.82	1.58	17	25
Vocational preferences match (1st, 2nd, 3rd, etc.)	1.45	0.73	1	3
Previous academic achievement (self-reported GPA)	3.41	0.96	1	6
Class attendance—transf. [$\log_{10}$]	0.18	0.24	0	0.70
Study h/wk—transf. [$\log_{10}$]	0.86	0.31	0	1.75
Cognitive functioning	9.56	2.46	0	16
Night outings (past midnight)	2.38	1.25	0	5
Cigarettes—transf. [$\log_{10}$]	0.16	0.35	0	1.43
Coffee—transf. [$\log_{10}$]	0.22	0.21	0	0.78
Alcohol—transf. [$\log_{10}$]	0.12	0.20	0	1.11
Other substances—transf. [$\log_{10}$]	0.06	0.15	0	0.70
Enough sleep (frequency)	2.56	1.12	0	4
Sleep Quality Index (7 items)	8.75	3.92	0	24
Weekend sleep phase	6:05	1h21	1:15	12:00
Bedtime irregularity along the school week	1h58	1h24	0h	9h

*Excluding 8 outliers and participants with missing data for 1 of the 16 variables (listwise deletion).

TABLE 3. Significant predictors of *z* scores selected through stepwise regression

					Change statistics			
Model (variables added at each step)	*R*	R^2	Adjusted R^2	Standard error of the estimate	R^2	*F*	*df*	*p*
1. Previous GPA	0.307	0.094	0.093	0.926	0.094	128.572	(1, 1238)	<0.001
2. Class attendance*	0.362	0.131	0.130	0.908	0.037	52.849	(1, 1237)	<0.001
3. Enough sleep (frequency)	0.369	0.136	0.134	0.905	0.005	6.814	(1, 1236)	0.009
4. Night outings	0.373	0.139	0.137	0.904	0.003	4.825	(1, 1235)	0.028
5. Sleep Quality Index	0.377	0.142	0.139	0.903	0.003	4.475	(1, 1234)	0.035

Constant included. Criterion variable: *z* scores. Durbin-Watson: 1.852. Condition Index = 14.270. Collinearity statistics for each predictor: tolerance values > 0.89, VIF < 1.1. *Transf. $\log_{10}$.

was conducted by entering the five predictors found plus neuroticism and its interactions with sleep quality and enough sleep. To represent the interactions between sleep quality or enough sleep and neuroticism, the variables were first centered and then multiplied together. The main effects for the five predictors previously selected by the stepwise regression analysis remained statistically significant, but the main effect of neuroticism was not significant ($p = .572$), and nor was its interaction with enough sleep ($p = .771$) or sleep quality ($p = .783$).

DISCUSSION

The present study examined associations between sleep patterns reported at the middle of the semester, self-reported performance measures, and, most importantly, subsequent academic achievement (end-of-semester marks) in relation to demographics, well-being, and academic and lifestyle variables in a sample of undergraduates. Four sleep aspects were considered: quantity, quality, regularity, and phase/schedule.

Our results with respect to the impact of *adequate sleep duration* on end-of-semester marks are in line with the findings of other naturalistic correlational investigations (Oginska & Pokorski, 2006), as well as with those of controlled studies, indicating that cumulative sleep debt (Van Dongen et al., 2003a), even in apparently small amounts and in healthy young adults, is associated with a variety of undesirable consequences (Banks & Dinges, 2007; Pilcher & Huffcutt, 1996; Spiegel et al., 1999; Van Dongen et al., 2003a, 2003b). For example, Banks and Dinges (2007) found that across nights of partial sleep deprivation, i.e., 14 nights with 6 h of sleep/night, the accumulation of neurobehavioral deficits may achieve levels equivalent to those found after 1 to 3 nights of total sleep deprivation. If these findings of controlled studies hold true in real-life circumstances, it is then understandable that those students obtaining enough sleep more frequently achieve greater marks.

The association found in our sample between enough sleep and end-of-semester marks is also comparable to the results of similar correlational studies in undergraduates reporting decreased academic performance with shorter sleep duration (Borisenkov et al., 2010; Jean-Louis et al., 1996; Kelly et al., 2001; Medeiros et al., 2001; Trockel et al., 2000). Compared with these naturalistic studies, one contributing factor of our investigation is that rather than sleep length, per se, we have considered a measure of insufficient sleep, i.e., frequency of enough sleep. This seemed to be more in line with the notion of sleep debt in the sense of chronic sleep restriction (Van Dongen et al., 2003a).

Our findings on *sleep quality* are in agreement with previous studies showing associations between poor sleep, lower academic performance of university students (Gilbert & Weaver, 2010; Howel et al., 2004; Johns et al., 1976), and other aspects of daytime functioning impairment, e.g., subjective complaints such as increased feelings of depression, tension, and fatigue, not only in sleep clinical samples (AASM, 2005) but also in community samples of young adults (Alapin et al., 2000; Oginska & Pokorski, 2006; Pilcher & Ott, 1998; Pilcher et al., 1997). Because of the nonexistence of a European Portuguese version of the Pittsburgh Sleep Quality Index (PSQI; Buysse et al., 1989), we adopted another measure of sleep quality; however, it should be stressed that our sleep-quality items show similarities with some of the PSQI items. Similar results on the associations of both sleep length and sleep quality with academic achievement have also been reported for other age groups, including children, e.g., a recent meta-analytic review of Dewal et al. (2010). However, precaution is needed in generalizing the current findings to other age groups or educational levels (e.g., Kopasz et al., 2010; Pagel et al., 2007).

As to sleep *regularity*, several associations with self-reported academic performance emerged, and one significant association with end-of-semester marks was found by univariate analysis, but it lost significance in multiple regression analysis. Abrupt shifts of sleep-wake schedules lead to internal dissociation among circadian rhythms (Reinberg et al., 1989), which may be accompanied by complaints of somnolence, attention deficit, concentration difficulty, and performance decrement that are commonly found in shiftwork and rapid travel across multiple time zones (AASM, 2005). In undergraduates, irregularities of 2 to 4 h in the sleep-wake schedule are associated with increased fatigue, deterioration of mood, and lower performance (Taub & Berger, 1973), and irregular sleep-wake schedules of healthy students are associated with excessive daytime somnolence compared to regular colleagues (Manber et al., 1996). In our sample, sleeping enough and with good quality were more important in determining subsequent academic performance than maintaining a regular sleep-wake schedule, but no definitive conclusion should be drawn. It seems critical to further scrutinize the potential impact of irregularities of sleep-wake schedules in academic samples using longitudinal measures, such as 1-wk sleep logs or actigraphy, to assess irregularity (Medeiros et al., 2001), as this topic seems to be under investigated.

Each of the three variables used to measure *chronotype/sleep phase* in the present study showed significant relationships in univariate analysis with previous year academic failure in most courses, perceived influence of sleep in academic performance, and university marks, and all (but one) were associated with prior GPA. The literature consistently reports associations between undergraduate later sleep-wake schedules and lower academic performance (Beşoluk et al., 2011; Borisenkov et al., 2010; Elliason et al., 2010; Johns et al., 1976; Lack, 1986; Medeiros et al., 2001, 1996; Randler & French, 2006; Smith et al., 1989; Trockel et al., 2000). Nevertheless, the association between sleep phase and end-of-semester grades lost its significance in stepwise multiple regression after controlling for the effects of class attendance, previous academic achievement, night outings, sleep quantity, and sleep quality. Thus, the association between late sleep-wake schedules/phases and academic performance appears to be mediated by other variables, such as sleep restriction, which is more pronounced in evening-type students (Giannotti et al., 2002; Gomes et al., 2008; Taillard et al., 1999), and class attendance, which was already found to be lower in evening-tendency students (Gomes, 2006). Indeed, there are normal interindividual differences linked to the peak time (acrophases) of circadian rhythms, which manifests along a continuum from morning- to evening-type individuals, with a majority of intermediate persons between the two extremes (Kerkhof, 1985). These would be normal variations, but uniform work and school schedules do not consider these differences; thus, inconsistencies may arise between the individual preferred schedules and externally imposed time schedules, which may lead to several undesirable consequences, such as when an evening-type student is confronted with morning class schedules (Beşoluk et al., 2011; Giannotti et al., 2002).

As to *multiple regression analysis*, in our study, based on an initial pool of 30 demographic, academic, well-being, neuroticism, and sleep variables, a stepwise regression entering 15 potential predictors of academic achievement for university students led to the selection of 5 variables that remained significantly associated with marks. Two were sleep variables, sleep quantity and sleep quality. These two sleep variables added a small, but independent and significant, contribution to university grades beyond previous academic achievement and class attendance. This low contribution may lead to a questioning of their pertinence, and it may be argued that significant associations emerged only by chance or because of large sample size. Although this might be true, both objections would also apply to any one of the other variables considered. Furthermore, these two sleep variables were better predictors of school achievement than other potential predictors, such as time devoted to study, subjective cognitive functioning, or vocational preferences. Using a stepwise regression method, which tends to select a relatively small number of predictors (Afifi et al., 2004), and considering the 15 potential predictors of academic results, two of the four sleep variables emerged in the group of the five selected significant predictors of student performance, whereas other apparently logical predictors of academic achievement lost significance and were not selected for the main group. In addition, no evidence was found that neuroticism moderates or influences the impact of sleep variables on end-of-semester marks. In conclusion, the results of our regression analysis study found that in students with similar previous academic achievement and class attendance, both sleep quantity and sleep quality may influence academic results in such a way that sleep reduction or poor-quality sleep may be associated with decreased academic performance.

The current results are in line with controlled studies cited at the beginning of our paper, showing consistent associations between sleep and a set of cognitive activities, memory in particular. Our results are also consistent with the review paper on sleep and academic performance by Curcio et al. (2006), who concluded that, as both REM and NREM sleep stages appear to be necessary for learning and memory, sleep loss and sleep fragmentation constitute a risk for efficient consolidation of declarative and procedural knowledge and skills. In light of this conclusion, it is understandable that sleep restriction and poor-quality sleep may impact academic performance of undergraduates.

It is interesting to note that the best predictors of end-of-semester marks were previous academic achievement and class attendance, in close agreement with findings reported in the literature. In fact, several studies found that student academic achievement prior to postsecondary education, e.g., high-school GPA (Robins et al., 2004) and admission tests (Kuncel et al., 2010; Sackett et al., 2009; Trapmann et al., 2007), is related, to a lesser or greater extent, with subsequent outcomes in college. As to class attendance, a recent meta-analytic review concluded that it explains a large degree of unique variance in college grades, superior to other known predictors of academic performance (Credé et al., 2010). However, to date, surprisingly few studies, if any, interested in the impact of sleep/biological rhythms on academic performance have considered this variable.

The present study has several further important strengths: (i) it encompasses a large sample of undergraduates from a variety of academic fields (engineering, exact and natural sciences, languages, education, and management) that may be found in universities all over the world; thus, our results have the potential to be extrapolated to other universities and countries; (ii) the sample represented in a balanced way both sexes and three academic years; (iii) the study was conducted in a single university; thus, all students were subjected to identical class timings, examination schedules, and school-year calendar; (iv) in line with expert recommendations (Curcio et al., 2006; Wolfson & Carskadon, 2003), several measures of academic achievement were collected (multimeasure approach) and were not limited to self-reported data; (v) the study included a longitudinal analysis of the relationship between sleep patterns and end-of-semester academic marks; therefore, although the nonexperimental nature of the present research does not allow for the extraction of causal inferences, we can be sure about the temporal sequence of the relationships found; (vi) a multivariable approach was adopted; that is, besides sleep patterns, a variety of other variables that might explain academic performance of university students was considered, which helped to better assess the relative impact of sleep on academic performance in real-life circumstances.

Certain limitations of the present work should be mentioned. First, we were unable to control for the time-of-day of the assessment tasks and written examinations. In addition, our study, like others in the field of sleep and biological rhythms, did not cover all of the possible relevant variables that could be related to academic performance. Some important variables not considered by us, but currently known to predict academic performance, were conscientiousness personality dimension, which is a strong predictor of postsecondary academic achievement (Kuncel et al., 2010; O'Connor & Paunonen, 2007; Trapmann et al., 2007); achievement motivation, the strongest predictor of GPA in the meta-analysis of Robins et al. (2004); and academic self-efficacy (Ferla et al., 2009; Robins et al., 2004). Furthermore, the present study did not control for socioeconomic status (SES) even though Pagel et al. (2007) reported that the number and type of sleep variables affecting the GPA of adolescents changed after statistically controlling for age and household income. On the other hand, SES is likely to be somewhat restricted in range in university samples. Furthermore, in our study, the most important predictor of end-of-semester marks was previous academic achievement, which is also supposed to have been influenced by SES (Robbins et al., 2004; Sackett et al., 2009). Therefore, as prior academic achievement was included in our final regression model, we believe that, indirectly, the effect of SES is not completely absent from our results regarding end-of-semester marks. We also did not control for mental or other medical disorders that might influence both sleep and academic outcomes. However, our study considered neuroticism, which has been reported to be strongly correlated with several mental disorders, especially mood disorders, eating disorders, somatoform disorders, anxiety disorders, and schizophrenia (Lahey, 2009). Furthermore, in our study, the associations between lower academic performance, poor sleep quality, and sleep debt were not moderated by neuroticism. In particular, we did not control for sleep disorders, such as sleep apnea, delayed sleep phase syndrome, or narcolepsy (AASM, 2005), commonly detected for the first time in this age group. We did not control either for medication use (other than medication to promote sleep), nor for its possible effects. Even though we measured daytime sleepiness, the present study did not fully explore the role of this variable over academic performance; however, a very recent meta-analytic review highlights the need to treat sleep duration, sleep quality, and sleepiness as separate variables in future research (Dewald et al., 2010). Although this review was based on child and adolescent sleep literature, we believe future studies on undergraduates should follow this recommendation. Despite its limitations, to date our study seems to be one of the most comprehensive within the biological rhythm and sleep research fields, combining an interesting set of different variables, two of which, class attendance and previous academic achievement, were identified in meta-analyses as among the most consistent predictors of academic achievement (e.g., respectively, Credé et al., 2010; Robins et al., 2004). Considering feasibility, the use of a self-response questionnaire was a perfectly adequate tool to collect data on sleep patterns from a large sample at the same point-in-time, but the limitations of this kind of instrument are well known. Thus, ideally, self-report measures of sleep should be complemented by more objective measures, such as actigraphy or polysomnography. In the present research, due to university restrictions for accessing student records, only one mark per participant was collected at the end of semester, which may not be necessarily representative of the student's usual performance. This limitation could explain the overall small percentage of variance found in stepwise regression analyses. Another potential reason for the relatively small variance is likely a consequence of the longitudinal design adopted. As we examined the prospective relationships among sleep, academic performance, and life-style variables (measured in the middle of the school semester) with subsequent academic performance (end-of-semester marks), changes in the variables studied between the two points-in-time (middle of semester and end of semester) might have occurred, or other variables that were not controlled by the researchers might have intruded and impacted end-of-semester achievement. In summary, the significance of the relative contribution of each sleep variable should be weighed, bearing in mind the inherently noisy nature of academic performance in real-life circumstances.

In conclusion, adequate sleep with respect to quantity, quality, and timing is likely associated with better marks for university students. Our results have several implications. In particular, sleep education should be incorporated into existing prevention programs to promote student health and academic success.

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APPENDIX

Sleep-Wake Questionnaire for University Students [SWQUS] - «during-the-semester» version

* Sex: ☐ Female. ☐ Male. *Age: ____ yr-old
* Do you have children? ☐ Yes. ☐ No.
* Undergraduate degree: _____________. *Curricular year: _____.
* Your current major was your… ☐ first ☐ second ☐ third or other … choice
* In the last year, have you completed enough course credits to progress to a new curricular year?
☐ Yes. ☐ No, I have failed most courses.
* What is your student status? ☐ full-time student; ☐ part-time student due to part-/full-time job; ☐ elite athlete student; ☐ student union delegate/representative
* Please indicate the town where you live…
… during the school week: __________ … and on weekends / holidays: ___________

<u>I. SLEEP-WAKE CYCLE DURING THE SEMESTER</u>
<u>Last Month</u>
Please consider <u>the last month</u>, keeping in mind what usually happens <u>in a typical class week.</u>
* 1. In a typical class week, at what time do you usually…
… go to bed? (on average) ___ h ___ min
…get up? (on average) ___ h ___ min
* 2. On weekends, during the semester, at what time do you usually
… go to bed? (on average) ___ h ___ min
… get up? (on average) ___ h ___ min

* 3. During the school week, does your bedtime change from night to night?
☐ Not at all ☐ Yes: it varies between ___ h ___ and ___ h ___
* 4. After going to bed, you usually fall asleep within ...
☐ 1-14 min ☐ 15-30 min ☐ 31-45 min ☐ 46-60 min ☐ more than 60 min
* 5. How often do you have trouble falling asleep?
☐ never ☐ rarely ☐ sometimes ☐ 3-4 nights a week ☐ almost every night/always
* 6. How many times do you usually wake up during a night's sleep?
☐ none ☐ once ☐ 2-3 times per night ☐ 4-5 times per night ☐ 6 times or more
* 7. How often do you wake up spontaneously much earlier than needed (i.e., much earlier than your planned waking time)?
☐ never ☐ rarely ☐ sometimes ☐ 3-4 nights a week ☐ almost every night/always
* 8. Are nocturnal or early morning awakenings a problem for you?
☐ not at all ☐ a bit ☐ somewhat ☐ often ☐ very often
* 9. During the school week, does your wake-up time change from day to day?
☐ Not at all ☐ Yes, it varies between ___ h ___ and ___ h ___
10. After waking up, you usually get up within ...
☐ 1-14 min ☐ 15-30 min ☐ 31-45 min ☐ 46-60 min ☐ more than 60 min
11. During the semester, how many hours per night do you usually sleep on weekends?
☐ 4h or less ☐ 4-5h ☐ 5-6h ☐ 6-7h ☐ 7-8h ☐ 8-9h ☐ 9-10h ☐ 10-11h ☐ 11h or more
12. In a typical class week, how many hours per night do you usually sleep?
☐ 4h or less ☐ 4-5h ☐ 5-6h ☐ 6-7h ☐ 7-8h ☐ 8-9h ☐ 9-10h ☐ 10-11h ☐ 11h or more
13. During a typical week of classes, does your sleep duration change from night to night?
☐ Not at all ☐ Yes, it varies between ___ h ___ and ___ h ___
* 14. In a typical week during the semester, how often do you get the sleep hours you need?
☐ never ☐ rarely ☐ 1-2 nights a week ☐ 3-4 nights a week ☐ almost every night/always
* 15. Regardless of its duration, how would you describe your...
[15.a] ... sleep quality? ☐ very poor ☐ poor ☐ fair ☐ good ☐ very good
[15.b] .. sleep depth? ☐ very light ☐ light ☐ fairly deep ☐ deep ☐ very deep
16. Do you use medication to promote sleep?
☐ never ☐ rarely ☐ sometimes ☐ often ☐ almost every night/always
17. Do you take naps?
☐ never ☐ rarely ☐ sometimes ☐ several times a week ☐ almost always/always
* 18. Usually, during the day:
a) [...] §
b) [...] §
c) [...] §
d) [...] §
e) [...] §
(§ items on daytime somnolence, each rated in a five-point Likert scale, from Manber et al., 1996)
f) How often do you feel excessively somnolent/sleepy during classes?
☐ never ☐ rarely ☐ sometimes ☐ often ☐ very often/always
*19.

	Not at all	A bit	Somewhat	Much	Very much
a) Energetic	☐	☐	☐	☐	☐
b) Tired	☐	☐	☐	☐	☐
c) Irritable	☐	☐	☐	☐	☐
d) Alert	☐	☐	☐	☐	☐
e) Depressed	☐	☐	☐	☐	☐
f) Nervous	☐	☐	☐	☐	☐
g) Happy	☐	☐	☐	☐	☐
h) Productive	☐	☐	☐	☐	☐
i) Relaxed	☐	☐	☐	☐	☐
j) Efficient	☐	☐	☐	☐	☐
k) Attentive	☐	☐	☐	☐	☐
l) Motivated	☐	☐	☐	☐	☐
m) Active	☐	☐	☐	☐	☐
n) Having difficulties concentrating	☐	☐	☐	☐	☐

Other Sleep Aspects
20. How many hours of sleep per night do you need to feel well?
☐ 4h or less ☐ 4-5h ☐ 5-6h ☐ 6-7h ☐ 7-8h ☐ 8-9h ☐ 9-10h ☐ 10-11h ☐ 11h or more
21. Did your sleep habits change at the university in comparison to high school?
☐ not at all ☐ a bit ☐ somewhat ☐ much ☐ very much
22. In your opinion, do you have any sleep problems?
☐ No ☐ Yes – Please describe: ________________________________
23. This academic year, did you ever stay awake all night to complete academic tasks?
☐ No ☐ Yes – Please specify how many sleepless nights: _____
24. This academic year, did you ever stay awake all night due to other reasons?
☐ No ☐ Yes – Please specify how many sleepless nights: _____
25. With respect to the place where you sleep most of the time when you are at the university:
a) Do you share your sleeping room with someone else?
☐ No ☐ Yes – specify (e.g., colleague; brother): ______
b) Is your sleep disturbed…
… by noise? ☐ not at all ☐ a bit ☐ somewhat ☐ much ☐ very much
… by your roommate? ☐ not at all ☐ a bit ☐ somewhat ☐ much ☐ very much ☐ not applicable

II. WAKING LIFE
* 26. How many cigarettes do you smoke per day (on average)? Week days: _____ Weekends: _____
* 27. How many glasses of alcoholic beverages do you drink per day (on average)? Week days: ____ Weekends: _____
* 28. How many cups of coffee do you have per day (on average)? Week days: _____ Weekends: _____
* 29. How often do you use other substances?
☐ never ☐ rarely ☐ sometimes ☐ often/many times ☐ very often/always
* 30. How many hours a week do you exercise (on average)? ____
* 31. How many hours a week (on average) do you spend engaging in other extracurricular activities ? ____
* 32. During the class semester, how many hours a week (on average) do you spend studying? ____
* 33. How often do you go out at night (e.g., party, club, disco) until after midnight?
☐ almost never ☐ once a month ☐ 2-3 times per month ☐ 1-2 times a week ☐ 3-4 times a week ☐ almost always/every night
* 34. How many lectures do you attend (on average)?
☐ every or almost every lecture ☐ more than half ☐ half ☐ less than half ☐ almost none or none
* 35.For 2nd or 3rd year students: Indicate the answer that best describes your classifications at the university (0-20 scale), on average:
☐ 10 or less ☐ 10-11 ☐ 12-13 ☐ 14-15 ☐ 16-17 ☐ 18 or more
For 1st year students- Indicate your admission classification to the university (0-200):
☐ less than 100 ☐ 100-114 ☐ 115-134 ☐ 135-154 ☐ 155-174 ☐ 175 or higher
* 36. Do you feel your sleep patterns have been negatively influencing your academic performance at the university?
☐ strongly disagree ☐ disagree ☐ do not know/neither agree nor disagree ☐ agree ☐ strongly agree

REFERENCES

AASM (American Academy of Sleep Medicine). (2005). *ICSD—International Classification of Sleep Disorders, 2nd ed.: Diagnostic and coding manual*. Westchester, IL: AASM, 297 pp.

Afifi A, Clark VA, May S. (2004). *Computer-aided multivariate analysis*. 4th ed. Boca Raton, FL: Chapman & Hall/CRC, 489 pp.

Alapin I, Fichten CS, Libman E, Creti L, Bailes S, Wright J. (2000). How is good and poor sleep in older adults and college students related to daytime sleepiness, fatigue, and ability to concentrate? *J. Psychosom. Res.* 49:381–390.

Banks S, Dinges DF. (2007). Behavioral and physiological consequences of sleep restriction. *J. Clin. Sleep Med.* 3:519–528.

Barton J, Spelten E, Totterdell P, Smith L, Folkard S, Costa G. (1995). The Standard Shiftwork Index: a battery of questionnaires for assessing shiftwork-related problems. *Work Stress* 9:4–30.

Beşoluk S, Önder I, Deveci I. (2011). Morningness-eveningness preferences and academic achievement of university students. *Chronobiol. Int.* 28:118–125.

Blagrove M, Akehurst L. (2001). Personality and the modulation of effects of sleep loss on mood and cognition. *Pers. Individ. Dif.* 30:819–828.

Borisenkov MF, Perminova EV, Kosova AL. (2010). Chronotype, sleep length, and school achievement of 11- to 23-year-old students in northern European Russia. *Chronobiol. Int.* 27:1259–1270.

Bruni O, Antignani M, Innocenzi M, Ottaviano P, Ottaviano S. (1995). Influence of sleep and temperament on school achievement. *Sleep Res.* 24:91.

Buckhalt JA, Wolfson AR, El-Sheikh M. (2009). Children's sleep and school psychology practice. *Sch. Psychol. Q.* 24:60–69.

Buysse DJ, Reynolds CF 3rd, Monk TH, Berman SR, Kupfer DJ. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res.* 28:193–213.

Costa G, Sartori S, Facco P, Apostoli P. (2001). Health conditions of bus drivers in a 6 year follow up study. *J. Hum. Ergol.* 30:405–410.

Credé M, Roch SG, Kieszczynka UM. (2010). Class attendance in college: a meta-analytic review of the relationship of class attendance with grades and student characteristics. *Rev. Educ. Res.* 80:272–295.

Curcio G, Ferrara M, De Gennaro L. (2006). Sleep loss, learning capacity and academic performance. *Sleep Med. Rev*. 10:323–337.

Dewald JF, Meijer AM, Oort FJ, Kerkhof GA, Bögels SM. (2010). The influence of sleep quality, sleep duration and sleepiness on school performance in children and adolescents: a meta-analytic review. *Sleep Med. Rev.* 14:179–189.

Diekelmann S, Wilhelm I, Born J. (2009). The whats and whens of sleep-dependent memory consolidation. *Sleep Med. Rev.* 13:309–321.

Digdon NL, Howell AJ. (2008). College students who have an eveningness preference report lower self-control and greater procrastination. *Chronobiol. Int.* 25:1029–1046.

Dotto L. (1996). Sleep stages, memory and learning. *Can. Med. Assoc. J.* 154:1193–1196.

Eliasson AH, Lettieri CJ, Eliasson AH. (2010). Early to bed, early to rise! Sleep habits and academic performance in college students. *Sleep Breath.* 14:71–75.

Fafrowicz M, Oginska H, Mojsa-Kaja J, Marek T, Golonka K, Tucholska T. (2010). Chronic sleep deficit and performance of a sustained attention task—an electrooculography study. *Chronobiol. Int.* 934–944.

Ferla J, Valcke M, Cai Y. (2009). Academic self-efficacy and academic self-concept: reconsidering structural relationships. *Learn. Individ. Dif.* 19:499–505.

Ficca G. (2010). *Caveats and pitfalls for the use of psychological models in the study of sleep and memory* [text and handouts]. Sleep and Cognition Teaching Course, 20th Congress of the European Sleep Research Society, Lisbon, 14–16 September 2010.

Ficca G, Salzarulo P. (2004). What in sleep is for memory. *Sleep Med.* 5:225–230.

Ficker JH, Wiest GH, Lehnert G, Meyer M, Hahn EG. (1999). Are snoring medical students at risk of failing their exams? *Sleep* 22:205–209.

Fogel SM, Smith CT, Cote KA. (2007). Dissociable learning-dependent changes in REM and non-REM sleep in declarative and procedural memory systems. *Behav. Brain Res.* 180:48–61.

Giannotti F, Cortesi F. (2002). Sleep patterns and daytime functioning in adolescence: an epidemiological survey of an Italian high school student sample. Carskadon MA *Adolescent sleep patterns. Biological, social, and psychological influences*. United Kingdom: Cambridge University Press, pp. 132–147.

Giannotti F, Cortesi F, Sebastiani T, Ottaviano S. (2002). Circadian preference, sleep and daytime behaviour in adolescence. *J. Sleep Res.* 11:191–199.

Gilbert SP, Weaver CC. (2010). Sleep quality and academic performance in university students: a wake-up call for college psychologists. *J. Coll. Stud. Psychother.* 24:295–306.

Gomes ACA. (2006). Sono, sucesso académico e bem estar em estudantes universitários. [Sleep, well being and academic success in undergraduates]. PhD dissertation. University of Aveiro, Aveiro, Portugal.

Gomes AA, Tavares J, Azevedo MHP. (2002). Sleep-wake patterns and academic performance in university students. Paper presented at the European Conference on Educational Research, University of Lisbon, Accessed 19 March, 2009, from 11–14 September 2002. *Education-Line* [electronic database]. http://www.leeds.ac.uk/educol/documents/00002200.htm.

Gomes AA, Tavares J, Azevedo MHP. (2008). Morningness-eveningness in undergraduates: consequences over sleep-wake patterns. *Sleep* 31(abstract suppl.):A53.

Gray EK, Watson D. (2002). General and specific traits of personality and their relation to sleep and academic performance. *J. Pers.* 70:177–206.

Härmä M. (1993). Individual differences in tolerance to shiftwork: a review. *Ergonomics* 36:101–109.

Harrison Y, Horne JA. (1997). Sleep deprivation affects speech. *Sleep* 20:871–877.

Harrison Y, Horne JA. (1999). One night of sleep loss impairs innovative thinking and flexible decision making. *Organ. Behav. Hum. Decis. Process* 78:128–145.

Harrison Y, Horne JA. (2000). The impact of sleep deprivation on decision making: a review. *J. Exp. Psychol. Appl.* 6:236–249.

Hess B, Sherman MF, Goodman M. (2000). Eveningness predicts academic procrastination: the mediating role of neuroticism. *J. Social Behav. Pers.* 15:61–74.

Hofman WF, Steenhof L. (1997). Sleep characteristics of Dutch adolescents are related to school performance. *Sleep Wake Res.* 8:51–55.

Horne JA. (1988). Sleep loss and “divergent” thinking ability. *Sleep* 11:528–536.

Howell AJ, Jahrig JC, Powell RA. (2004). Sleep quality, sleep propensity and academic performance. *Percept. Mot. Skills* 99:525–535.

Jean-Louis G, von Gizycki H, Zizi F, Friedman K, Spielman AJ, Taylor D, Fullilove R, Taub H. (1996). Psychosocial determinants of sleepiness and performance: consideration of gender differences. *Sleep Res.* 25:101.

Johns MW, Dudley HA, Masterton JP. (1976). The sleep habits, personality and academic performance of medical students. *Med. Educ.* 10:158–162.

Kelly WE, Kelly KE, Clanton RC. (2001). The relationship between sleep length and grade-point average among college students. *Coll. Stud. J.* 35:84–86.

Kerkhof GA. (1985). Inter-individual differences in the human circadian system: a review. *Biol. Psychol.* 20:83–112.

Kopasz M, Loessl B, Hornyak M, Riemann D, Nissen C, Piosczyk H, Voderholzer U. (2010). Sleep and memory in healthy children and adolescents—a critical review. *Sleep Med. Rev.* 14:167–177.

Kuncel NR, Ones DS, Sackett PR. (2010). Individual differences as predictors of work, educational, and broad life outcomes. *Pers. Individ. Dif.* 49:331–336.

Lahey BB. (2009). Public health significance of neuroticism. *Am. Psychol.* 64:241–256.

Li D, Wu Z, Shao D, Liu S. (1991). The relationship of sleep to learning and memory. *Int. J. Ment. Health* 20:41–47.

Lim J, Dinges DF. (2010). A meta-analysis of the impact of short-term sleep deprivation on cognitive variables. *Psychol. Bull.* 136:375–389.

Manber R, Bootzin RR, Acebo C, Carskadon M. (1996). The effects of regularizating sleep-wake schedules on daytime sleepiness. *Sleep* 19:432–441.

Maquet P. (2001). The role of sleep in learning and memory. *Science* 294:1048–1052.

Medeiros ALD, Mendes DBF, Lima PF, Araujo JF. (2001). The relationships between sleep-wake cycle and academic performance in medical students. *Biol. Rhythm Res.* 32:263–270.

Meijer AM, Wittenboer GLH. (2004). The joint contribution of sleep, intelligence and motivation to school performance. *Pers. Indiv. Dif.* 37:95–106.

Neale JM, Liebert RM. (1986). *Science and behavior: an introduction to methods of research*. 3rd ed. Englewood Cliffs, NJ: Prentice-Hall, 324 pp.

O’Connor MC, Paunonen SV. (2007). Big Five personality predictors of post-secondary academic performance. *Pers. Indiv. Dif.* 43:971–990.

Oginska H, Pokorski J. (2006). Fatigue and mood correlates of sleep length in three age-social groups: school children, students, and employees. *Chronobiol. Int.* 23:1317–1328.

Pagel JF, Kwiatkowski CF. (2010). Sleep complaints affecting school performance at different educational levels. *Front. Neurol.* 1:125.

Pagel JF, Forister N, Kwiatkowski C. (2007). Adolescent sleep disturbance and school performance: the confounding variable of socioeconomics. *J. Clin. Sleep Med.* 3:19–23.

Pilcher JJ, Huffcutt AI. (1996). Effects of sleep deprivation on performance: a meta-analysis. *Sleep* 19:318–326.

Pilcher JJ, Ott ES. (1998). The relationships between sleep and measures of health and well-being in college students: a repeated measures approach. *Behav. Med.* 23:170–178.

Pilcher JJ, Ginter DR, Sadowsky B. (1997). Sleep quality versus sleep quantity: relationships between sleep and measures of health, well-being and sleepiness in college students. *J. Psychosom. Res.* 42:583–596.

Poropat AE. (2011). The Eysenckian personality factors and their correlations with academic performance. *Br. J. Educ. Psychol.* 81:41–58.

Portaluppi F, Smolensky MH, Touitou Y. (2010). Ethics and methods for biological rhythm research on animals and human beings. *Chronobiol. Int.* 27:1911–1929.

Randler C, French D. (2006). Correlation between morningness-eveningness and final school leaving exams. *Biol. Rhythm Res.* 37:233–239.

Ravid S, Afek I, Suraiya S, Shahar E, Pillar G. (2009). Sleep disturbances are associated with reduced school achievements in first-grade pupils. *Dev. Neuropsychol.* 34:574–587.

Reinberg A, Motohashi Y, Bourdeleau P, Touitou Y, Nouguier J, Nouguier J, Lévi F, Nicolaï A. (1989). Internal desynchronization of circadian rhythms and tolerance of shift work. *Chronobiologia* 16:21–34.

Robbins SB, Lauver K, Le H, Davis D, Langley R, Carlstrom A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychol. Bull.* 130:261–288.

Roberts RE, Roberts CR, Chen IG. (2001). Functioning of adolescents with symptoms of disturbed sleep. *J. Youth Adolesc.* 30:1–18.

Rodrigues RN, Viegas CA, Abreu E, Silva AA, Tavares P. (2002). Daytime sleepiness and academic performance in medical students. *Arq. Neuropsiquiatr.* 60:6–11.

Roehrs T, Roth T. (2000). Sleep-wake state and memory function. *Sleep* 23:564–568.

Roenneberg T, Kuehnle T, Pramstaller PP, Ricken J, Havel M, Guth A, Merrow M. (2004). A marker for the end of adolescence. *Curr. Biol.* 14: R1038–R1039.

Sackett PR, Kuncel NR, Arneson JJ, Cooper SR, Water SD. (2009). Does socioeconomic status explain the relationship between admissions tests and post-secondary academic performance? *Psychol. Bull.* 135:1–22.

Sadeh A, Gruber R, Raviv A. (2003). The effects of sleep restriction and extension on school-age children: what a difference an hour makes. *Child Dev.* 74:444–455.

Saksvik IB, Bjorvatn B, Hetland H, Sandal GM, Pallesen S. (2011). Individual differences in tolerance to shift work—a systematic review. *Sleep Med. Rev.* 15:221–235.

Silva CF, Azevedo MHP, Dias MRVC. (1995). Estudo padronizado do trabalho por turnos – versão portuguesa do SSI. *Psychologica* 13:27–36.

Singleton RA, Wolfson AR. (2009). Alcohol consumption, sleep, and academic performance among college students. *J. Stud. Alcohol Drug.* 70:355–363.

Smith C. (1995). Sleep states and memory processes. Special Issue: The function of sleep. *Behav. Brain Res.* 69:137–145.

Smith C. (2001). Sleep states and memory processes in humans: procedural versus declarative memory systems. *Sleep Med. Rev.* 5:491–506.

Smith CS, Reilly C, Midkiff K. (1989). Evaluation of three circadian rhythm questionnaires with suggestions for an improved measure of morningness. *J. Appl. Psychol.* 74:728–738.

Spiegel K, Leproult R, Van Cauter EV. (1999). Impact of sleep debt on metabolic and endocrine function. *Lancet* 354:1435–1439.

Stickgold R, Walker MP. (2007). Sleep-dependent memory consolidation and reconsolidation. *Sleep Med.* 8:331–343.

Stickgold R, Hobson JA, Fosse R, Fosse M. (2001). Sleep, learning and dreams: off-line memory reprocessing. *Science* 294:1052–1057.

Taillard J, Philip P, Bioulac B. (1999). Morningness/eveningness and the need for sleep. *J. Sleep Res.* 8:291–295.

Taub J, Berger R. (1973). Performance and mood following variations in the length and timing of sleep. *Psychobiology* 10:559–570.

Taub J, Berger R. (1976). The effects of changing phase and duration of sleep. *J. Exp. Psychol. Hum. Percept. Perform.* 2:30–41.

Taylor DJ, McFatter RM. (2003). Cognitive performance after sleep deprivation: does personality make a difference? *Pers. Indiv. Dif.* 33:1179–1193.

Trapmann S, Hell B, Hirn J-OW, Schuler H. (2007). Meta-analysis of the relationship between the Big Five and academic success at university. *J. Psychol.* 215:132–151.

Trockel MT, Barnes MD, Egget, DL. (2000). Health-related variables and academic performance among first-year college students: implications for sleep and other behaviors. *J. Am. Coll. Health* 49:125–131.

Urner M, Tornic J, Bloch KE. (2009). Sleep patterns in high school and university students: a longitudinal study. *Chronobiol. Int.* 26:1222–1234.

Van Dongen HPA, Maislin G, Mullington JM, Dinges DF. (2003a). The cumulative cost of additional wakefulness: dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep* 26:117–126.

Van Dongen HPA, Rogers NL, Dinges DF. (2003b). Sleep debt: theoretical and empirical issues [review]. *Sleep Biol. Rhythms* 1:5–13.

Walker MP, Stickgold R. (2004). Sleep-dependent learning and memory consolidation. *Neuron* 44:121–133.

Walker MP, Stickgold R. (2006). Sleep, memory, and plasticity. *Annu. Rev. Psychol.* 57:139–166.

Wimmer F, Hoffmann RF, Bonato RA, Moffitt AR. (1992). The effects of sleep deprivation on divergent thinking and attention processes. *J. Sleep Res.* 1:223–230.

Wolfson AR, Carskadon MA. (1998). Sleep schedules and daytime functioning in adolescents. *Child. Dev.* 69:875–887.

Wolfson AR, Carskadon, M. (2003). Understanding adolescents' sleep patterns and school performance: a critical appraisal. *Sleep Med. Rev.* 7:491–506.