Sleep and academic performance in undergraduates: A multi-measure, multi-predictor approach

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Authors and affiliations:

Ana Allen Gomes* (1, 2), José Tavares (1), & Maria Helena P. de Azevedo (3)

(1) Department of Education, University of Aveiro, ana.allen@ua.pt

(2) IBILI (FCT), Faculty of Medicine, University of Coimbra.

(3) Institute of Medical Psychology, Faculty of Medicine, University of Coimbra. psicomed@fmed.uc.pt

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* **Corresponding author:** Ana Allen Gomes. Address: Departamento de Educação. Universidade de Aveiro. Campus Universitário de Santiago. 3810-193 Aveiro. Portugal. Phone: +351 234 370 353. Fax: +351 234 370 640. Email: ana.allen@ua.pt

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Abstract

The aim of the present study was to examine the associations of sleep patterns with multiple measures of academic achievement and to test whether sleep variables would emerge as significant predictors of subsequent academic performance of university students when other potential predictors such as class attendance, time devoted to study and substance use are considered. A sample of 1,654 (55% female) full-time undergraduates from 17 to 25 years 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 of the academic performance measures. As to the main predictors of end-of-semester marks, from fifteen potential predictors using stepwise multiple regression analysis, five were selected as significant predictors: previous academic achievement, class attendance, sufficient sleep, night outings and sleep quality with R-squared =.14 and adjusted R-squared = .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 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.

Key words: sleep, academic performance, multiple regression.

INTRODUCTION

Controlled studies that manipulated sleep in healthy adults through a variety of methodologies (e.g., post-training sleep; total, partial or selective-stage sleep deprivation) have found that sleep is associated with a range of cognitive activities, such as attention (e.g., Lim & Dinges, 2010; Van Dongen, Maislin, Mullington & Dinges, 2003; 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 (e.g., Li et al., 1991; Diekelmann, Wilhelm & Born, 2009; Dotto, 1996; Ficca & Salzarulo, 2004; Fogel, Smith & Cote, 2007; Maquet, 2001; Roehrs & Roth, 2000; Smith, 1995, 2001; Stickgold et al., 2001; Stickgold & Walker, 2007; Walker & Stickgold, 2004, 2006). Both total (Lim & Dinges, 2010) and partial (chronic) sleep deprivation (Banks & Dinges, 2007; Van Dongen, Maislin, Mullington & Dinges, 2003) 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).

As there has been intense research focusing on the role of sleep on memory, a few further notes deserve mention. Research findings indicate that the role of sleep on memory is not merely a passive one (interference reduction). Rather, the research indicates that sleep actively facilitates memory (cf. Diekelmann, Wilhelm & Born, 2009; Ficca, 2010). Sleep appears to be related (i) to distinct memory types such as working memory (e.g., Kopasz et al., 2010; Lim & Dinges, 2010; Van Dongen, Maislin, Mullington & Dinges, 2003) and long-term memory; (ii) to several kinds of materials, namely, memory for procedural/non-declarative and declarative knowledge (cf., e.g., Dotto, 1996; Smith, 1995, 2001; Fogel et al., 2007); and (iii) to different memorization stages, such as encoding, consolidation, and reconsolidation (cf. Walker & Stickgold, 2006). [A full discussion on 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 we cannot directly generalize the findings of controlled studies based on standardized cognitive tasks 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 (for an overview, cf. Curcio et al., 2006; Dewald et al., 2010; Gomes, Tavares & Azevedo, 2002; Wolfson & Carskadon, 2003). Although the focus of the present paper is on undergraduates, it is worth mentioning that the relationships between sleep aspects and school performance have been more regularly investigated in children and adolescents of several ages and educational levels (e.g., Bruni, Antignani, Innocenzi, Ottaviano & Ottaviano, 1995; Buckhalt, Wolfson & El-Sheikh, 2009; Dewald et al., 2010; Giannotti & Cortesi, 2002; Hofman & Steenhof, 1997; Meijer & Wittenboer, 2004; Pagel, Forister, & Kwiatkowski, 2007; Pagel & Kwiatkowski, 2010; Ravid et al., 2009; Roberts, Roberts, & Chen, 2001; Wolfson & Carskadon, 1998). There have been also a growing number of experimental studies in younger samples, showing, for instance, that sleep facilitates memory in children and adolescents (Kopasz et al., 2010) and that sleep restriction or extension in school-age children by only one hour during consecutive nights leads to differential impacts over neurobehavioral measures (e.g., Sadeh et al., 2003).

However, it cannot be assumed that sleep effects on cognition or academic performance are the same in all ages or at all points of human development (cf. e.g., Dewald et al., 2010). For instance, academic outcome measures seem to be differentially influenced by sleep depending on the student educational level and age (Pagel et al., 2010), and recent reviews (Diekelmann, Wilhelm & Born, 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. Therefore, the present paper will focus on the literature that more directly targets university 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 (cf. Urner et al., 2009). Specifically, in samples of university students observed in their natural environments, 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 symptoms (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 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) including 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 amount/*quantity*, sleep *quality*, sleep *regularity*, and sleep *phase* schedules. Specifically, sleep restriction, poor sleep quality, 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 the impact of these sleep functions on cognitive/neuropsychological functioning (cf. references cited in the beginning of the present Introduction), it is reasonable to expect students with greater sleep debt to demonstrate worse academic performance. In fact, both REM (Rapid Eye Movements) 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*, research on shift work and jet lag suggests that abrupt changes in the sleep-wake schedules lead to internal dissociation of circadian rhythms, which may imply a variety of undesirable effects, including performance decrements (cf. AASM, 2005). As jetlag symptoms may arise whenever three or more time zones are suddenly crossed, it is reasonable to suppose that university students showing comparable irregularities in their sleep-wake schedules will suffer from undesirable consequences, such as higher fatigue, deterioration of mood, lower performance (Taub and Berger, 1973, 1976), and excessive daytime somnolence (Manber et al., 1996). Finally, studies in student samples have consistently reported poorer school performance to be associated with *later* sleep-wake schedules and/or diurnal type preferences towards *eveningness*. In this case, it is worth mentioning that morningness-eveningness is a continuum of *normal* inter-individual differences. That is, along this continuum, sleep should be normal in quantity (e.g., Roenneberg et al., 2004) and quality, providing the individual has the possibility to adapt to her/his preferred schedules (cf. AASM, 2005). Therefore, in contrast to sleep restriction, sleep irregularity, or poor sleep quality, it is worth noting that later sleep-wake schedules and eveningness are not problematic *per se*, in the sense that there are no alterations with regard to sleep duration and architecture. Thus, it should be hypothesized that the associations between later sleep-wake schedules and academic performance are not direct, but are most probably mediated by other variables, such as sleep restriction and sleep irregularity (both of which are found to be higher in various evening-type subsamples, e.g., Giannotti et al., 2002, Gomes et al., 2008; Taillard et al., 1999), and/or lower class attendance, which may occur as a consequence of the conflict between later sleep-wake schedules/eveningness diurnal type tendencies and externally imposed morning schedules.

Despite the cumulative number of publications on sleep and academic performance among university students, very few studies, to date, have examined the relative impact of sleep variables on academic results in real-life circumstances when *other potential predictor*s 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 college student performance. Multiple regression analysis identified six significant predictors, three of which were sleep variables (weekend sleep amount, sleep latency, and falling asleep in 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, gender and age. Multiple regression analyses selected five significant predictors, two of which were sleep variables (weekday and weekend wake-up times), which accounted for the highest proportion of explained variance in grade point averages. In a study interested in the links between alcohol use, sleep, and academic performance in college students, Singleton and Wolfson (2009) found that the Scholastic Aptitude Test scores were the strongest predictor of grade point average and that other significant predictors were gender, alcohol consumption, sleep duration, and daytime sleepiness. By considering other variables that might explain academic results, these kinds of studies provide valuable data, as they help to better assess the relative effect of various sleep aspects.

In a relatively recent literature review, Curcio, Ferrara and Degennaro (2006) state that the first step in the research agenda about sleep and academic performance should be to find reliable measures of academic performance or, alternatively, adopt the Wolfson and Carskadon’s (2003) recommendation of using a multi-measure approach (e.g., grades, tests, teacher reports). In addition, Carskadon and Wolfson 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, very few published studies, to date, have adopted such a multi-measure, multi-predictor approach.

Moreover, research aimed at studying the associations between sleep and academic performance has rarely measured neuroticism (one exception being the study of Gray & Watson, 2002), apparently overlooking the fact that literature on shift work has emphasized neuroticism to be one of the most important individual predictors of intolerance to shift work, as neurotic individuals are more prone to experience undesirable consequences following abrupt changes in their sleep-wake schedules (e.g., cf. Costa et al., 2001; Härma, 1993; Saksvik et al., 2011). In addition, there appears to be an inter-individual variability in susceptibility to sleep restriction (e.g., Banks & Dinges, 2007; Van Dongen et al., 2003), as well as to the desynchronization of internal rhythms' (e.g., Reinberg et al., 1989), and neuroticism is likely to be 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 central aims of the present study were twofold: (1) to analyze the associations between sleep patterns and multiple measures of academic performance of university students (self-reported retention, previous grade point average [GPA], subjective impact of sleep patterns on academic results, and end-of-semester marks as indicated by university records); (2) to examine longitudinally whether sleep variables would 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, it was also our intent to determine whether neuroticism plays a moderating role in the associations between sleep patterns and subsequent end-of-semester marks. Indeed, we may suppose that inadequate sleep, such as sleep curtailment, has a detrimental effect on daytime functioning only in neurotic subjects, not in stable subjects.

We will focus on four fundamental sleep patterns: sleep amount, sleep quality, sleep regularity, and sleep phase schedules. Specifically, sleep restriction, poor sleep quality, irregular and late sleep schedules are expected to be associated with poorer academic performance.

METHODS

Sample

The selected participants were 1654 full-time students, 55% female and 45% male, aged 17 to 25 years (M = 19.98, SD = 1.65), from a public Portuguese University, located in a city at the littoral, centre-north region of Portugal. The participants were distributed across the 1st (31.3%), 2nd (39.5%), and 3rd (29.2%) years of university study, from 18 undergraduate degree programs representative of 50% of the existing undergraduate degree programs of the university, which were grouped into five academic fields: engineering (40%), sciences (30%), pre-/primary-school education (12%), management (10%), and languages (9%). Based on the student’s residency status on school days vs. weekends/holidays, three groups were inferred and labeled: "moved students" (66%), that is, those who are presumably studying outside their home, living in the university city during the week; "non residents" (23.7%), that is, students that presumably travel daily from their home town to the university city to attend classes; and "residents" (10.3%), that is, students whose family home is presumably located in the university city (exclusion criteria: age above 25 years of age; part-time student status such as working students, elite athletes; having children; other, such as pregnancy).

Instruments and measures

i. 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 and 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 five years 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, some minor improvements were introduced based on the results of their feedback. After these steps, the authors agreed on a definitive version of the questionnaire. The entire questionnaire is shown in the appendix, and items used in the present work are identified with an asterisk. The psychometric properties will be further addressed below.

ii. The Composite Morningness Questionnaire [CMQ] (Smith et al., 1989), Portuguese version (cf. Silva, Azevedo & Dias, 1995), was used to measure diurnal type. In our sample, internal consistency of the CMQ, assessed through Cronbach alpha, was .81.

iii. The Eysenck Personality Inventory (EPI), 12 item version, from the Standard Shiftwork Index (SSI) (Barton et al., 1995) (Portuguese version: Silva, Azevedo & Dias, 1995), was used to measure neuroticism and extroversion. Two main reasons lead us to prefer this tool instead of other measures of these constructs. First, the small number of items is an advantage when researchers need to collect numerous data in an already busy booklet (as in our study). Second, this version was chosen to integrate the SSI, a battery of tests elected by authority researchers to improve the investigation on shift work through the adoption of standardized measures (cf. 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 alpha = .68), and an additional five items loaded on the neuroticism factor (22.07% of the explained variance; Cronbach alpha = .66).

Variables derived from the self-response questionnaires and relevant for the analyses of the present study covered several domains (note: except for the other specification, the variables described are taken from the sleep-wake questionnaire; thus, further details about the respective items may be found in the 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), academic failure in most courses of the previous curricular year. These variables require further explanation. As regards prior GPA, in Portugal, marks are expressed on a 0- to 20-point scale (at 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 prior GPA on a 6-point scale such that 10 or less [coded as 1], 10 to 11 [coded as 2], 12 to 13 [coded as 3], 14-15 [coded as 4], 16-17 [coded as 5], 18 or more [coded as 6] for university classification or as similar options formulated in terms of a to 0 to 200 points (rather than 0 to 20) for admission to the university (cf. item 35 in appendix). As to vocational preferences match, in Portugal, student admission to majors in public universities occurs once a year throughout the country. Students must complete a form where they indicate their preferences with regard to undergraduate degree program and preferred 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, students may or may not be admitted to their first preference (alternatively, they may be admitted to their second, third or other choice). In the present study, we have assumed that student’s choice (assessed in the “Demographics/Academics” section of the questionnaire) reflects vocational preference. As to previous year academic failure in most courses (the seventh question on the “Demographics/Academics” part of the questionnaire), in many Portuguese facilities 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 at least 10 points on a 20-point scale (below 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 per curricular year that students much 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. We will denominate 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), study time (hours per week, cf. item 32 in appendix);
- *Lifestyle and substance usage* variables include (cf. items 26-31, and 33, in appendix) exercise (hours per week), other extracurricular activities (hours per week), night outings (frequency), cigarette use (weighted mean = [units per week day * 5 + units per weekend day * 2] / 7 days), alcohol consumption (weighted mean = [units per week day * 5 + units per weekend day * 2] / 7 days), coffee consumption (weighted mean = [units per week day * 5 + units per 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, adapt.). 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 19-a to 19-n in appendix. The selected method was a principal component analysis with varimax rotation for components with eigenvalues equal to or higher than 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. As to the internal consistency of each factor, Cronbach alpha values were .77, .74 and .73, respectively. The daytime somnolence index consisted of 5 items adapted from Manber et al. (1996) plus one item about somnolence during class (items 18 a to 18 e and 18 f in appendix). Cronbach alpha was .84.

- *Neuroticism* (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 seven 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 15 a and 15 b in appendix). A sleep quality index was obtained through the sum of these items. Higher scores equate to poorer sleep quality. Cronbach alpha was determined to assess the internal consistency of this index, and a value of .73 was found.

- *Sleep phase/diurnal type* variables include sleep phase during week nights, 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 [week nights mid-sleep = rise time on week nights + (time in bed on week nights / 2) and weekend nights mid-sleep = rise time on weekends + (time in bed on weekends / 2)], where time in bed was the time interval between bedtime and rise time (either on week nights 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 the appendix) and week/weekend sleep phase irregularity (difference between week and weekend night sleep phases, expressed in hours and minutes).

iv. 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) The objective prospective measure consisted of the final mark obtained by each student at the end of the semester as indicated 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 that results from a certain number of tasks (assignments and written exams). The assessment tasks are defined by each professor in agreement with the university rules. To allow for a combination and a comparability 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.

The research protocol conforms to international ethical standards, as described in Portaluppi et al. (2010) for biological rhythms research.

A teacher from each university year and selected degree program was approached. The voluntary nature and the general format of research were explained to the professors. 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 one month after the beginning of the classes. Data collection was carefully planned so that events that could potentially influence sleep-wake patterns (e.g., holidays, student festivities) were excluded.

All questionnaires were collected after 12:00 noon to prevent under representation of evening-type students in the sample.

Participation rate, determined through the difference between the number of questionnaires distributed (2,018) and the number of questionnaires returned (1,819), was 90.1%.

From the questionnaires collected, a total of 165 were excluded due to the following reasons: missing answers on key questions, that is, sleep-wake schedules and sleep durations (33 participants); atypical cases or circumstances, e.g., pregnancy (4 participants); age equal to or above 26 years (61 participants); have children (5 participants); *not* a full-time student, that is, students with part- or full-time jobs, elite athlete students, those involved in University Student Union activities (62 participants).

At the *end of the semester*, a final classification for each participant was obtained through university records.

Data analyses

First, the 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 have passed versus students who have failed the previous curricular year. As to the remaining academic achievement measures (previous GPA, subjective detrimental effect of sleep on academic performance, and end-of-semester marks), mean values for each variable were compared between sleep groups. First, following Neale and Libert’s

(1986) recommendations, for each sleep variable, three to four (as appropriate) non-extreme groups of similar size were formed, based on quartiles or on frequencies. Then, academic performance mean values were determined for each sleep group and compared through ANOVAs.

It should be noted that, as to end-of-semester classifications, to allow for combination and comparability among marks from different courses, raw classifications were converted into standardized z scores in all analyses.

Second, considering a whole 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:

i) The normality assumption was checked for numeric variables. For variables not showing normal distribution, data were transformed to approximation of a Gaussian curve ($\log_{10}$ transformations were used to correct for skewed distributions).

ii) A correlation matrix was examined to select the potential predictors and prevent multicollinearity (whenever nominal variables were involved, we used other magnitude of association measures instead of correlation coefficients, e.g., Eta)

- variables showing non-significant associations with z scores were excluded
- among variables significantly associated with z-scores, redundant variables were also removed (for each set of inter-related 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 ~ 2 ; *condition index* < 15.

iii) 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 (cf. 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, that is, 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 consisted of a greater proportion of men (49.8% in the excluded group vs. 43.2% in the sample group, chi-square test where $p < .05$) and had a higher mean age ($M = 20.47$, $SD = 1.77$ versus $M = 19.82$, $SD = 1.59$, t-test where $p < .05$).

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 ($t = 7.12$, d.f. = 1637, $p < 0.0001$) and on weekends ($t = 3.45$, d.f. = 1637, $p < 0.0001$), higher eveningness orientation (i.e., lower morningness scores at the CMQ, $t = 3.92$, d.f. = 1637, $p < 0.0001$), and greater rise time variation during the week ($t = 3.01$, d.f. = 1607, $p < 0.01$). This pattern of results was also evident when examining, per sleep group, the percentage of students who had failed most courses (cf. percentages in Table 1).

Prior GPA by sleep group. From eveningness to morningness chronotype tendency groups ($F = 5.511$, $p < 0.001$) and across groups of students showing progressively lower rise time oscillations during the week ($F = 3.185$, $p < 0.05$), there were increased improvements in past academic achievement grades. Previous GPAs were also found to be higher in groups with earlier sleep-wake phases during the school week ($F = 14.760$, $p < 0.0001$) and in groups reporting better sleep quality ($F = 2.710$, $p < 0.05$), cf. Table 1.

Table 1 approximately here

Perceived impact of sleep on academic performance. Across groups showing progressively later sleep-wake phases on weeknights ($F = 17.115$, $p < 0.0001$) and on weekends ($F = 4.247$, $p < 0.01$), lower morningness scores ($F = 23.284$, $p < 0.0001$), lower frequency of enough sleep ($F = 91.141$, $p < 0.0001$), poorer sleep quality ($F = 19.699$, $p < 0.0001$), and larger bedtime ($F = 11.936$, $p < 0.0001$) and rise time ($F = 10.853$, $p < 0.0001$) oscillations during the week, there was an increase in mean values for the perception that sleep has had a negative impact on academic performance at the university (cf. Table 1).

End-of-semester marks by sleep group. The sleep groups who achieved higher marks (mean z-scores) at the end of the semester (cf. Table 1) were those who reported earlier sleep-phases during the week ($F = 5.335$, $p < 0.001$) and on weekends ($F = 4.649$, $p < 0.01$), higher morningness scores ($F = 3.486$, $p < 0.05$), 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 ($F = 3.689$, $p < 0.05$).

Main predictors of end-of-semester marks: stepwise multiple regression

After identifying through ANOVAs those sleep variables significantly associated with end-of-semester marks, we sought to find out 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 32 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 that 19 were significantly related to z-scores ($p < .05$). Non-significant associations were found for 13 variables (gender, residential status, curricular year, academic field, whether the student passed or failed most courses the previous year, exercise, other extracurricular activities, mood/anxiety complaints, neuroticism, and, as already seen, nightly sleep reduction during the school week, rise time irregularity during the school week and week/weekend sleep phase irregularity).

From the 19 variables significantly associated with z-scores, 4 were removed from the analysis (vigor; daytime somnolence; sleep phase on week nights; QCM total score) to prevent multicollinearity with similar variables, thus assuring independence among potential predictors. The intent was to identify, within each group of inter-related 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.

Table 2 approximately here

Using the stepwise regression method, from the 15 variables entered in the multiple regression analysis, 5 were selected as significant predictors (the remaining lost significance with z-scores). Results are summarized in Table 3.

Table 3 approximately here

From the fifteen variables included in the model as potential predictors of university grades (z-scores), five were shown to be significant predictors of marks. It was found that R-squared =.14, adjusted R-squared = .14, $F(5, 1234) = 40.99$, $p < .0001$, thus, together, the five variables explain 14% of the variance of z-scores (cf. 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.

The selected predictors showed associations 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 (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 of them, 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 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 ($p = .572$), nor were its interactions with enough sleep ($p = .771$) or sleep quality ($p = .783$).

DISCUSSION

The present study examined the 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) while considering demographics, well being, academic and lifestyle variables in a sample of undergraduates. Four sleep aspects were considered: quantity, quality, regularity and phase/schedules.

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 the conclusions of controlled studies, indicating that cumulative sleep debt (cf. Van Dongen et al., 2003), even in apparently small amounts and in healthy young adults, is associated with a variety of undesirable consequences (cf., Banks & Dinges, 2007; Pilcher & Huffcutt, 1996; Spiegel et al., 1999; Van Dongen, Rogers & Dinges, 2003; Van Dongen, Maislin, Mullington & Dinges, 2003). For instance, it has been found that across nights of partial sleep deprivation (e.g., 14 nights with 6 hours of sleep per night), the accumulation of neurobehavioral deficits may achieve levels equivalent to those found after 1 to 3 nights of total sleep deprivation (cf. Banks & Dinges, 2007). If these findings in 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 work is that rather than sleep length, per se, we have considered a measure of insufficient sleep (i.e., the frequency of enough sleep). This seemed to be more in line with the notion of sleep debt in the sense of chronic sleep restriction (cf. Van Dongen, Rogers & Dinges, 2003).

Our findings about *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 (cf. AASM, 2005) but also in community samples of young adults (e.g., Alapin et al., 2000; Oginska & Pokorski, 2006; Pilcher et al., 1997; Pilcher & Ott, 1998).

Because of the nonexistence of a European Portuguese version of the Pittsburgh Sleep Quality Index (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 about 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 from Dewal et al., 2010). However, precaution is needed in generalizing the current findings to other age groups or educational levels (cf., 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 in univariate analysis, but it lost significance in multiple regression analysis. Abrupt shifts of sleep-wake schedules lead to internal dissociation among circadian rhythms (e.g., Reinberg et al., 1989), which may be accompanied by complaints of somnolence, attention deficits, concentration difficulties, and performance decrements, commonly found in shift work and rapid travels across multiple time zones (cf. AASM, 2005). In undergraduates, it has been found that irregularities of 2 to 4 hours in the sleep-wake schedule are associated with increased fatigue, a deterioration of mood, and lower performance (Taub & Berger, 1973) and that healthy students with irregular sleep-wake schedules had excessive daytime somnolence when compared to regular colleagues (Manber et al., 1996). In our sample, sleeping enough and with good quality were more important for subsequent academic performance than maintaining regular sleep-wake schedules, 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 one-week sleep logs or actigraphy to assess irregularity (cf. Medeiros et al., 2001) as this topic seems to be under investigated.

Each of the three variables used to measure *diurnal type/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 (cf. 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-types students (e.g., 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 inter-individual differences linked to the acrophases of the 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 (e.g., cf. Giannotti et al., 2002).

As to *multiple regression analysis*, in our study, based on an initial pool of approximately 30 demographic, academic, well-being, personality and sleep variables, a stepwise regression entering 15 potential predictors of academic achievement for university students leads to the selection of 5 variables, which remained significantly associated with marks. Two were sleep variables, sleep quantity and sleep quality. The two sleep variables added a small but independent and significant contribution to university grades beyond previous academic achievement and class attendance. Their reduced contribution may lead to question its 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 variables considered in the present study. Furthermore, those 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 (cf. Afifi et al., 2004), and considering 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 the present 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). They 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 an 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 have an impact on 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 post-secondary education (e.g., high school GPA, cf. Robins et al., 2004; admission tests, cf. Kuncel et al., 2010; Trapmann et al., 2007; Sackett et al., 2009) 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), which may be found in many 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 (multi-measure approach) and were not limited to self-reporting data; (v) the study included a longitudinal analysis of the relationship between sleep patterns and end-of-semester academic marks; therefore, although the non-experimental 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 multi-variable approach was adopted; that is, besides sleep patterns, a variety of other variables that might explain academic performance of university students were 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 the written examinations. In addition, our study (like others in the field of sleep and biological rhythms) did not cover all 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 (a strong predictor of post-secondary academic achievement, cf. O'Connor & Paunonen review, 2007; Kuncel et al., 2010; 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 socio-economic status (SES) even though Pagel et al. (2007) reported that the number and type of sleep variables affecting adolescents' GPAs 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 (cf. Robbins et al., 2004 and Sackett et al., 2009 meta-analyses). 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, cf. 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 have measured daytime sleepiness, the present study did not fully explore the role of this variable over academic performance, while a very recent meta-analytic review highlight 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 children and adolescents sleep literature, we believe future studies in undergraduates should follow this recommendation

Despite its limitations, to date, our study seems to be one of the most comprehensive within the biological rhythms and sleep research fields, combining an interesting set of different variables, two of which, class attendance and previous academic achievement, were identified in meta-analysis 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, which were not controlled by the researchers, might have intruded and impacted end-of-semester achievement. In sum, 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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REFERENCES

Afifi A, Clark VA, May S (2004). *Computer-aided multivariate analysis*. Chapman & Hall/CRC, Boca Raton, London, New York, Washington DC (fourth edition).

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.

American Academy of Sleep Medicine [AASM]. (2005). *ICSD - International Classification of Sleep Disorders, 2nd ed: Diagnostic and coding manual*. AASM, Westchester, Illinois (second edition).

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. Educat. 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.

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

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

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. In Carskadon MA (ed). *Adolescent sleep patterns. Biological, social, and psychological influences*. 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. Psychoth.* 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, 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, 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 Beh.. Pers*. 15: 61-74

Hofman WF, Steenhof L (1997). Sleep characteristics of Dutch adolescents are related to school performance. *Sleep-Wake Res. The Netherlands*. 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.

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

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.

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.

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*. Prentice-Hall, Englewood Cliffs NJ (third edition).

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

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

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.

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.

Poropat AE (2011). The Eysenckian personality factors and their correlations with academic performance. *B. 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.

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

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.

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. *Current Biol*., 14: R1038-1039.

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. Studies Alcohol Drugs*. 70: 355-363.

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.

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

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. *Psychobiol*. 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 (2003). 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. (2003). 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.

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.

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.

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: ___________

I. SLEEP-WAKE CYCLE DURING THE SEMESTER

Last Month

Please consider the last month, keeping in mind what usually happens in a typical class week.

* 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. Please indicate how you have been feeling lately, during daytime.

	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	☐	☐	☐	☐	☐

<u>Other Sleep Aspects</u>

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 credit hour classification 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