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Der Einfluss von Schlaf auf die akademischen Leistungen

Dissertation
zum Erwerb des Doktorgrades der Medizin
an der Medizinischen Fakultät der
Ludwig-Maximilians-Universität zu München

vorgelegt von
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aus Darmstadt

2014

Mit Genehmigung der Medizinischen Fakultät
der Universität München

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Tag der mündlichen Prüfung:	10.04.2014

Meinen Eltern gewidmet

Inhaltsverzeichnis

Seite

1. Einleitung

Schlaf gehört zu unseren Grundbedürfnissen und wir verbringen ein Drittel unseres gesamten Lebens damit. Obwohl er für uns Menschen eine so wesentliche Rolle spielt, ist die Funktion des Schlafes für die heutige Forschung noch ein Rätsel.

Schlaf beschreibt einen natürlichen, wiederkehrenden Zustand, welcher durch eine Spanne von fehlendem Bewusstsein, verminderter sensorischer Funktion und Inaktivität der Skelettmuskulatur charakterisiert ist. Er unterscheidet sich vom Wachzustand durch eine verminderte Fähigkeit auf äußerliche Reize zu reagieren und vom Koma durch die sofortige Reversibilität dieses Zustands. Die eigentliche Funktion des Schlafes ist weiterhin umstritten. Eine Theorie besagt, dass Schlaf dem Körper dabei hilft, Energie zu sparen und die verschiedenen Spezies davon abhält in für sie gefährlichen Zeiten aktiv zu werden. Eine andere Lehrmeinung wiederum hebt den für das zentrale Nervensystem ausschließlich erholenden Nutzen hervor [1-3]. Unumstritten jedoch ist die lebenserhaltene Funktion von Schlaf, wie es eine Studie verdeutlichte, bei der Ratten anhaltendem Schlafentzug ausgesetzt waren und die Tiere innerhalb von zwei bis drei Wochen verstarben [4]. Die Ansicht, dass sich in der Zeit des Schlafs der Körper einfach „herunterfährt“, scheint unzutreffend. Vielmehr nutzt der Körper diese Phase, um verschiedene Änderungen einzuleiten. So wird z.B. das Immunsystem regeneriert [5, 6] oder der Körper in einen erhöhten anabolischen Stoffwechsel versetzt, indem vermehrt Wachstumshormone ausgeschüttet werden [7].

Der Mensch durchläuft während dem Schlaf zwei Stadien, die zyklisch auftreten und allgemein in sog. rapid eye movement (REM)-Schlaf und non-rapid eye movement (NREM)-Schlaf unterteilt werden. NREM-Schlaf wird weiterhin in die Schlafstadien 1-4 untergliedert, wobei 3 und 4 den Tiefschlaf darstellen und durch langsame Wellen -ein spezielles Muster in der Elektroenzephalografie (EEG)- charakterisiert sind (siehe Abbildung 1). Der REM-Schlaf unterscheidet sich wesentlich von den

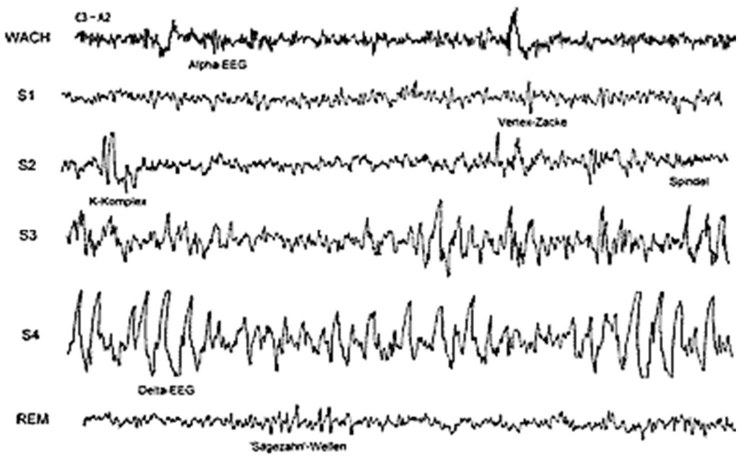

Abb. 1: Die verschiedenen Schlafstadien im EEG [8]

anderen Schlafphasen, da sich das EEG dem Wachzustand ähnelt, die gesamte Skelettmuskulatur erschlafft, aber gleichzeitig schnelle Augenbewegungen auftreten, daher wird der REM-Schlaf auch „paradoxer Schlaf" genannt. Jede Nacht durchläuft der Mensch 3-5 Zyklen und während die erste Schlafhälfte vor allem durch lange Phasen von Tiefschlaf dominiert wird, tritt REM-Schlaf hauptsächlich in der zweiten Nachthälfte auf.

1.1 Schlaf und kognitive Funktionen

In den letzten Jahren ist Schlaf vermehrt in den Fokus der Neurowissenschaften gerückt. Dabei hat sich gezeigt, dass Schlaf einen wesentlichen Einfluss auf das Lernen und die Gedächtnisfunktion hat. Obwohl der exakte Mechanismus noch nicht ganz verstanden ist, kann der Prozess des Lernens und des Gedächtnisses in drei verschiedene Phasen erklärt werden: 1. Die Enkodierung – die Aufnahme neuer Informationen. 2. Die Konsolidierung – der Prozess, bei dem neu aufgenommene Informationen in das Gedächtnis integriert und dadurch gefestigt werden. 3. Der Wiederaufruf – die Fähigkeit, bewusst oder unbewusst, auf die neu gespeicherten Informationen zurückzugreifen; dabei ist jeder dieser einzelnen Schritte für die volle Gedächtnisfunktion notwendig. Die Enkodierung und der Wiederaufruf dieser Informationen erfolgt im Zustand der Wachsamkeit, während die Konsolidierung von Informationen wahrscheinlich am effektivsten während des Schlafs stattfindet [9, 10].

Gedächtnisinhalte können generell in zwei Untergruppen unterschieden werden: 1. Das deklarative Gedächtnis beinhaltet alle Erinnerungen, die unserem Bewusstsein zugänglich sind, also Faktenwissen oder Ereignisse aus dem eigenen Leben wie z.B. das Wissen, dass Paris die Hauptstadt von Frankreich ist. Dem gegenüber beinhaltet das prozedurales Gedächtnis bestimmte Fähigkeiten, die nicht unbedingt bewusst vollzogen werden. Beispiele hierfür ist die Fähigkeit, Fahrrad zu fahren oder Gitarre zu spielen.

Zahlreiche Studien untermauern den förderlichen Nutzen von Schlaf auf das deklarative und prozeduralen Gedächtnis in diversen Aufgabenstellungen. Im Vergleich zu einer Wachphase von gleicher Zeitdauer, fördert Schlaf nach einer Lernphase die Speicherung von deklarativen Informationen [11, 12] und verbessert die Durchführung von prozeduralen Fähigkeiten [13]. Schlafmangel, auf der anderen Hand, scheint die Integration und den Wiederaufruf von Informationen zu erschweren [14]. Es zeigte sich ebenfalls, dass Schlaf kategorisches Lernen fördert [15] und zu Einsichten in versteckte Regeln anregt [16].

All diese kognitiven Fähigkeiten spielen eine wesentliche Rolle während der Hochschulbildung, die häufig als einer der schwierigsten und anspruchsvollsten Weiterbildungsphasen eines Menschen angesehen wird. Besonders von Studenten in lernintensiven Fächern wie Humanmedizin wird erwartet, dass sie sich innerhalb einer relativ kurzen Zeit komplexe Mengen an Faktenwissen und Konzepten aneignen. Gleichzeitig sind Studenten im Allgemeinen für ihre unregelmäßigen und späten Schlafenszeiten und ihren Einsatz von –legalen oder illegalen- schlafunterdrückenden Substanzen bekannt. Das führt dazu, dass, je nach Studie, 39% bis 60% der Studenten einen gestörten Schlaf angeben [17], welches wiederum ein erhöhtes Risiko für die Entstehung von körperlichen und psychischen Erkrankungen, wie z.B. Depressionen oder Angstzuständen, darstellt [18]. In Anbetracht dieser Umstände ist wenig verwunderlich dass bei Studenten ein direkter Zusammenhang zwischen der Schlafqualität und -dauer mit der akademischen Leistung nachgewiesen wurde [19].

1.2 Schlaf und Chronotyp

Ein weiterer Faktor, der nachweislich einen Einfluss auf die kognitive Fähigkeit haben kann, ist der Schlafzeitpunkt [20]. Dieser wird endogen durch die zirkadiane Uhr des Menschen durch den Prozess des Entrainments (Synchronisation) mit dem Tag/Nacht-Zyklus kontrolliert. Der Chronotyp beschreibt die individuellen Unterschiede in diesem Prozess und ist festgelegt durch genetische Disposition, Alter, Geschlecht und Umweltbedingungen. Er wird unterteilt in sog. „Lerchen“, also die Personen, die früh aufstehen und früh ins Bett gehen und vor allem in der ersten Hälfte des Tages aktiv sind, und „Eulen“, die eher in der zweiten Hälfte leistungsfähig sind und deshalb erst spät ins Bett gehen und spät aufstehen. Das Auftreten der verschiedenen Chronotypen zeigt eine Normalverteilung innerhalb der Bevölkerung, wobei die beiden Extreme die beiden Pole der Kurve darstellen [21]. In diesem Kontext zeigte eine Studie, dass Schüler, die sich eher als Abendtypen sahen, mit kürzeren Schlafenszeiten während der Woche, unregelmäßigem Schlafrhythmus sowie schlechterer subjektiver Schlafqualität assoziiert waren. Ferner klagten diese Schüler über eine vermehrte Tagesmüdigkeit, Aufmerksamkeitsprobleme und schlechten schulischen Leistungen [22]. Da die meisten Schul-, Universitäts- und Arbeitszeiten nicht mit dem normalen Schlafrhythmus der Mehrheit der „normalen“ Chronotypen vereinbar sind, sind ungefähr 80% der Bevölkerung an Arbeitstagen auf einen Wecker angewiesen [21]. Wie auch viele andere Dinge in unserer heutigen Gesellschaft sind Lernpläne im medizinischen Curriculum meist auf die frühen Schläfer zugeschnitten, was ein Nachteil für normale und spätere Schläfer bedeuten kann.

1.3 Schlaf und Stress

Prüfungsphasen sind für Studenten Zeiten in denen sie vermehrt Stress ausgesetzt sind. Allgemein betrachtet, verursacht Stress eine erhöhte physiologische und psychologische Aktivierung als Antwort auf gesteigerte umweltbedingte Anforderungen und diese Aktivierung kann sich negativ auf den Schlaf und dessen Qualität auswirken. So wird Stress als wesentliche Ursache für die Entstehung von primärer Insomnie in Betracht gezogen [23]. Außerdem scheint insbesondere die Antizipation auf erhöhte Beanspruchung und Leistung am nächsten Tag wichtig zu sein, was in erster Linie auf Studenten, die kurz vor einer Prüfung stehen, zutrifft [24]. Stress führte in verschiedenen Studien zu einem Rückgang von Tiefschlaf, REM-Schlaf und Schlafeffizienz, sowie einem Anstieg von nächtlichem Erwachen [25]. Diese Schlafstörungen haben zur Folge, dass es während der Nacht zu einer Steigerung typischer Stressmarker, wie z.B. Kortisol, kommt, was wiederum die Effekte des Stresses verschlimmern könnte [26]. Interessanterweise, können nicht nur aufreibende Ereignisse unseren Schlaf beeinträchtigen, sondern die Schlafqualität kann auch Einfluss nehmen, wie wir auf solche Ereignisse reagieren

[27]. Während erholsamer Schlaf uns für einen stressigen Alltag wappnet, scheint Schlafentzug uns vermehrt auf emotionale und belastende Reize zu sensibilisieren. Zusammenfassend zeigt sich eine enge Beziehung zwischen Stress und gestörten Schlaf.

Ziel der nachfolgenden Studien war es, den Zusammenhang von Schlaf (Schlafzeitpunkt, Qualität) und akademischer Leistung näher zu untersuchen. Dazu wurden die verschiedenen Lern- und Schlafgewohnheiten zweier Kohorten von Medizinstudenten der Ludwig-Maximilians-Universität (LMU) erfasst. Der überwiegende Teil der bisherigen Studien, die sich mit dieser Fragestellung befassten, basieren auf einer einmalige Erfassung der Variablen. Die nachfolgenden Studien gehören zu den wenigen Beobachtungen, die prospektiv über mehrere Zeiträume die Zusammenhänge beleuchteten.

1.4 Beitrag des Doktoranden

Beide Studien wurden von Kurosh Ahrberg und Dr. med. Lisa Genzel entworfen, durchgeführt und ausgewertet. Die zweite Publikation wurde zunächst durch den Autor verfasst und anschließend durch Dr. med. Genzel revidiert und in gemeinsamer Arbeit in ihre endgültige Fassung gebracht. Darüber hinaus standen Sophie Niedermaier, Prof. Axel Steiger, Martin Dresler, Carolina Roselli und Prof. Till Roenneberg als Koautoren unterstützend bei dem Studiendesign und der Auswertung der Daten zur Verfügung. Alle Autoren haben bei der Fertigstellung mitgewirkt.

2. Zusammenfassung

2.1 Sleep timing is more important than sleep length or quality for medical school performance.

In unserer ersten Studie untersuchten wir, wie Lern- und Schlafgewohnheiten (Dauer, Qualität und Zeitpunkt) und der natürliche Chronotyp (zirkadianer Rhythmus) die akademische Leistung beeinflussen. Dazu wurden 31 Medizinstudenten der Ludwig-Maximilians-Universität im Wintersemester 2010/2011, die sich zu diesem Zeitpunkt im 2. und 3. klinischen Semester befanden, befragt. Diese führten im Verlauf ihres Semesters für jeweils 2 Wochen ein Aktivitätstagebuch während drei verschiedenen Zeiträume, repräsentativ für den Verlauf eines „normalen“ Semesters: Zuerst während der normalen Vorlesungszeit, gefolgt von der Prüfungsvorbereitungszeit und den Prüfungstagen, sowie in den Semesterferien. In diesem Tagebuch mussten die Studenten im Form eines Buchstabens täglich für jede halbe Stunde eintragen, welche Tätigkeit sie nachgegangen sind, so stand z.B. der Buchstabe „S“ für Schlaf oder „U“ für Lehrveranstaltungen an der Universität. Außerdem mussten die Studenten einmalig einen Fragebogen, bezüglich vorangehender schulischer und akademischer Leistungen (inklusive Abitur- und Physikumsnote), ihres Chronotyps (Munich Chronotype Questionnaire; MCTQ [28]) und ihrer Schlafqualität (Pittsburgh Sleep Qualtiy Index, PSQI [29]), beantworten.

Die Auswertung ergab, dass der Schlafzeitpunkt während der Prüfungsphase mit der erzielten Abschlussnote signifikant zusammenhängt: so bedeuteten frühe Schlafgewohnheiten eine bessere Prüfungsleistung. Ferner korrelierte die Abschlussnote mit der des ersten Abschnitts der ärztlichen Prüfung („Physikums“). Eine durchgeführte Regressionsanalyse mit Schlafgewohnheit vor der Prüfung und der Physikumsnote als Einflusswert erklärte 42.7% der Varianz der Abschlussnote.

Alle anderen Faktoren, wie Chronotyp, Schlafdauer und -qualität, Alter und interessanterweise Lerndauer zeigten keinen signifikanten Einfluss.

2.2 The interaction between sleep quality and academic performance

Bei der Auswertung der vorangestellten Studie beobachteten wir einen Zusammenhang zwischen der Schlafqualität und der Physikumsnote. Studenten, die besser schliefen, erzielten im Physikum eine bessere Leistung. Allerdings wurde die Schlafqualität von den Probanden ein Jahr nach dem Examen eingeschätzt und eine Kausalität konnte so nicht ermittelt werden. Ziel der zweiten Studie war es, diese Beziehung eingehend zu untersuchen, indem die Faktoren Schlafqualität, psychosozialer Stress und akademische Leistung mehrfach erhoben und in Relation gesetzt wurden.

An dieser Untersuchung beteiligten sich 144 Medizinstudenten der Ludwig-Maximilian-Universität, die im Herbst 2011 am ersten Abschnitt der ärztlichen Prüfung teilnahmen. Angelehnt an die vorausgehende Studie, füllten die Studenten retrospektiv für das Semester, kurz vor und 8 Wochen nach der Prüfung, Fragebögen aus hinsichtlich ihrer Schlafqualität (PSQI) und ihr subjektives Stressniveau mit Hilfe einer 10-Punkte Skala. Darüber hinaus beantworteten die Studenten einmalig soziodemographische Fragen und die erzielte Note im Physikum.

Es zeigte sich, dass die erreichte Leistung im Physikum mit dem Stressniveau und der Schlafqualität vor der Prüfung assoziiert war, so ging eine schlechte Note mit einer schlechten Schlafqualität und höheren Stresslevel einher. Für die beiden weiteren Zeitpunkte –während des Semesters und nach der Prüfung– konnte ein solcher Zusammenhang nicht gefunden werden. Stress korrelierte bei jedem Zeitpunkt mit der Schlafqualität. 59% der Studenten wiesen während der Prüfungsvorbereitung einen schlechten Schlaf auf, wohingegen die Anzahl der

Schlafgestörten sich während des Semesters bei 29% und nach der Prüfung bei 8% befand. Generell betrachtet, scheinen nicht die, die schlecht schlafen, eine schlechte Leistung zu erbringen, sondern die, die eine schlechte Note erwarten, scheinen gestresster zu sein, was sich negativ auf die Schlafqualität niederschlagen kann. Das wiederum kann die Leistung negativ beeinflussen und so in einem circulus vitiosus resultieren. Außerdem ist die hohe Anzahl von Schlafgestörten alarmierend und bedarf einer Intervention.

3. Publikationen

Chronobiology International, Early Online: 1–6, (2013)
© Informa Healthcare USA, Inc.
ISSN: 0742-0528 print / 1525-6073 online
DOI: 10.3109/07420528.2012.763132

informa healthcare

Sleep timing is more important than sleep length or quality for medical school performance

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Overwhelming evidence supports the importance of sleep for memory consolidation. Medical students are often deprived of sufficient sleep due to large amounts of clinical duties and university load, we therefore investigated how study and sleep habits influence university performance. We performed a questionnaire-based study with 31 medical students of the University of Munich (second and third clinical semesters; surgery and internal medicine). The students kept a diary (in 30-min bins) on their daily schedules (times when they studied by themselves, attended classes, slept, worked on their thesis, or worked to earn money). The project design involved three 2-wk periods (A: during the semester; B: directly before the exam period—pre-exam; C: during the subsequent semester break). Besides the diaries, students completed once questionnaires about their sleep quality (Pittsburgh Sleep Quality Index [PSQI]), their chronotype (Munich Chronotype Questionnaire [MCTQ]), and their academic history (previous grades, including the previously achieved preclinical board exam [PBE]). Analysis revealed significant correlations between the actual sleep behavior during the semester (MS_{diary}; mid-sleep point averaged from the sleep diaries) during the pre-exam period and the achieved grade ($p = 0.002$) as well as between the grades of the currently taken exam and the PBE ($p = 0.002$). A regression analysis with MS_{diary} pre-exam and PBE as predictors in a model explained 42.7% of the variance of the exam grade (effect size 0.745). Interestingly, MS_{diary}—especially during the pre-exam period—was the strongest predictor for the currently achieved grade, along with the preclinical board exam as a covariate, whereas the chronotype did not significantly influence the exam grade.

Keywords: Academic performance, chronotype, medical education, memory, sleep timing

INTRODUCTION

A large amount of evidence shows that sleep is important for memory functions (Diekelmann & Born, 2010; Rattenborg et al., 2011). Yet, sleep of students is often challenged during medical school and residency. Despite this being the most learning-intensive period of their lives (Curcio et al., 2006), these challenges potentially influence learning and memory performance (Beebe et al., 2010; Curcio et al., 2006; Taras & Potts-Datema, 2005; Wolfson & Carskadon, 2003). Students sleep too short for their needs, often suffer from poor sleep quality, and/or have erratic sleep-wake schedules (Curcio et al., 2006; Gruber et al., 2010; Lund et al., 2010; Nojomi et al., 2009; Taras & Potts-Datema, 2005). Not only sleep quality and duration may influence cognitive performance, the timing of sleep is another important factor. Sleep timing depends on both the length of prior wakefulness (homeostasis) and on the control of the circadian clock. Circadian clocks synchronize with their environment predominantly with the light-dark cycle of day and night. This active synchronization process (entrainment) results in highly interindividual relationships between the internal timing of physiology and behavior and the external timing, be it the social clock or the light-dark cycle. Some people would naturally (i.e., without social obligations) fall asleep as early as 8 PM and wake up by themselves at around 4 AM (the colloquial larks), whereas others may only find sleep at that time waking up 7 to 8 h later (owls). These chronotypes show a close-to-normal distribution in the general population between the two extremes described above. The average German, for example, would fall asleep on work-free days sometime between midnight and 1 AM and would wake up voluntarily between 8 and 9 AM. Since most work, school, and university schedules are not compatible with the natural sleep times of the

Submitted July 30, 2012, Returned for revision December 28, 2012, Accepted December 29, 2012

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majority of chronotypes (Roenneberg et al., 2007; Urner et al., 2009), around 80% of the population depends on waking up by alarm clocks on workdays (Roenneberg et al., 2012). Like in many other settings, teaching schedules in medical schools often fit early types more than late types, creating a disadvantage for ''owls.'' Studies investigating how sleep timing affects school or university performance have shown an advantage for students keeping an early sleep-wake schedule (Eliasson & Lettieri, 2010; Wolfson & Carskadon, 2003). These studies are, however, mostly based on short, one-time questionnaires assessing subjective average sleep timing and other factors such as subjective morning-evening preferences. For example, Eliasson and Lettieri (2010) have shown that students with the highest performance had earlier sleep and wake times compared with subjects with the lowest academic performance. Interestingly, individuals in those two performance levels did not differ in their morning-evening preference scores (assessed by four questions). It has to be noted that the results of this study were entirely based on a single, one-time self-reporting questionnaire with 29 items. Another study using a 2-wk sleep-wake diary showed similar results: academic performance correlated strongest with sleep onset and less with sleep length and sleep irregularity (Medeiros et al., 2001). The connection between sleep onset and academic performance may be mediated by general lifestyle choices and not the sleep per se. With a one-time questionnaire, Onyper and colleagues could show that amount of alcohol consumption on a typical weekend night was the strongest predictor for grade point average (GPA) performance, with greater consumption showing lowed GPAs. At the same time, heavy drinkers were more likely to report later bedtimes and wake times (Onyper et al., 2012).

Here, we revisit the question of how study routines and sleep (duration, quality, and timing) affect performance by using detailed daily protocols: for three 2-wk periods (semester, pre-exam, and semester break), medical students of the surgical and internal medicine semester at the of Medical School of Ludwig Maximilian University kept diaries (for every half-hour of their days) how they used their time regarding the following four categories: sleep, self-study, university classes, or non-university work. In addition, they completed several one-time questionnaires, assessing sleep quality, chronotype (CT_{MCTQ}), academic background, and university performance. We focused our analysis on the sleep and study routines while controlling for general academic performance via the values of the previous grades.

METHODS

Participants

Thirty-one third- and fourth-year medical students of the Ludwig Maximilian University were included in the study. As compensation for their participation, students received one of several prizes (by lottery). The Ethics Committee of the Ludwig Maximilian University Faculty of Medicine, Munich, Germany, approved the research project. Subjects gave their informed consent. The experimental protocol is conform to international ethical standards (Portaluppi et al., 2010).

Procedures

Activity Diaries

For three two-wk periods, students recorded (in half-hour bins) how they used their time (self-study, university classes, sleep, thesis work, or extracurricular paid work). If activities did not apply to any of the above, they were instructed to leave the half-hour bin blank. The three inquiry periods were placed as follows: (A) midway during the semester; (B) directly before the exam period at the end of the semester—pre-exam; and (C) during the semester break (Easter vacation). The questionnaire was sent daily to the students via e-mail to be filled out online. The students also had the possibility to print a written version and fill it out by hand. The (half-hour) entries into the activity diaries were used to calculate the average durations of each activity, separately for the two analysis stages (semester and pre-exam). First, for each participant the daily amount of each activity was calculated and then averaged across the study period. In addition, averages for only the weekends and the weekdays were calculated. The second weekend in the pre-exam period was not included in the analysis, since the exam was on the Thursday and Friday before.

Questionnaires

In addition, students filled out one-time questionnaires about their sleep quality (Pittsburgh Sleep Quality Index [PSQI]; Buysse et al., 1989), chronotype (Munich Chronotype Questionnaire [MCTQ]; Roenneberg et al., 2007), and academic background and performance. The MCTQ was sent to participants during the semester break (presuming a higher likelihood of keeping their own rhythm on weekends needed to correctly assess the chronotype). To assess academic background and performance, the subjects noted at the beginning of the study their high school exit grade (HSE), preclinical board exam (PBE) grade, and after the semester questionnaire period the grades in the surgical or internal medicine semester, respectively (final semester exam [FSE]). In addition, smoking, alcohol, and caffeine habits, age, and sex were assessed. For sleep quality, the PSQI provides a single value in the range of 0–21, with >5 points representing disturbed sleep. All grades (high school, board exam, and semester) are obtained in the German system, with 1 being the best and 5 the worst grade (4 is usually the threshold to pass the exam). Chronotype was assessed for each participant by the Munich Chronotype Questionnaire (Roenneberg et al., 2003; for the current version of the questionnaire, see Roenneberg et al., 2012). Chronotype represents how the circadian clock (in this case assessed by sleep-wake behavior) embeds itself into the light-dark cycle. The first step in assessing chronotype is based on mid-sleep on free days without the use of an alarm clock (MSF; half-time point between sleep onset and sleep end). Since most people accumulate a significant sleep deprivation over the work week and therefore tend to oversleep on free days, MSF is corrected in a second step for this oversleep, resulting in an individual's chronotype (MSF_{sc}; for the correction algorithm, see supplement in Roenneberg et al., 2012).

Mid-sleep Assessment by Activity Diaries

The MCTQ-assessed chronotype (MSF_{sc}) estimates the general phase of entrainment of an individual's circadian clock (based on sleep-wake behavior). During the two test periods (semester and pre-exam), students rarely had completely work-free days. Since we wanted to correlate performance with the participants' actual sleep behavior, we additionally assessed sleep timing (MS_{diary}) and sleep duration from the activity diaries. MS_{diary} was calculated as mid-sleep time over the whole 2 wks including weekdays and weekends, separately for the two test periods. We further calculated mid-sleep separately for weekdays (MSW_{diary}) and weekends (MSF_{diary}) for the respective test periods.

Statistical Analysis

For the analysis, we focused on sleep and self-study behavior while considering the impact of general performance level measured via the previous achieved grades (HSE, PBE). Possible associations of the exam grade to the considered covariates, namely, age, academic background, sleep quality, chronotype (MSF_{sc}), actual sleep behavior (MS_{diary}), sleep duration, and study time, were tested by Spearman correlation coefficients. If a significant correlation was found between FSE and sleep or study behavior from the activity diaries, more detailed analysis with the respective behaviors on weekend and weekdays was performed. Additionally, a stepwise regression analysis with exam grade as criterion variable and the previously listed variables as potential predictive variables was conducted. Stepwise regression detects the model with the smallest number of predictors explaining the maximum amount of variance in the data. One-factorial analysis of covariance (ANCOVA) were performed to detect whether the factors (MSF_{sc}, MS_{diary}, sleep duration, study times, and sleep quality) each affected the outcome variable exam grades after removing the variance of other covariates. For this analysis, the variables were divided into two groups ($\leq$median and >median). Nominal level of significance (α) was set to 0.05, corrected according to the Bonferroni procedure for multiple testing (to keep the type I error $\leq$05). Results are presented as means ± SEM. PASW Statistics 18.0 (SPSS, Hong Kong) was used for all statistical analysis.

RESULTS

The study included 7 male (22.58 %) and 24 female (77.42 %) students, reflecting the gender distribution in German medical schools. Mean sleep duration was 8.22 ± 0.14 h during the semester and 8.11 ± 0.13 h during the pre-exam period. None of the students took daytime naps. Mean study duration per day was 2.55 ± 0.22 h during the semester and 4.96 ± 0.29 h during the pre-exam period. Mean chronotype was 4.65 ± 0.17 (MSF_{sc}; local time) and mean MS_{diary} was 3.83 ± 0.12 during the semester and 3.96 ± 0.11 during the pre-exam period. Sleep duration and MS_{diary} did not differ between the two analysis stages, whereas there was a significant difference between study duration during the semester and the pre-exam period ($p < 0.001$; see Table 1).

The grade of the final semester exam (FSE) significantly correlated with that achieved in the preclinical board exam (PBE; $p = 0.002$, spearman correlations). FSE grades also significantly correlated with MS_{diary} (sleep midpoint) during the pre-exam period and marginally during the semester period ($p = 0.002$ and $p = 0.023$, respectively; note that earlier sleep meant higher achievement; see Table 2 and Figure 1). Detailed analysis showed that correlations between MS_{diary} pre-exam and FSE increased towards the exam date (weekdays 2 wks before: $R = 0.319$, $p = 0.04$; weekend before: $R = 0.510$, $p = 0.002$; last weekdays before the exam: $R = 0.484$, $p = 0.003$). All three measures for sleep timing (MS_{diary} semester, MS_{diary} pre-exam, and MSF_{sc}) showed significant positive correlations (Spearman correlation analysis; all $r > 0.5$, $p < 0.005$).

A stepwise regression analysis model revealed MS_{diary} pre-exam and the PBE grade as the only predictors explaining 42.7% (R^2) of the variance of the FSE grade (see Table 3). Standardized errors were tested for normal distribution (Kolmogorov-Smirnov test) and inspected regarding homoscedasticity (residual plot). The effect size of the regression analysis was $f^2 = R^2/(1 - R^2) = 0.427/(1 - 0.427) = 0.745$, indicating a large effect size.

Analysis of covariance with the FSE grade as dependent variable and the PBE grade as covariate showed a significant effect of actual sleep behavior (MS_{diary}) during the pre-exam stage ($p = 0.039$), indicating that sleeping earlier versus later before the exam is the only factor that significantly influenced the achieved grade (explaining 39.9% of the variance with an effect size of $f = 0.51$; see Table 4). In an additional analysis grouping the ANCOVAs via a different median split (< and $\geq$) confirmed the above mentioned findings and additionally MS_{diary} during the semester also became significant ($p = 0.038$). An analysis of covariance with sleep quality (divided into three groups: <median, median, and >median) as factor and PBE grade as covariate showed no effect on FSE grade ($p = 0.702$).

TABLE 1. Average values.

	Mean	SEM			
Final semester exam grade (FSE)	2.90	0.15			
High school exit grade (HSE)	1.57	0.09			
Preclinical board exam grade (PBE)	2.69	0.15			
Age	23.33	0.29			
Sleep quality (PSQI)	4.28	0.37			
Chronotype (MSF_{sc})	4.65	0.17			
	Semester		Pre-exam		
	Mean	SEM	Mean	SEM	p value[a]
Average sleep duration	8.22	0.14	8.11	0.13	0.339
Average study time	2.55	0.22	4.96	0.29	0.000
Actual sleep timing (MS_{diary})	3.83	0.12	3.96	0.11	0.166

Chronotype (MSF_{sc}, in 24-h time from 0:00 to 24:00) was assessed with the Munich Chronotype Questionnaire (MCTQ) and actual sleep timing (MS_{diary}, in 24-h time from 0:00 to 24:00) was determined by the activity diaries (see Methods). Sleep duration and study time is presented in hours.

[a]p value from paired Student t test between the assessment periods, semester and pre-exam.

TABLE 2. Spearman correlation coefficients between variables and exam grade.

	Exam grade	
	Spearman's rho	p Value
MS_{diary} pre-exam	0.544	0.002
Preclinical board exam grade (PBE)	0.530	0.002
MS_{diary} semester	0.408	0.023
High school exit grade (HSE)	0.323	0.077
Chronotype (MSF_{sc})	0.276	0.133
Age	0.208	0.271
Average sleep duration semester	0.141	0.450
Average study time semester	−0.070	0.707
Average sleep duration pre-exam	0.055	0.769
Average study time pre-exam	−0.044	0.816
Sleep quality	−0.040	0.832

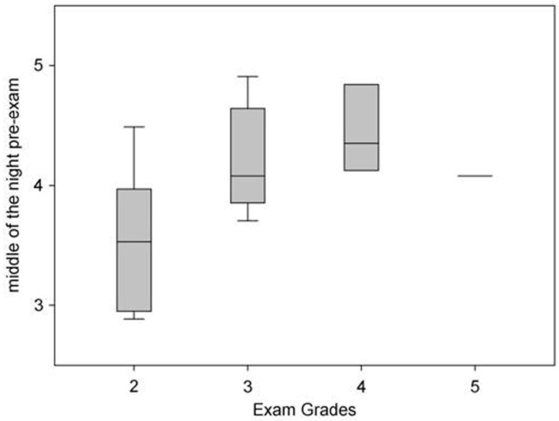

FIGURE 1. Sleep behavior and exam grade. Shown are the actual sleep timing (MS_{diary}; see Methods) pre-exam and the final semester exam grades (FSE). Exams are graded with 1 being the highest grade and 5 the lowest.

In a secondary analysis, we performed a spearman correlation with the PBE grades, the high school exit (HSE) grade, and sleep quality (PBE and HSE: $r=0.483$, $p=0.005$; PBE and PSQI: $r=0.529$, $p=0.002$; HSE and PSQI: $r=0.160$, $p=0.383$).

TABLE 3. Stepwise regression analysis.

Criterion variable: exam grade		
	Regression coefficient	p value
(constant) Intercept	−0.450	0.587
MS_{diary} pre-exam	0.553	0.011
Preclinical board exam grade (PBE)	0.425	0.013
$R=0.653$; $R^2=0.427$; corrected $R^2=0.383$		

DISCUSSION

During the most intense learning period of their lives, medical students and residents are rarely able to maintain regular sleep schedules due to their high workload and are therefore often sleep-deprived and/or suffer from poor sleep quality (Curcio et al., 2006; Gruber et al., 2010; Lund et al., 2010; Nojomi et al., 2009; Taras & Potts-Datema, 2005). Yet, sleep plays an important role in memory consolidation (Diekelmann & Born, 2010; Rattenborg et al., 2011) and cognitive performance (Van Der Werf et al., 2009). We therefore investigated the sleep and study habits of medical students. The results indicate that only actual sleep timing during the semester and especially during the weeks prior to the exam (average mid-sleep phase extracted from the diaries, MS_{diary}) significantly influence exam performance, whereas all other factors—chronotype (MSF_{sc}; assessed by the Munich Chronotype Questionnaire), sleep duration and quality, study time, and age—showed no significant correlations.

TABLE 4. One-factorial analysis of covariance.

ANCOVA Dependent variable: exam grade Covariate: preclinical board exam grade					
				Group 1 (≤Median)	Group 2 (>Median)
Model no.	Factor	p value[a]	R^2	n	n
1	MS_{diary} pre-exam	0.039	0.399	17	14
2	MS_{diary} semester	0.121	0.358	16	15
3	MSF_{sc}	0.888	0.299	16	15
4	Average sleep duration semester	0.613	0.305	16	15
5	Average sleep duration pre-exam	0.274	0.329	17	14
6	Average study time semester	0.425	0.315	16	15
7	Average study time pre-exam	0.766	0.301	16	15

[a] p value of the factor.

Each analysis—correlation, regression analysis and ANCOVAs—indicated a large effect size ($r > 0.5$, $f^2 > 0.7$, and $f > 0.5$, respectively). Individual grades significantly correlated across all three exams (high school exit exam [HSE], preclinical board exam [PBE], and final semester exam [FSE]).

Our study shows that students who kept an earlier sleep-wake schedule during the 2 wks prior to their end-of-semester exam were more likely to achieve better grades. Chronotype (MSF_{sc}) had no association with exam performance. Notably, chronotype and exam performance correlate in German high school graduates (the earlier the better the grade; Randler & Frech, 2006). An association between morning-evening preference and exam performance in university students has already been reported in a study based on a one-time two-page questionnaire (Eliasson & Lettieri, 2010). Since a one-time questionnaire may lead to biased answers (e.g., towards socially acceptable norms), we used detailed daily activity diaries for three 2-wk periods (during the semester, pre-exam, and in the semester break). The fact that sleep timing was the only predictor of performance in our study is remarkable. The amount of time students reported studying, sleep quality, sleep duration, or age would have been reasonable additional candidates, but neither associated with exam performance (despite large interindividual differences in study time: 24 min to 8 h; sleep quality: 0 to 10; and sleep duration: 6.2 to 10 h).

Early-types are traditionally associated with higher performance (e.g., "The early bird catches the worm"). Although our results confirm this traditional belief regarding the acute sleep-wake behavior of the students—especially during the period when studying for their exam, we did not find an association with their chronotype (MSF_{sc}; assessed by the MCTQ), i.e., with the phase of how their individual body clocks synchronize to the light-dark cycle. This apparent contradiction suggests that the positive correlation between an early start of the day and exam performance represents how well students adapt/conform to a busy university schedule. The early starters did not study more than other students but possibly visited university classes more diligently and learnt more efficiently (all students studied significantly more in the pre-exam period than during the semester). This assumption is supported by reports from other studies. Amount of alcohol consumption was shown to be the strongest predictor for academic performance in college students in the United States, with heavy drinkers also being more likely to report later bedtimes and wake times (Onyper et al., 2012; Singleton & Wolfson, 2009).

Besides actual sleep-wake timing, performance history is another strong predictor for exam grades. The preclinical board exam grade correlated significantly with the grades of the semester exams.

Subjective sleep quality and sleep duration did not significantly correlate with exam performance. It seems that the timing of the actual sleep-wake behavior or its implications have a larger influence on exam grades than sleep itself. However, it is noticeable that 23% of the students in our sample had a high sleep quality index (PSQI > 5), indicating a significant sleep problem or disorder. The fact that we found no correlations between exam performance and sleep (duration and quality) does not rule out that these effects exist but that their impact is smaller than that of the timing of the actual sleep-wake behavior and may have not been detectable due the relatively small sample size of our study. Medeiros and colleagues (2001) reported a strong correlation between sleep onset and academic performance and only a very weak correlation between sleep length, irregularity of sleep, and academic performance. In a secondary analysis, we did find a correlation between sleep quality and preclinical board exam grades. Notably, the sleep quality was assessed more than a year after the board exams, diminishing the explanatory power of this result. It is also an open question whether poor grades lead to lower sleep quality or vice versa.

Caveats

The results of this study should be viewed with some caution concerning sample size and gender bias. Due to the extensive questionnaire and data load, only 10% of the student population was able to participate. Notably, other studies, applying a combination of sleep diaries and questionnaires to comparable sample sizes, reported similar results (Lima et al., 2002; Medeiros et al., 2001). The overrepresentation of women (78%) faithfully mirrors the current gender distribution in German medical schools.

CONCLUSION

In summary, our study shows that the timing of the actual sleep-wake behavior and not chronotype is a predictor for academic performance in medical school. Sleep quality, sleep length, and study time surprisingly did not show a significant influence on academic performance, but this negative result has to be validated in future studies with more participants.

ACKNOWLEDGEMENTS

We would like to thank Prof. M Siebeck and Prof. R Schmidtmeier for their help recruiting the students and providing other information.

DECLARATION OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Journal of Psychiatric Research 46 (2012) 1618–1622

Contents lists available at SciVerse ScienceDirect

Journal of Psychiatric Research

journal homepage: www.elsevier.com/locate/psychires

The interaction between sleep quality and academic performance

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ARTICLE INFO

Article history:
Received 30 April 2012
Received in revised form
11 September 2012
Accepted 12 September 2012

Keywords:
Sleep quality
University
PSQI
Grades
Education
stress

ABSTRACT

Sleep quality has significant effects on cognitive performance and is influenced by multiple factors such as stress. Contrary to the ideal, medical students and residents suffer from sleep deprivation and stress at times when they should achieve the greatest amount of learning. In order to examine the relationship between sleep quality and academic performance, 144 medical students undertaking the pre-clinical board exam answered a survey regarding their subjective sleep quality (Pittsburgh sleep quality index, PSQI), grades and subjective stress for three different time points: semester, pre- and post-exam. Academic performance correlated with stress and sleep quality pre-exam ($r = 0.276$, $p < 0.001$ and $r = 0.158$, $p < 0.03$, note that low performance meant low sleep quality and high stress), however not with the stress or sleep quality during the semester and post-exam. 59% of all participants exhibited clinically relevant sleep disturbances (PSQI > 5) during exam preparation compared to 29% during the semester and 8% post-exam. This study shows that in medical students it is not the generally poor sleepers, who perform worse in the medical board exams. Instead students who will perform worse on their exams seem to be more stressed and suffer from poor sleep quality. However, poor sleep quality may negatively impact test performance as well, creating a vicious circle. Furthermore, the rate of sleep disturbances in medical students should be cause for intervention.

1. Introduction

Many findings in recent years point toward the importance of sleep for memory consolidation: Sleep seems to stabilize as well as enhance a wide variety of memory contents (Diekelmann and Born, 2010). Not only the consolidation of memories, also the encoding itself is negatively influenced by sleep deprivation (Van Der Werf et al., 2009; Yoo et al., 2007; Van Der Werf et al., 2011). Furthermore, sleep inspires insight into hidden rules and facilitates generalization of knowledge (Ellenbogen et al., 2007; Gómez et al., 2006; Wagner et al., 2004). All these cognitive competences are of great importance during higher education, often considered the most demanding and challenging learning period in many people's life. Especially medical students are expected to retain a large amount of complex factual knowledge in a comparably short time period.

Many studies strongly suggest that timing of sleep as well as its quality and quantity are linked with students' learning abilities and academic achievement and that students are often chronically sleep deprived (Curcio et al., 2006; Wolfson and Carskadon, 2003). Studies have indicated that over 60% of college students were poor-quality sleepers, resulting in daytime sleepiness and an increase of physical and psychological health problems (Lund et al., 2010; Sing and Wong, 2010). Another study investigating medical-students could not only show significant sleep disturbances, these problems were also related to depressive symptoms (Eller et al., 2006). Beebe et al. (2010) restricted sleep in a simulated classroom, which led to lower quiz scores, more inattentive behaviors and lower arousal. Due to an impressive workload sleep disturbances seem especially prevalent in medical students and residents (Nojomi et al., 2009), an alarming fact considering the clinical responsibilities of these populations. People working in medical fields also often suffer from large amounts of stress; and stress and sleep have long time been known to co-enact with each other (Friedman et al., 1995; Hall et al., 2000; Kachikis and Breitkopf, 2012; Morin et al., 2003; Van Reeth et al., 2000; Kashani et al., 2011). Acute and chronic stressors have pronounced effects on sleep architecture and circadian rhythms and sleep deprivation is a stressor (Van Reeth et al., 2000). Both sleep and stress are closely linked to the hypothalamo-pituitary-adrenal (HPA) axis, which explains the close interrelationship between these two factors (Steiger, 2003; Van Reeth et al., 2000).

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http://dx.doi.org/10.1016/j.jpsychires.2012.09.008

In a recent study (Genzel et al., sub) investigating circadian rhythms and academic performance in a side-analysis we observed a significant correlation between current sleep quality and performance in the pre-clinical board exam in medical school. However, the sleep quality was assessed over one year after the board exams, and a causal relationship could not be determined. We therefore investigated in a new sample the sleep quality and stress levels in students before, during and after exam preparation for the pre-clinical board-exams with the goal to further clarify the relationship between sleep, stress and academic performance.

2. Methods

2.1. Procedures

The pre-clinical board-exam is the first comprehensive examination within medical school in Germany and takes place after four semesters. During the preceding 2 months no classes are scheduled to enable a free learning period. The successful completion of the exams allows medical students to enter clinical training.

For this study, 943 medical students of the University of Munich, who were eligible to take the pre-clinical board-exams, were asked to participate in a web-based survey. Of the 943 students 632 took the actual exams. Students were invited to fill out the survey for three different points of time: during the semester, during the preparation phase for their exam (pre-exam) and 8 weeks after completion of the exam (post-exam). In total, 144 students (95 females, age 19–31 yrs, mean ± SD 22.4 ± 2.48) completed the survey for all three time points. The survey included a 10-point rating stress-scale, questions about the pre-clinical board-exam-grade, sociodemographic characteristics and the Pittsburgh sleep quality index (PSQI) as a measure of subjective sleep quality (Buysse et al., 1989). The PSQI comprises 10 questions related to sleep habits over a one-month period. It includes subscales assessing sleep latency, sleep duration, sleep disturbances, and daytime-dysfunction. Several psychometric aspects of the PSQI have been investigated and reported, such as internal consistency, reliability and construct validity, and stability over 1 year among a population-based sample (Curcio et al., in press; Backhaus et al., 2002; Buysse et al., 1989; Knutson et al., 2006; Carpenter and Andrykowski, 1998). A global score above 5 has been found to be a reliable and validated indicator for clinically relevant pathological sleep (Backhaus et al., 2002; Curcio et al., in press; Aloba et al., 2007). Academic performance was reported in the German grade system which ranges from 1 to 5 with 1 being the best grade.

For the semester the students filled out the PSQI and stress scale considering the time period from April until July. The pre-exam questionnaires could be filled out for 7 days prior to the exam and the students were asked to consider the previous 4 weeks, while the post-exam questionnaires were sent out 8 weeks after the exam and again the students were asked to consider the previous 4 weeks. Each time the students had a 1 week period to fill out the questionnaires.

The Ethics Committee of the Ludwig-Maximilian-University Faculty of Medicine, Munich/Germany, approved this research project and the study was carried out in accordance with the latest version of the Declaration of Helsinki.

2.2. Statistics

We performed one-tailed spearman correlation analyses between the variables grade, stress and PSQI. Partial correlation with the variables grade and stress/PSQI with PSQI and stress respectively as covariates were additionally calculated. Further, we calculated a MANOVA with within-subject factor time with three levels (semester, pre-exam, post-exam), between-subject factor grades with two levels (≥median, <median) and the dependent variables stress and PSQI. Sleep latency and length was extracted from the PSQI questionnaires and changes across time (semester, pre-exam, post-exam) in sleep latency, sleep length and percentage of students with PSQI > 5 was tested with ANOVAs with repeated measures.

3. Results

The average grade of the 144 students in this study did not significantly differ from the grades achieved by all 632 students taking the exam at the university (mean ± SD 2.57 ± .88 and 2.61 ± .78 respectively, $T_{774} = 0.595$, $P > 0.5$).

Academic performance was associated with the level of stress and sleep quality pre-exam (stress: $r = 0.276$, $P < 0.001$; PSQI: $r = 0.158$; $P < 0.03$; note that low performance meant low sleep quality and high stress, see Fig. 1), however not during the semester or post-exam (stress: $r = 0.094$ $P > 0.1$, $r = -0.074$ $P > 0.1$; PSQI: $r = 0.027$, $P > 0.3$; $r = 0.023$, $P > 0.3$ for the semester and post-exam respectively). Stress levels correlated with the respective sleep quality for each investigated time period (semester: $r = 0.348$, $P < 0.001$; pre-exam: $r = 0.227$, $P = 0.003$; post-exam: $r = 0.367$, $P < 0.001$). After including PSQI pre-exam as covariate in a partial correlation stress pre-exam still correlated significantly with exam grade ($r = 0.203$, $P = 0.008$), while the partial correlation between PSQI pre-exam and exam grade with stress pre-exam as covariate only remained marginally significant ($r = 0.110$, $P = 0.095$).

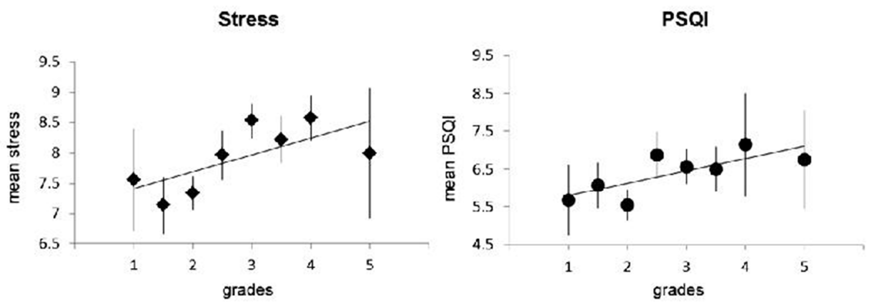

Fig. 1. Shown are the significant correlations between stress pre-exam (left panel) and subjective sleep quality pre-exam (PSQI, right panel) with the academic performance (grade). stress: $r = 0.276$, $P < 0.001$; PSQI: $r = 0.158$; $P < 0.03$. Note that low performance (1 is the best grade) meant low sleep quality (high PSQI) and high stress. PSQI and stress are presented as the mean and SEM of the 144 students for the different possible grades (1–5 in 0.5 steps).

During exam preparation 59% of the students exhibited poor sleep quality (PSQI > 5) with a mean PSQI score of 6.3 ± 2.6, whereas the percentage of poor sleepers was at 29% (mean PSQI score 4.6 ± 2.3) during the semester and dropped to 8% post-exam (mean PSQI score 3.1 ± 1.9; see Fig. 2B). An ANOVA showed a significant effect of time on the percentage of poor sleepers ($F_{2,142} = 71.106$, $P < 0.001$) and the pairwise comparisons showed that each time point significantly differed from each other time point (all $P < 0.001$). The subscales contributing primarily to these high PSQI-scores were sleep latency (see Fig. 2A), day dysfunction due to sleepiness and subjective sleep quality. There was a significant effect of time (semester, pre-exam, post-exam: $F_{2,142} = 55.580$, $P < 0.001$) on sleep latency. Pairwise comparisons showed that sleep latency at each time point significantly differed from each other time point (pre-exam–semester: $T_{143} = 3.723$, $P < 0.001$; pre-exam–post-exam: $T_{143} = 9.118$, $P < 0.001$; semester–post-exam: $T_{143} = 5.007$, $P < 0.001$).

Mean total sleep time during the three time points "semester", "pre-exam" and "post-exam" were 7.8 h ± 0.95, 7.3 h ± 0.93 and 8.6 h ± 1.03 respectively. There was a significant effect of time ($F_{2,142} = 68.709$, $P < 0.001$) on sleep length and subsequent *T*-tests could show that each time point was significantly different than each other time point (pre-exam–semester: $T_{143} = -3.757$, $P < 0.001$; pre-exam–post-exam: $T_{143} = -11.710$, $P < 0.001$; semester–post-exam: $T_{143} = -6.967$, $P < 0.001$).

A MANOVA with within-subject factor time and between-subject factor grade (divided into 2 groups: ≥median, <median) with the repeated measures of stress and PSQI showed a significant time and time × grade effect on the variables (time: $F_{4,139} = 182.97$, $P < 0.001$, time × grade $F_{4,139} = 2.453$, $P < 0.05$, grade: $F_{4,139} = 2.122$, $P = 0.124$; see Fig. 3). In 2-tailed post-hoc *T*-test the two groups differed significantly on the values of PSQI and stress pre-exam (PSQI: $T_{142} = 2.258$, $P = 0.025$; stress: $T_{142} = 3.216$, $P = 0.002$), however not during the semester or post-exam (all $T_{142} < 0.5$, $P > 0.6$).

4. Discussion

This study showed that academic performance is linked to sleep quality and stress prior to the exam. Both stress and sleep quality correlated with exam grades, note that low performance meant low sleep quality and high stress; yet, this relationship was not found for the other time points. It seems however that those students who generally sleep poorly do not receive bad grades. Perceived stress has been identified as one major factor contributing to these low scores in sleep quality, resulting in delayed sleep onset, increased day dysfunction due to sleepiness and reduced subjective sleep quality. In all three time points, stress levels correlated with the PSQI-score, supporting previous findings suggesting a close relationship between these two factors (Vandekerckhove and Cluydts, 2010). Most medical students prepare for their exams by practicing old exam questions, so their performance during studying allows a prediction of their exam grades. Possibly, students, who are expecting lower grades, are likely to suffer from higher stress, resulting at the same time in worse sleeping quality. The high stress and low sleep quality in turn could negatively influence exam preparation and performance, which again negatively influences stress and sleep quality. The outcome is a vicious circle requiring intervention. Another explanation could be that students, who are more resistant to stressors and stay more relaxed and less stressed pre-exam, perform on a higher level on the exam. It might be that it is poor sleep quality that actually affects performance mediated by the negative effect of stress on sleep. Alternatively, poor sleep quality might increase stress resulting from sleep deprivation and stress in turn might affect performance. Also, stress and sleep might independently influence academic performance. Many studies have found a close relationship between sleep and stress (Friedman et al., 1995; Hall et al., 2000; Kachikis and Breitkopf, 2012; Morin et al., 2003; Van Reeth et al., 2000; Kashani et al., 2011). Acute and chronic stressors have pronounced effects on sleep architecture and circadian rhythms and sleep deprivation is a stressor (Van Reeth et al., 2000). Acute stress is accompanied by a decrease in slow wave and REM sleep and after recovery a rebound of these stages is seen (Van Reeth et al., 2000). Both sleep and stress are closely linked to the hypothalamo-pituitary-adrenal (HPA) axis, which explains the close interrelationship between these two factors (Steiger, 2003; Van Reeth et al., 2000). Stress-induced elevation of plasma ACTH is associated with an increase in REM sleep and to a lesser extent in SWS sleep (Van Reeth et al., 2000). With sleep deprivation the modulatory effect of sleep–wake transitions on cortisol release are absent resulting in reduced amplitude of the cortisol profile in the

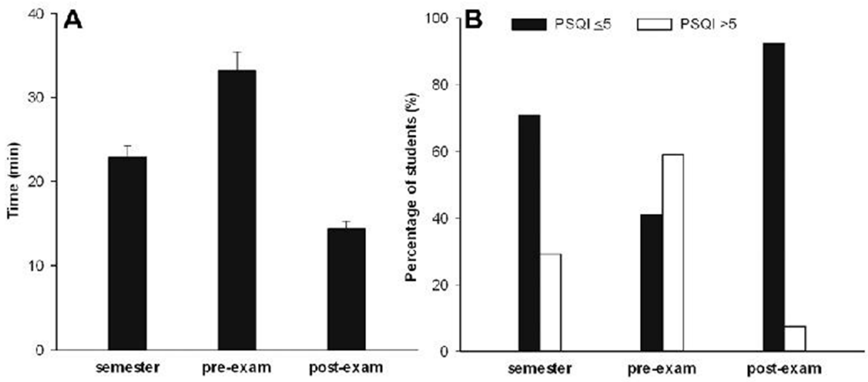

Fig. 2. A. Shown is the mean sleep latency with SEM for the three different time points: the preceding semester, pre- and post-exam, which was 8 weeks later during the semester break. During the four weeks prior the exam (pre-exam) the average sleep latency reach pathological values (>30 min). Sleep latency at each time point differed significantly from each other time point ($p < 0.001$). B. The figure shows the percentage of students with a sleep quality index below or above 5 points at three different time points: during the preceding semester, pre- and post-exam. The post-exam assessment was 8 weeks after the exam during the semester vacation. Sleep quality was assessed with the use of the Pittsburgh sleep quality index (PSQI). A global score greater than 5 is a strong indicator for clinically relevant sleep disturbances. The percentage of students with poor sleep quality was significantly different for the three time points ($p < 0.001$).

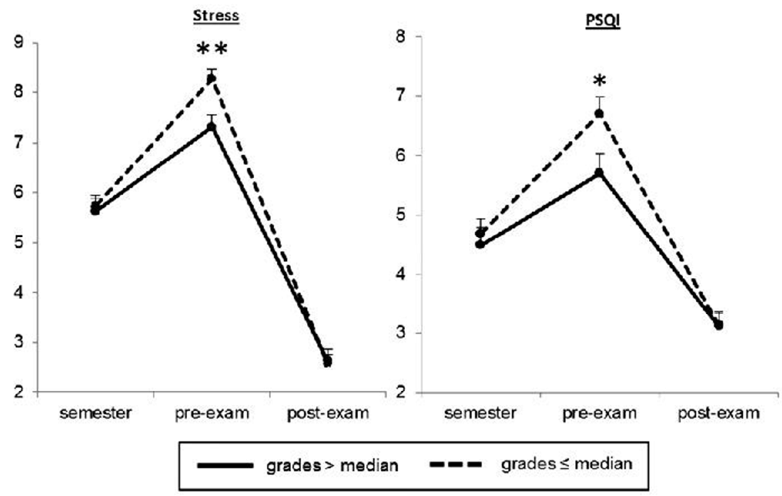

Fig. 3. Shown are the mean stress and PSQI values with SEM for the three different time points. The students were divided into two groups according to their grades in the board exams. The MANOVA showed a significant time and time × grade effect on the variables (time: $F_{4,139} = 182.97$, $P < 0.001$, time × grade $F_{4,139} = 2.453$, $P < 0.05$, grade: $F_{4,139} = 2.122$, $P = 0.124$) and post-hoc *T*-test revealed that the two groups had significantly different stress and PSQI values pre-exam but not during the semester or post-exam. *$P < 0.05$, **$P < 0.01$.

morning and elevated cortisol the following evening (Van Reeth et al., 2000).

The causal relationship between sleep, stress and academic performance remains unknown and cannot be determined by this study. However, the results do further underline the significant interaction between these factors. Perhaps students would benefit from a cognitive-behavioral approach e.g. meditation or progressive muscle relaxation reducing stress and therefore increasing sleep quality. By increasing sleep quality a positive foundation for memory consolidation and exam performance would be created. Of note, the correlation coefficients were below 0.3 in this study which can be considered as small to medium effect size and may not have reached significance with a smaller population. The Spearman correlations were calculated 1-tailed and the correlation between PSQI and grades would only have reached significance 2-tailed with a sample size of more than 240. However, since other factors as intelligence, previous knowledge, study time etc. should have the largest effect on grades, our findings seem comparatively large. The association between stress and exam grade seemed stronger than PSQI and the grade, especially noticeable in the partial correlations correcting for each the other variable (PSQI for stress/stress for PSQI). Only the stress and grade correlation remained significant with the correlation between PSQI and grades achieving marginal significance. However, including PSQI as covariate did decrease the correlation between stress and grades suggesting that the two factors sleep quality and stress may have a co-acting effect on grades.

More than half of the students pre-exam and almost one-third during semester had a pathological PSQI-score above the clinical cut-off. Our results are consistent with recent studies showing sleep disturbances in more than fifty percent in college populations (Lund et al., 2010; Sing and Wong, 2010). Poor sleep quality in medical students has been related to depressive symptoms and – in females – symptoms of anxiety (Eller et al., 2006). Sleep disturbances are important symptoms in many psychiatric diseases e.g. mood and anxiety disorders (Steiger, 2007). Since sleep disturbances often precede other signs of a depressive disorder, some authors hypothesize that these sleep disturbance may actually cause the drop in mood or that hormone changes first cause sleep disturbances and consecutively the change in mood (Steiger, 2007; Manber and Chambers, 2009).

The questionnaires in this study were sent out to 943 students, who were eligible to take the board exams. Of these 632 students actually took the board exams and again of these 144 students filled out all questionnaires of the study. This results in a return rate of 23%. The average grade of our population was 2.57 in comparison to 2.61 of all students, and they did not significantly differ. This would suggest that our sample is a representative of the general population but perhaps they might be part of a specific subgroup (e.g. having sleep problems, being extraordinary conscientious), which led to their participation in this study.

In our previous study (Genzel et al., sub) we observed a significant correlation between sleep quality during the semester and performance during the pre-clinical board exam in medical school. However, the sleep quality was assessed over one year after the board exams and a causal relationship could not be determined, which led to the current study. In the current study we did not find any relationship between general sleep quality during the semester and the academic performance in the board exam. This difference is surprising, especially since the PSQI during the semester and the grades of both study populations were very similar (PSQI: 4.28 and 4.6, grade: 2.73 and 2.57). We cannot explain this discrepancy; however, we do believe the current results to be more accurate since it was the main focus of the study and not a side-finding as in the previous study and the number of participants is higher (144 vs. 31 students).

To summarize, this study investigated the interrelationship of exam performance, sleep quality and stress. We could show that sleep quality and stress directly prior to the exam but not during the semester or after the exam is linked with exam performance. Medical students present with sleep quality issues, which have so far been overlooked should be addressed by the medical community.

Author disclosure

All authors report no conflict of interest.

Contributors

K.A. and L.G. designed, performed and analyzed the study. K.A. wrote the first draft of the article. S.N., A.S and M.D. helped design and analyze the study. All authors contributed to writing and discussing the article.

Role of the funding source

The study was funded by the Max Planck Institute of Psychiatry.

Acknowledgments

We would like to thank Karin Samson for the help recruiting the subjects. Further we would like to thank the participants for answering the questionnaire.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jpsychires.2012.09.008.

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4. Danksagung

An erster Stelle danke ich Herrn Prof. Holsboer und meinen Doktorvater Prof. Steiger für die optimalen Arbeitsbedingungen und die Möglichkeit am Max-Planck-Institut für Psychiatrie zu promovieren. Während des gesamten Forschungsaufenthalts stand Prof. Steiger mir bei Fragen und Problemen sofort zur Seite, was die Arbeit ungemein bereicherte. Einen ganz besonderen Dank möchte ich außerdem meiner Betreuerin, Dr. med. Lisa Genzel, aussprechen. Ohne sie und ihre großartigen Betreuung und Zusammenarbeit wäre vieles nicht so weit gekommen. Nicht vergessen will ich zudem alle Mitarbeiter der AG Steiger für ihre konstruktiver Kritik und stetige Hilfe.

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