Chronic sleep reduction is associated with academic achievement and study concentration in higher education students

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SUMMARY

Inadequate sleep impairs cognitive function and has been associated with worse academic achievement in higher education students; however, studies that control for relevant background factors and include knowledge on sleep hygiene are scarce. This study examined the association of chronic sleep reduction (i.e. symptoms of chronic sleep reduction such as shortness of sleep, sleepiness and irritation), subjective sleep quality and sleep hygiene knowledge with academic achievement (grades and study credits) and study concentration among 1378 higher education students (71% female, mean age 21.73 years, SD = 3.22) in the Netherlands. Demographic, health, lifestyle and study behaviour characteristics were included as covariates in hierarchical regression analyses. After controlling for significant covariates, only chronic sleep reduction remained a significant predictor of lower grades (last exam, average in current academic year). Better sleep quality and sleep hygiene knowledge were associated with better academic achievement, but significance was lost after controlling for covariates, except for a remaining positive association between sleep hygiene beliefs and grades in the current academic year. Moreover, better sleep quality and lower scores on chronic sleep reduction were associated with better study concentration after controlling for significant covariates. To conclude, chronic sleep reduction is associated with academic achievement and study concentration in higher education students. Inadequate sleep hygiene knowledge is moderately associated with worse academic achievement. Future research should investigate whether sleep hygiene interventions improve academic achievement in students of higher education.

INTRODUCTION

Experimental studies that manipulated sleep in healthy adults through total or partial sleep deprivation have found performance declines across a wide range of cognitive functions, such as attention, processing speed, working memory and short-term memory (Lim and Dinges, 2010). Students in higher education are required to perform

cognitively at demanding levels; however, they often suffer from sleep curtailment (Zeek *et al.*, 2015) and insomnia (Jiang *et al.*, 2015) due to lifestyle preferences, such as nightlife activities and use of drugs that increase stimulation and alertness prior to sleep onset, or use of alcohol, which is a depressant that, notwithstanding weak positive effects on sleep onset, has deteriorating effects on sleep quality (Hershner and Chervin, 2014). Adolescents and young adults tend to have a delayed circadian preference, physiologically related with puberty development, which increases susceptibility for delayed sleep–wake rhythm, sleep curtailment and increased daytime sleepiness (Hershner and Chervin, 2014).

In primary and secondary school students, impaired sleep quantity and quality were associated with decreased academic achievement (meta-analysis; Astill *et al.*, 2012), while sleep interventions resulted in positive effects on academic achievement and working memory (de Bruin *et al.*, 2017). Studies in higher education students are more scarce, and demonstrated that sleep quality and quantity were positively associated with academic achievement (Ahrberg *et al.*, 2012; Baert *et al.*, 2015; Genzel *et al.*, 2013; Gomes *et al.*, 2011; Lemma *et al.*, 2014; Valic *et al.*, 2014; Wong *et al.*, 2013), with two exceptions revealing no significant associations (Eliasson *et al.*, 2010; Trockel *et al.*, 2000). To date, very few studies have controlled for other potential predictors of academic achievement and sleep, such as health, lifestyle and academic behaviour. A recent study, which controlled for general and psychological health, revealed that increments of total sleep quality predicted a higher course mark later in the academic year (Baert *et al.*, 2015). Ahrberg *et al.* (2012) showed that after inclusion of pre-exam stress as a covariate, the association of sleep quality and exam grade lost significance. Possibly, poor sleep quality might have increased stress resulting from sleep deprivation and stress in turn affected performance, or students expecting lower grades might have experienced higher stress, resulting in worse sleep quality. The findings indicate that in order to investigate the association between sleep and academic achievement, it is important to take other health, lifestyle and academic behaviour factors into account.

The main aim of this study was to investigate the association of chronic sleep reduction, sleep quality and sleep hygiene knowledge with academic achievement and study concentration in a population of higher education students. Our study adds to the existing literature by: (1) controlling for important factors that influenced academic achievement and/or sleep, such as health, lifestyle and academic behaviour; (2) obtaining multiple measures of academic performance, in accordance with previous recommendations (Wolfson and Carskadon, 2003); (3) assessing sleep quality as well as chronic sleep reduction (symptoms of tiredness, sleepiness, loss of energy and emotional instability); (4) including a measure of sleep hygiene knowledge in order to identify specific beliefs that are unfavourable to healthy sleep. Dysfunctional beliefs about sleep interact with physical and psychological risk factors to disturb sleep, and contribute to development and maintenance of disordered sleep and to reduced academic achievement (Eidelman *et al.*, 2016). The results might provide more insight into appropriate sleep education components for students in order to improve sleep and potentially academic achievement.

MATERIALS AND METHODS

Participants

The sample consisted of 1378 students, of which 71% were female (57% female in Dutch higher education; Central Agency for Statistics http://statline.cbs.nl/Statweb/?LA=en). Participants were aged between 17 and 56 years (M = 21.73 years, SD = 3.22, 98.5% below 30 years), of which the majority (95%) were born in the Netherlands. Eighty-two percent were enrolled in a Bachelor's degree programme, and 18% studied at Master's degree level. A wide range of disciplines was included: 35% social sciences, business and law; 24% education, health and welfare studies; 15% physics, mathematics and computer science; 12% technology, engineering and construction; 8% linguistics, history and art studies; 6% other.

Procedure

During December 2015 to February 2016, students were approached with flyers, advertisements in newsletters and on websites of institutions for higher education across the Netherlands and via student associations. After written informed consent was provided, students anonymously completed an online survey. Participation was voluntary, and 10 gift cards were raffled. Ethical approval was given by the institutional review board of Leiden University.

Instruments

The online survey consisted of several sections, which are described below.

Academic achievement

Academic achievement was based on self-reported information regarding average grade and last exam grade in the current academic year (2015–2016). Furthermore, students were asked about their average grade (scale 1–10) and achieved credits (ECTS) in the past academic year (2014–2015) if they were already enrolled in the same educational programme. Self-reported grades in high school students were previously found to be a good estimate of actual grades, especially among older adolescents and students with better grades (Escribano and Diaz-Morales, 2014).

Study concentration

Students' subjective concentration was assessed with the subscale Concentration of the Learning and Study Strategies Inventory Second Edition (LASSI; Weinstein and Palmer, 2002). It consists of eight items addressing student's ability to concentrate and maintain focused during academic tasks (e.g. 'My mind wanders a lot when I study'). Using five-point Likert scales, students indicated their degree of agreement with the statements (1: 'not at all typical of me' to 5: 'very much typical of me'). After recoding negatively stated items, the scores were summed yielding a continuous variable ranging from 8 to 40. Low scores indicate poor concentration and little ability to deal with distracting thoughts and feelings when performing study activities. Cronbach's alpha for the individual Concentration subscale was high (0.83), and predictive validity of the Concentration subscale regarding university student performance has been demonstrated (Loomis, 2000).

Chronic sleep reduction

The Chronic Sleep Reduction Questionnaire (CSRQ) is a 20-item self-report questionnaire to measure symptoms of chronic sleep reduction, such as shortness of sleep, loss of energy, sleepiness and irritation during the previous 2 weeks (Meijer, 2008), with four subscales: shortness of sleep (six items; e.g. 'I am a person who does not get enough sleep'); sleepiness (four items; e.g. 'Do you feel sleepy during the day?'); loss of energy (five items; e.g. 'I am active during the day'); and irritation (five items; e.g. 'Others think that I am easily irritated'). The CSRQ does not inform about the specific type of sleep problem, for example, insomnia, circadian or sleep apnea. All items have an ordinal three-point response scale (1–3), and form a total CSRQ score ranging from 20 to 60 (higher scores, stronger indication of chronic sleep reduction). Psychometric properties of the CSRQ were shown to be satisfactory (Meijer, 2008). Cronbach's alpha in the current sample was 0.83.

Sleep quality

Sleep quality and sleep disturbances during the past month were assessed with the Pittsburgh Sleep Quality Index (PSQI; Buysse *et al.*, 1989), which consists of 19 items resulting in seven component scores (0–3) about subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. The sum of all component scores yields a global score (range 0–21), with higher scores indicating worse sleep quality. The PSQI is widely used, and has good internal consistency, test–retest reliability and moderate validity (Dietch *et al.*, 2016). Cronbach's alpha in the current sample was 0.72.

Sleep hygiene knowledge

The Sleep Beliefs Scale (SBS) is a 20-item questionnaire that explores the participants' knowledge on the influence of specific factors on sleep, such as consumption behaviours (alcohol, caffeine, nicotine, sleep medication), diurnal behaviours (physical exercise and naps), and activities and thoughts prior to sleep (eating, studying, relaxing, worries; Adan *et al.*, 2006). For all items, the participants selected whether they believed it has no effect, a positive effect or a negative effect on the quantity and/or quality of peoples' sleep in general. A score (range 0–20) is obtained by means of 1 point for each correct item. Higher scores correspond to better knowledge on sleep hygiene. Psychometric properties of the SBS were tested in university students and were shown to be good (Adan *et al.*, 2006). Cronbach's alpha in the current sample was 0.76.

Lifestyle, health and academic behaviour

Lifestyle, health and academic behaviour were assessed to control for in analyses on sleep and academic performance associations. Lifestyle: alcohol and drugs consumption both measured with a single item with an ordinal five-point response scale (0: 'never' to 4: 'four times a week or more'), in accordance with the self-report Drug Use Disorders Identification Test (Berman *et al.*, 2005) and the Alcohol Use Disorders Identification Test (Bohn *et al.*, 1995). Health: students indicated the presence of chronic physical illnesses or disorders, and diagnoses of mental health disorders, such as attention deficit hyperactivity disorder, depression, or anxiety disorder after clinical investigation by a psychiatrist, psychologist or physician on single items ('yes' or 'no'). Academic behaviour: students were asked to indicate the time (h per week) they usually spent on self-study (including assignments) and contact hours (i.e. on-campus, face-to-face time with teaching staff in lectures or workgroups). Intrinsic study motivation was assessed using the six-item Personal Development Scale (Lee and Pang, 2014), test anxiety using the five-item Test Anxiety Scale of the Motivated Strategies for Learning Questionnaire (Pintrich and De Groot, 1990), and perceived stress over the previous month using the four-item Perceived Stress Scale (Cohen *et al.*, 1983).

Statistical analyses

Hierarchical linear regression analyses were performed to investigate whether sleep characteristics (i.e. chronic sleep reduction, sleep quality and sleep hygiene knowledge) were associated with academic achievement (i.e. average grade and last exam grade current academic year, average grade and achieved credits past academic year) and study concentration, after controlling for significant covariates. Covariates that were included as binary variables were: sex, physical illness and/or psychiatric diagnosis, alcohol

consumption, drugs consumption. The latter two, originally measured on a five-point ordinal scale, were transformed to binary variables for meaningful analyses (i.e. some of the five-point categories included only small numbers of participants). For alcohol consumption, we created the categories 'never-rarely' (combination of 'never', 'monthly or less' and 'two-four times a month') and 'frequently' (combination of 'two-three times a week' and 'four or more times a week'). For drugs consumption, we created the categories 'never' and 'ever' (combination of 'monthly or less', 'two-four times a month', 'two-three times a week' and 'four or more times a week'). Continuous covariates were: time investment in study (self-study and contact hours combined); intrinsic study motivation; test anxiety; perceived stress. For the final hierarchical linear regression analyses, we first included only the covariates that were significant for each particular model, after which we entered the sleep variable of interest. Standardized regression coefficients (β) indicate effect sizes, which can be considered small: $\beta < 0.30$; moderate: $0.30 \leq \beta < 0.50$; or large: $\beta \geq 0.50$. Previous to these analyses, data were inspected to check for outliers, missing data

and assumptions applying to the statistical tests used, such as linearity, no multicollinearity and homoscedasticity, using descriptive statistics, histograms, scatterplots, correlation matrixes and residual plots. Only for the academic achievement indicators, some data were missing: last exam grade ($n = 22$); average grade current academic year ($n = 98$); average grade past academic year ($n = 7$); achieved credits ($n = 23$; data were not imputed). Non-normally distributed variables (all variables except CSRQ total score and time investment; Table 1) were successfully Blom-transformed to standardized scores. The analyses were conducted with the Statistical Package for Social Sciences version 23.0. An alpha value of 0.05 (two-sided) indicates statistical significance.

RESULTS

Sample characteristics and descriptive statistics of all variables are provided in Table 1. Fifty-four percent of the students had a global PSQI score greater than 5, which is indicative of poor sleep quality (Buysse et al., 1989). Pearson

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Table 1 Sample characteristics and descriptive statistics of the study variables

Sample characteristics	N = 1378						
Age	M = 21.7 years, SD = 3.2, range 17–56 years						
Sex	71%	female					
Physical illness and/or psychiatric diagnosis	30%						
Alcohol consumption	70%	Never-rarely					
	30%	Frequently					
Drugs consumption	79%	Never					
	21%	Ever					
Study degree level	82%	Bachelor					
	18%	Master					
	N	M	SD	Min.	Max.	Std. skewness	Std. kurtosis
Academic achievement*							
Last exam grade 2015–2016	1356	7.2	1.4	1.0	10.0	−13.1	11.9
Average grade 2015–2016	1280	7.1	1.0	2.0	10.0	−6.6	8.9
Average grade 2014–2015†	991	7.1	0.7	2.0	9.8	−7.8	32.0
Achieved credits 2014–2015†	975	54.6	15.2	2.0	100.0	−11.1	14.8
Study concentration							
LASSI total score	1378	23.9	5.7	9	40	1.1	−4.3
Sleep characteristics							
CSRQ total score	1378	36.2	6.7	21	56	2.5	3.0
PSQI global score	1378	6.4	3.4	0	21	12.9	5.5
SBS total score	1378	13.4	3.7	0	20	−12.0	5.5
Covariates							
Time investment (h per week)	1378	26.7	12.8	6	66	2.4	−2.6
Intrinsic motivation	1378	23.0	4.0	6	30	6.8	4.1
Test anxiety	1378	12.8	4.7	5	25	6.0	−3.4
Perceived stress	1378	6.6	3.0	0	16	4.0	−2.1

CSRQ, Chronic Sleep Reduction Questionnaire; LASSI, Learning and Study Strategies Inventory – Second Edition; PSQI, Pittsburgh Sleep Quality Index; SBS, Sleep Beliefs Scale.
*Grades vary between 1 and 10, the norm for one academic year is 60 credits according to the European Credit Transfer System.
†Applies to 998 students (72%) who followed the same study in the past academic year.

correlations showed a significant association between worse sleep quality (higher global PSQI score) and chronic sleep reduction ($r = 0.55$, $P < 0.001$). Sleep hygiene knowledge was not associated with PSQI scores ($r = 0.02$, $P = 0.510$) nor with the total CSRQ score ($r = -0.02$, $P = 0.502$). Better study concentration was positively associated with all four academic achievement indicators: exam grade ($r = 0.25$, $P < 0.001$); average grade current year ($r = 0.28$, $P < 0.001$); average grade past academic year ($r = 0.30$, $P < 0.001$); and study credits ($r = 0.20$, $P < 0.001$). Missing data analysis showed that students who did not report the average grade in the current academic year showed a lower time investment ($P = 0.002$) and reduced test anxiety ($P = 0.022$), but there were no differences in last exam grade in the current academic year, and average grade and achieved credits in the past academic year, compared with their counterparts.

Bivariate correlations were calculated between sleep characteristics, continuous covariates, and academic achievement and study concentration (Table 2). Higher chronic sleep reduction and worse sleep quality were both significantly associated with worse academic achievement (correlation coefficients from -0.09 to -0.18) and study concentration ($r = -0.30$ to -0.45). Better sleep hygiene knowledge was only positively associated ($r = 0.09$) with average grade in the current and past academic year. Furthermore, more time investment and higher intrinsic motivation were associated with better academic achievement ($r = 0.07$ to 0.17) and concentration ($r = 0.11$ to 0.19). Test anxiety and higher perceived stress were correlated with worse academic achievement ($r = -0.07$ to -0.20) and concentration ($r = -0.28$ to -0.33).

Independent-sample *t*-tests showed that academic achievement was significantly better for females than males, except for last exam grade (Table 3). Students with a physical illness and/or psychiatric diagnosis achieved less credits and reported worse concentration compared with healthy students. They did not differ on the other academic outcome measures. Academic achievement and study concentration of students who reported rare or no use of alcohol or no use of drugs were better than of students who took alcohol and drugs more frequently.

Academic achievement

Chronic sleep reduction

Total CSRQ score was a significant predictor for two out of four indicators of academic achievement, after controlling for the significant covariates (Table 4). These were last exam grade ($\beta = -0.07$, $t = -2.21$, $P = 0.027$, $n = 1356$) and average grade ($\beta = -0.07$, $t = -2.35$, $P = 0.019$, $n = 1280$) in the current academic year. The association between total CSRQ score and average grade ($\beta = -0.06$, $t = -1.80$, $P = 0.072$, $n = 991$) and achieved credits ($\beta = -0.01$, $t = -0.27$, $P = 0.789$, $n = 975$) in past academic year became non-significant after controlling for the covariates sex, physical illness and/or psychiatric diagnosis, alcohol consumption, time investment, intrinsic motivation, test anxiety and stress.

Sleep quality

Pittsburgh Sleep Quality Index global score lost significance as a predictor for academic achievement after controlling for significant covariates: last exam grade ($\beta = -0.05$, $t = -1.51$, $P = 0.131$, $n = 1356$); average grade in the current academic year ($\beta = -0.04$, $t = -1.28$, $P = 0.203$,

Table 2 Pearson correlations between sleep characteristics, covariates, academic achievement and study concentration

	Academic achievement				Study concentration LASSI total score[†] (n = 1378)
	Current academic year		Past academic year		
	Last exam grade (n = 1356)	Average grade (n = 1280)	Average grade (n = 991)	Achieved credits (n = 975)	
Sleep characteristics					
CSRQ total score[‡]	−0.16***	−0.18***	−0.14***	−0.12***	−0.45***
PSQI global score[‡]	−0.12***	−0.13***	−0.09**	−0.13***	−0.30***
SBS total score[§]	0.05	0.09**	0.09**	0.04	<0.01
Covariates					
Time investment (h per week)	0.10***	0.13***	0.14***	0.10**	0.11***
Intrinsic motivation	0.11***	0.14***	0.17***	0.07*	0.19***
Test anxiety	−0.18***	−0.20***	−0.18***	−0.15***	−0.33***
Perceived stress	−0.14***	−0.15***	−0.07*	−0.15***	−0.28***

CSRQ, Chronic Sleep Reduction Questionnaire; LASSI, Learning and Study Strategies Inventory – Second Edition; PSQI, Pittsburgh Sleep Quality Index; SBS, Sleep Beliefs Scale.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
[†]Higher score indicates better concentration.
[‡]Higher score indicates more chronic sleep reduction and worse sleep quality, respectively.
[§]Higher score indicates better sleep hygiene knowledge.

Table 3 Independent sample *t*-tests on academic achievement and study concentration

	Female			Male			t	df	P	d
	N	M	SD	N	M	SD				
Academic achievement										
Last exam grade 2015–2016	961	7.2	1.3	395	7.1	1.6	−0.8	1354	0.403	–
Average grade 2015–2016	910	7.1	1.0	370	7.0	1.0	−2.0	1278	0.047	0.12
Average grade 2014–2015*	699	7.2	0.7	292	7.0	0.8	−3.5	989	<0.001	0.26
Achieved credits 2014–2015*	685	55.1	14.8	290	53.2	16.1	−2.4	973	0.017	0.12
Study concentration										
LASSI total score	977	23.9	5.7	401	24.1	5.9	0.8	1376	0.419	–
	No physical illness and/or psychiatric diagnosis			Physical illness and/or psychiatric diagnosis						
Academic achievement										
Last exam grade 2015–2016	956	7.2	1.4	400	7.1	1.5	−0.25	1354	0.801	–
Average grade 2015–2016	903	7.1	0.9	377	7.0	1.1	1.56	1278	0.120	–
Average grade 2014–2015*	693	7.1	0.7	298	7.1	0.7	0.36	989	0.723	–
Achieved credits 2014–2015*	683	55.9	14.8	292	51.5	15.8	4.10	973	<0.001	0.28
Study concentration										
LASSI total score	971	24.3	5.5	407	23.1	6.1	3.83	1376	<0.001	0.22
	Alcohol consumption (never-rarely)			Alcohol consumption (frequently)						
Academic achievement										
Last exam grade 2015–2016	946	7.2	1.3	410	7.0	1.5	3.21	1354	0.001	0.20
Average grade 2015–2016	897	7.1	1.0	383	7.0	1.0	2.92	1278	0.004	0.19
Average grade 2014–2015*	677	7.2	0.7	314	7.0	0.7	2.81	989	0.005	0.20
Achieved credits 2014–2015*	665	55.3	15.3	310	53.0	15.0	2.47	973	0.014	0.15
Study concentration										
LASSI total score	960	24.4	5.7	418	22.9	5.6	4.58	1376	<0.001	0.27
	Drugs consumption (never)			Drugs consumption (ever)						
Academic achievement										
Last exam grade 2015–2016	1069	7.2	1.4	287	7.0	1.4	2.15	1354	0.032	0.13
Average grade 2015–2016	1006	7.1	1.0	274	6.9	1.0	2.72	1278	0.007	0.18
Average grade 2014–2015*	778	7.2	0.7	213	7.0	0.7	2.43	989	0.015	0.17
Achieved credits 2014–2015*	765	55.0	15.0	210	53.2	16.1	1.50	973	0.133	–
Study concentration										
LASSI total score	1087	24.3	5.7	291	22.6	5.8	4.43	1376	<0.001	0.29

Groups based on the binary covariates (sex, physical illness and/or psychiatric diagnosis, alcohol and drugs consumption).
LASSI, Learning and Study Strategies Inventory – Second Edition; grades vary between 1 (poor performance) and 10, and the norm for one academic year is 60 credits according to the European Credit Transfer System.
*Applies to 998 students (72%) who followed the same study in the past academic year.

$n = 1280$); average grade in the past academic year ($\beta = -0.03$, $t = -0.86$, $P = 0.389$, $n = 991$); and achieved credits ($\beta = -0.03$, $t = -0.88$, $P = 0.379$, $n = 975$).

Sleep hygiene knowledge

Sleep Beliefs Scale total score remained a significant predictor of average grade in the current academic year ($\beta = 0.07$, $t = 2.41$, $P = 0.016$, $n = 1280$), after controlling for significant covariates. For all other indicators of academic achievement, significance was lost after controlling for

significant covariates: last exam grade ($\beta = 0.04$, $t = 1.31$, $P = 0.188$, $n = 1356$); average grade in the past academic year ($\beta = 0.06$, $t = 1.90$, $P = 0.057$, $n = 991$); and achieved credits ($\beta = 0.03$, $t = 1.06$, $P = 0.289$, $n = 975$).

Study concentration

Chronic sleep reduction

Total CSRQ score was a significant predictor for study concentration as indicated by LASSI total score ($N = 1378$;

Table 4 Hierarchical regression analyses on academic achievement and study concentration

Sleep characteristics	Academic achievement	Model*	Model change statistics				
			ΔR^2	ΔF	df1	df2	P
CSRQ total score	Last exam grade 2015–2016	1[†]	0.065	18.89	5	1350	<0.001
		2	0.003	4.90	1	1349	**0.027**
	Average grade 2015–2016	1[‡]	0.091	21.21	6	1273	<0.001
		2	0.004	5.53	1	1272	**0.019**
	Average grade 2014–2015	1[§]	0.100	21.92	5	985	<0.001
		2	0.003	3.25	1	984	0.072
	Achieved credits 2014–2015	1[¶]	0.071	12.34	6	968	<0.001
		2	<0.001	0.07	1	967	0.789
PSQI global score	Last exam grade 2015–2016	1[†]	0.065	18.89	5	1350	<0.001
		2	0.002	2.29	1	1349	0.131
	Average grade 2015–2016	1[‡]	0.091	21.21	6	1273	<0.001
		2	0.001	1.63	1	1272	0.203
	Average grade 2014–2015	1[§]	0.100	21.92	5	985	<0.001
		2	0.001	0.74	1	984	0.389
	Achieved credits 2014–2015	1[¶]	0.071	12.34	6	968	<0.001
		2	0.001	0.78	1	967	0.379
SBS total score	Last exam grade 2015–2016	1[†]	0.065	18.89	5	1350	<0.001
		2	0.001	1.74	1	1349	0.188
	Average grade 2015–2016	1[‡]	0.091	21.21	6	1273	<0.001
		2	0.004	5.82	1	1272	**0.016**
	Average grade 2014–2015	1[§]	0.100	21.92	5	985	<0.001
		2	0.003	3.62	1	984	0.057
	Achieved credits 2014–2015	1[¶]	0.071	12.34	6	968	<0.001
		2	0.001	1.12	1	967	0.289
	Study concentration						
CSRQ total score	LASSI total score	1**	0.206	59.12	6	1371	<0.001
		2	0.078	148.49	1	1370	**<0.001**
PSQI global score	LASSI total score	1**	0.206	59.12	6	1371	<0.001
		2	0.018	30.89	1	1370	**<0.001**
SBS total score	LASSI total score	1**	0.206	59.12	6	1371	<0.001
		2	<0.001	0.67	1	1370	0.413

CSRQ, Chronic Sleep Reduction Questionnaire; LASSI, Learning and Study Strategies Inventory – Second Edition; PSQI, Pittsburgh Sleep Quality Index; SBS, Sleep Beliefs Scale.
*Hierarchical regression models: model 1 only contained significant covariates, and in model 2 the specific sleep characteristic is added to model 1. P-values are bold when addition of the specific sleep characteristic in model 2 is statistically significant.
[†]Covariates: alcohol consumption, time investment, intrinsic motivation, text anxiety, perceived stress.
[‡]Covariates: sex, alcohol consumption, time investment, intrinsic motivation, text anxiety, perceived stress.
[§]Covariates: sex, alcohol consumption, time investment, intrinsic motivation, text anxiety.
[¶]Covariates: sex, alcohol consumption, physical illness and/or psychiatric diagnosis, time investment, text anxiety, perceived stress.
**Covariates: alcohol consumption, drugs consumption, time investment, intrinsic motivation, text anxiety, perceived stress.

$\beta = -0.32$, $t = -12.19$, $P < 0.001$), after controlling for the significant covariates alcohol consumption, drugs consumption, time investment, intrinsic motivation, test anxiety and stress.

Sleep quality

Pittsburgh Sleep Quality Index global score was a significant predictor for study concentration as indicated by LASSI total score ($\beta = -0.15$, $t = -5.56$, $P < 0.001$), after controlling for the significant covariates alcohol consumption, drugs consumption, time investment, intrinsic motivation, test anxiety and stress.

Sleep hygiene knowledge

Prediction by SBS total score lost significance after controlling for the covariates ($\beta = -0.02$, $t = -0.82$, $P = 0.413$).

DISCUSSION

The aim of this study was to investigate the association of chronic sleep reduction, sleep quality and knowledge of sleep hygiene with academic achievement and subjective study concentration in higher education. In line with our hypotheses, regression analyses showed that chronic sleep reduction is associated with lower academic achievement even

after controlling for relevant covariates (demographic, health, lifestyle and study behaviour characteristics). This finding is important given that disturbed sleep is highly prevalent among higher education students (18.5%, versus 7.4% in the general population; Jiang *et al.*, 2015).

In contrast to our hypotheses, sleep quality was not significantly associated with any of the academic achievement parameters, after correction for relevant factors. This is in line with the study of Ahrberg *et al.* (2012), but in contrast to the majority of previous studies (Baert *et al.*, 2015; Genzel *et al.*, 2013; Lemma *et al.*, 2014), although most of these studies did not control for health, lifestyle and academic behaviour factors.

Our results regarding sleep quality appear incongruent with our significant findings for chronic sleep reduction. Although chronic sleep reduction and sleep quality are conceptually closely related ($r = 0.55$), the constructs show important differences. Sleep quality assessed with the PSQI involves a subjective opinion about the quality of sleep as well as a more objective account on sleep characteristics, whereas chronic sleep reduction merely comprises symptoms of sleep curtailment. Therefore, chronic sleep reduction in our study did not reflect the quality or quantity of sleep, but rather the extent to which the received sleep has been sufficient to the individual. The current findings suggest it is the experience of inadequacy or insufficiency of sleep that is predictive of academic achievement, in contrast to the more 'objective' measures of sleep. That notion is in line with a previous meta-analysis that revealed that the effects of sleepiness on school performance in children and adolescents were considerably larger than for sleep quality or duration (Dewald *et al.*, 2010).

Study concentration was related to chronic sleep reduction as well as to sleep quality, after adjustment for relevant factors. Previous studies showed that attention is the most sensitive cognitive domain for experimental sleep curtailment (Lim and Dinges, 2010). Furthermore, attention has shown to be important for academic achievement in higher education, given its role in information processing, memory, planning and study progress monitoring. Our findings suggest that chronic sleep reduction possibly affects academic achievement through a deteriorating effect on study concentration, although that model was not tested specifically, because a more profound analysis of the interrelationship of the various academic and sleep-related factors in this study is beyond the scope of this paper. Knowledge of sleep hygiene was a significant predictor of average grade in the current academic year, but not of study concentration, last exam grade, average grade or achieved credits in the past academic year. A previous study demonstrated that students with irregular sleep patterns – which is a component of sleep hygiene 'behaviour' (not of 'knowledge of' sleep hygiene) – showed reduced academic results (Medeiros *et al.*, 2001). However, another study failed to find such an association between sleep hygiene behaviour and academic performance (Eliasson *et al.*, 2010). Our results suggest that

inadequate 'knowledge of' sleep hygiene might be one of the underlying causes of chronic sleep reduction and reduced sleep quality in students, although we acknowledge that the role of sleep hygiene is probably moderate given that it was a significant predictor for only one out of five achievement measures. Although research addressing the direct effects of sleep hygiene interventions on academic achievement is currently lacking, there are studies indicating that education campaigns with a focus on sleep hygiene in college students exhibit beneficial effects on student sleep quality (Orzech *et al.*, 2011).

An unexpected finding was that, after controlling for covariates, both sleep hygiene knowledge and chronic sleep reduction were associated only with achievement measures of the current academic year and not of the past academic year. An explanation might be that measures of sleep hygiene knowledge and chronic sleep reduction were representative of the current situation and, therefore, showed stronger associations with current than with past achievement measures. This study has several strengths. First, the adjustment for health, lifestyle and academic behaviour factors, which was clearly relevant given that several associations that initially showed significance in correlation analyses without correction lost significance in the corrected regression analyses. Other strengths were the large sample size and the multi-measure approach, including multiple predictors within the domain of sleep and multiple outcome measures within the academic domain.

We also acknowledge several limitations. First, given the cross-sectional and correlational design, we need to remain cautious regarding inferences about causality. Secondly, all assessments relied on subjective retrospective self-reports, which might have inflated the associations between variables. Although prospective assessments with objective instruments are considered more reliable, long-term assessments of sleep over several weeks would have been more demanding for the participants and could have affected the participation rate. The addition of a sleep duration measure to this study could have been valuable. However, sleep duration measures in naturalistic studies have the limitation that their variation is partly due to individual differences in sleep need. Therefore, short sleep does not necessarily signify impaired sleep, but may also reflect a reduced need for sleep. Furthermore, subjective retrospective self-reports might have led to a social desirability bias, for example, by students reporting better grades than they actually achieved. Although self-reported grades in high school students were previously found to be a good estimate of actual grades, the reliability might be reduced in students with worse grades (Escribano and Diaz-Morales, 2014).

Thirdly, we assessed the students' knowledge of sleep hygiene instead of their sleep hygiene practice. A previous study found a significant but weak association between sleep hygiene knowledge and actual practice (Brown *et al.*, 2002). Adequate sleep hygiene knowledge does not necessarily translate into practice, partly because positive sleep hygiene

practices, such as a quiet environment and use of the bedroom only for sleep, may be challenging in student houses.

A note regarding the generalizability of our findings: we adopted an 'open' recruitment strategy via flyers, websites, etc. and therefore we were unable to gain insight into the proportion and characteristics of students that declined to participate. Nevertheless, average grades in our sample (7.1) were equal to those reported by the Dutch Ministry of Education, Culture and Science (http://www.studentenmoni tor.nl/tabellen/index.html), and PSQI scores were comparable to previous studies of higher education in other countries (Cates *et al.*, 2015; Lund *et al.*, 2010), which supports the generalizability.

To conclude, this study demonstrates that chronic sleep reduction is a predictor of worse academic achievement and subjective study concentration. Our findings show that inadequate knowledge of sleep hygiene is associated with worse performance on one of the academic achievement measures. Sleep education programmes for students might prevent or diminish chronic sleep reduction, and might therefore exert beneficial effects on cognitive functioning and academic achievement (Dewald-Kaufmann *et al.*, 2014). However, we emphasize that sleep education programmes do not suffice for individuals suffering from sleep disorders. In such cases, individualized and extensive sleep interventions are necessary, such as cognitive behavioural therapy for insomnia or light therapy (Geerdink *et al.*, 2016; Van Maanen *et al.*, 2016). Future studies should disentangle whether sleep education programmes are effective to improve sleep as well as academic achievement in higher education students, and whether inadequate sleep hygiene moderates the effectiveness of sleep education programmes.

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CONFLICT OF INTEREST

All authors declare no conflicts of interest.

AUTHOR CONTRIBUTIONS

All authors have contributed to this manuscript by one or more of the following activities: study design, data collection, data analysis, interpretation of results, preparation of the manuscript.

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