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Sleep disruption in medicine students and its relationship with impaired academic performance: a systematic review and meta-analysis.

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Conflict of interests

Authors have no conflicts to disclose.

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Summary

Sleep disruption severely impairs learning ability, affecting academic performance in students. This systematic review and meta-analysis aimed at assessing the prevalence of sleep disruption in medical students and its relationship with academic performance. PubMed, Web of Sciences, EBSCO and SciELO databases searches allowed to retrieve 41 papers with data about the prevalence of sleep deprivation, 20 of which also contained data on its association with academic performance. Poor sleep quality was reported by 5,646 out of 14,170 students in 29 studies (39.8%, 95% confidence interval= 39.0-40.6%), insufficient sleep duration by 3,762/12,906 students in 28 studies (29.1%, 23.3-29.9%) and excessive diurnal sleepiness by 1,324/3,688 students in 13 studies (35.9%, 34.3-37.4). Academic grades correlated significantly with sleep quality scores (r, 95% CI= 0.15, 0.05 to 0.26, random-effects model; p=0.002, n=10,420 subjects, k=15 studies) and diurnal sleepiness (r=-0.12, -0.19/-0.06 under the fixed effects model, p<0.001, n=1,539, k=6), but not with sleep duration (r=0.03, -0.12/0.17 under the random-effects model, p=0.132, n=2,469, k=9). These findings advocate for an urgent intervention aiming at improving sleep quality among medical students as a way of increasing academic achievements and, ultimately, the quality of health care.

Keywords: medicine students; diurnal somnolence; Academic Performance; sleep disruption

Introduction

Sleep is essential for learning and memory consolidation.[1] It is clear that sleep is essential for efficient consolidation of both (declarative) knowledge and (procedural) skills. Initial studies led to a hypothesis that procedural memory would be enhanced by rapid-eye movement (REM) sleep,[2] whereas declarative memory consolidation would be linked to non-REM sleep.[3] Even if this hypothesis is not fully backed up by experimental data, it is clear that sleep is essential for efficient consolidation of both (declarative) knowledge and (procedural) skills. New memories acquired during wakefulness experience offline reactivation during sleep, which seems fundamental for consolidation at the hippocampus.[4, 5] Sleep may provide a fine orchestration of global downscaling of unspecific synapses and local strengthening or protection of task-relevant synapses. Indeed, Long-Term Potentiation, which is a key aspect of synaptic plasticity, would be induced by regular sleep and reduced after extended wakefulness, according to a recent study.[6]

Disturbed sleep leads to altered memory formation. For example, when subjects were sleep deprived for 36 hours before an incidental memory encoding session composed of sets of emotionally negative, positive, and neutral words, retention was 40% of normal sleep controls.[7] Neuroimaging studies have shown that impaired memory encoding after sleep deprivation was related to abnormal cortical activation patterns, including overcompensation by prefrontal regions combined with a failure of the medial temporal lobe to engage normally, leading to compensatory activation in the parietal lobes.[8] Reduction in growth factor levels at the hippocampus have been observed after sleep deprivation, which may be the basis for altered plasticity in these conditions.[9, 10]

Sleep deprivation also displays adverse consequences on mood. Fatigue, sleepiness, and confusion are common feelings in sleep-deprived subjects.[11] Fatigue is in turn related to worse cognitive performance. This may be the consequence of ''microsleeps'' intruding into wakefulness when sleep-deprived subjects fail to respond during cognitive tasks.[12] It is thus not surprising to find altered academic performance in sleep-deprived students of all ages. In a recent meta-analysis involving 19,000 children and adolescents, school performance correlated negatively with sleepiness and positively with sleep quality and sleep duration.[13] University students are equally affected by sleep disturbances. Indeed, 2 recent meta-analyses reported sleep disturbances in 18 to 25% of university students.[14, 15] It has been observed that medical students are more affected than students of other careers.[15, 16] Notwithstanding, no systematic review and meta-analysis on the effects of sleep disturbances on academic performance in medical students have been carried out, to the best of our knowledge. Therefore, the objective of the present systematic review and meta-analysis was to assess the prevalence of sleep disturbances in medical students worldwide and its relationship with academic performance.

Methods

PICOS criteria

This systematic review and meta-analysis included scientific studies that fulfilled the following PICOS criteria,

1) Population: medical students assessed during regular school period (mixed samples of medical plus related careers, e.g. nursing, kinesiology, students were also accepted);

2) Intervention (exposure): at least one validated or unvalidated, subjective or objective, measure of sleep quality, sleep duration, or diurnal sleepiness, covering more than a single night;

3) Comparison: none;

4) Outcome: academic performance assessed by questionnaires, standardized tests or grade point average;

5) Study type: cross-sectional, cohort or case-control studies were accepted.

No studies were excluded from the analyses based on flawed designs. Studies containing information about sleep characteristics but not on academic performance were included in the analysis of the prevalence of sleep disruption.

This systematic review and meta-analysis followed the PRISMA guidelines.[17]

PROSPERO registration number is CRD42019127734.

Selection of studies

We searched the PubMed, Web of Sciences, EBSCO and SciELO with the following keywords: sleep, somnolence, insomnia, achievement, grade, accomplishment, function, university, academic, student, medicine. Keywords were searched in Spanish and English. Search period was 1980 to 2018. Reference lists from relevant reviews and original articles were also searched for additional studies. The flow of information is depicted in Figure 1.

Two independent reviewers randomly selected from a list (HS, LM, FO, JO, ES, MIC, SPLL) screened the titles and abstracts and selected those that contained references to sleep characteristics in medical students, and were written in English, Spanish, French, or Portuguese. Full-texts of these articles were retrieved. If studies could not be retrieved from the databases, authors were contacted and asked for a copy of their publication. In a second stage, full-texts were reviewed and those fulfilling PICOS criteria were selected for data extraction. In all cases, agreement was close to 100% and discrepancies were solved by a third reviewer.

Data extraction

Data extraction from articles selected in the second stage was performed by two independent coders randomly selected from a list (LM, FO, JO, ES, MIC, SPLL). The basic characteristics of the article including date and geographical situation of the study were extracted. Demographics data extracted included: gender (proportion of males), comorbidities, the proportion of medical students, duration of studies, smoking, intake of hypnosedatives, use of stimulants, alcohol intake, coffee consumption, and overweight. Data on sleep quality, sleep duration, and daytime sleepiness, including the assessment tool used were recorded. Definitions of poor sleep quality, insufficient sleep duration, and excessive daytime sleepiness, were also recorded and used in the statistical analysis without modifications.

Statistical analysis

Pearson product-moment correlation coefficient (r) between sleep quality scores, sleep duration, or daytime sleepiness scores and academic performance, served as effect size estimator. If r coefficients could not be obtained from the publication, other given statistics (e.g., p-value, F-value) were used to estimate it.[18] Missing data was not imputed.

R coefficients were transformed to Fisher’s z values. Random and fixed effects models were computed by using Meta-Essentials.[19] This software uses the Knapp□Hartung adjustment of the DerSimonian□Laird estimator to calculate confidence interval of the overall effect. For the ease of interpretation overall effect sizes were transformed back into r. Heterogeneity was tested by Q-test and I^2 statistic.[20] If significant heterogeneity was found, random effect models were preferred and subgroup analysis was performed. Funnel plots and Egger regression were used to evaluate publication bias.

Results

As can be observed in Figure 1, 2,332 publications were initially retrieved from the bibliographical searches, and 21 extra studies were obtained from secondary searches. Forty-one studies met all criteria and were selected for calculating the prevalence of sleep disruption [21-61], while 20 could also be used for the study of its association with academic performance [22, 23, 25-27, 30, 32-35, 38, 43, 44, 51, 53, 56-60]. Eighteen studies (44%) were conducted in the Americas, 11 (27%) in Asia and Oceania, 8 (19%) in the Middle East region and 4 (10%) in Europe. In total, 20 countries were represented in this systematic review (Table 1). All studies had a cross-sectional design. Assessment tools used in each of them are shown in Table 1. The most commonly used sleep quality rating scale was Pittsburg Quality Sleep Index (PSQI) in 23 studies, poor sleep quality being defined as a PSQI total score > 5 in 21 studies. Sleep duration was assessed by the PSQI in 14 studies, and by custom questionnaires in 12 cases. The most common definition of insufficient sleep duration was <6 hours (19 studies). Finally, daytime sleepiness was assessed by the Epworth Sleepiness Scale (ESS) in 16 cases, with an abnormal total score being defined as > 10 in 10 cases. The characteristics of the samples of studies selected are shown in Table 2. Overall, 40% of studied subjects were males, 95% studied medicine, and the mean±standard deviation (SD) of studies duration was 2.5±2.5 years.

As can be observed in Table 3, mean ± SD of the PSQI total scores was 5.1±2.7 points (k= 13 studies), and poor sleep quality was reported by 5,646 students out of 14,170 (39.8%, 95% confidence interval [95% CI] = 39.0 to 40.6%; k=28). Mean ± SD sleep duration was 6.5±4.9 hours (k=28), and the prevalence of insufficient sleep duration was 3762 students / 12,906= 29.1%, 95%CI=28.3 to 29.9% (k=21). Finally, mean±SD

ESS scores was 8.9±4.9 points (k=6), while the prevalence of excessive daytime sleepiness was 1,324/3,688 students= 35.9%, 95%CI= 34.3 to 37.4 (k=13).

Relationships between academic performance and sleep disruption can be observed in Figure 2. Fifteen studies assessed the correlation between sleep quality and academic performance, with a total sample of 10,420 subjects. Heterogeneity was significant (Q-score= 142.3 $p<0.001$), with an I^2 value of 90.23%. As observed in Figure 2 (top panel), the overall correlation coefficient and 95% CI under the random-effects model were 0.15, 0.05 to 0.26 (Z-score=3.07, $p=0.002$). Positive correlation coefficients reflect an association between good sleep quality and better academic performance. Subgroup analysis revealed that the correlation between sleep quality and academic performance was significantly stronger in the Middle East and Asia/Oceania regions, in studies conducted in 2012 or after, and in those in which women comprised > 50% of the sample (Table 4). In a sensitivity analysis, the meta-analysis was run after excluding studies using non-standard cut-off values in the PSQI (which is normally >5 points). Results were essentially similar to the full-set analysis.

Correlation between sleep duration and academic performance was assessed in 9 studies, with a total sample of 2,469 students (Figure 2, middle panel). Heterogeneity was significant (Q-score=60.6, $p<0.001$, I^2=86.74%). Overall correlation coefficient (95% CI) under the random-effects model was 0.03 (-0.12 to 0.17; Z-score=0.42, $p=0.67$). Positive correlation coefficients reflect an association between longer sleep duration and better academic performance. Subgroup analysis revealed a significantly stronger correlation in studies with sample sizes <150 students (Table 4).

Finally, correlation with daytime sleepiness was assessed in 6 studies (n=1,539), as shown in Figure 2 bottom panel. Heterogeneity was non-significant (Q-score=4.7, $p<0.45$). Overall correlation coefficient under the fixed effects model was -0.12 (-0.19

to -0.06; Z-score=4.78, $p<0.001$). Negative correlation coefficients reflect an association between greater sleepiness scores and worse academic performance. No subgroup analysis was performed as there was no significant heterogeneity.

A sensitivity analysis was conducted for each correlational analysis, by sequentially excluding each study from the dataset and recalculating the overall combined correlation coefficient. Results remained unchanged, which indicates that no individual study significantly influenced the overall results. This is further confirmed by visual inspection of study weights in Figure 2, which are essentially similar, thus suggesting that all studies contributed equally to the pooled results. In a sensitivity analysis, the meta-analysis was run after excluding studies using non-standard cut-off values in the ESS (which is normally >10). Results were essentially similar to the full-set analysis. Funnel plots are shown in Figure 3. Publication bias was not evident. Furthermore, Eggert regression models were not significant, indicating no correlation between correlation coefficients and their standard errors (sleep quality: t= 0.08, p= 0.94; sleep duration: t= 1.89, p= 0.10; daytime sleepiness: t=0.53, p=0.63). Notwithstanding, the findings of a significantly stronger correlation coefficient between sleep duration and academic performance in studies with sample sizes <150 students could be suggesting publication bias.

Discussion

This is one the largest, and probably most representative, systematic review and meta-analysis about the prevalence of sleep disruption and its relationship with academic performance in medical students around the globe. We observed poor sleep quality, insufficient sleep duration and excessive daytime sleepiness in about a third of students. Furthermore, sleep quality and daytime sleepiness scores, but not sleep duration, correlated significantly with academic performance.

Our results indicate that sleep disruption is pandemic in the population of medical students. The prevalence herein observed is higher than in the general population, which was 16.6% in Asia and Africa prevalence,[62] 20% in Canada and the US,[63, 64] 22.7% in Latin America,[65] 23% in Japan, and 31% in Western Europe.[66] Furthermore, previous research indicates that medical students may be more affected than students of other careers.[16] It has been suggested that academic loads, attitude towards study, and lifestyle may be connected with worse sleep in the former.[15, 67] In our study, sleep duration was not related to academic performance. Furthermore, shorter sleep time was observed in outperforming medical students in some studies.[26, 32] Notwithstanding, this strategy may not be effective for all students. Indeed, retention rates are superior in subjects with adequate sleep, as shown in other studies.[7] Misperceptions about sleep physiology and health are common, both in the general population and among medical students.[16] Indeed, the misbelief that sleepiness can be overcome by willpower was common in one study involving medical students.[68] Furthermore, most students were unaware of the minimum sleep time recommendations, i.e. 7 or more hours according to the most recent expert consensus.[69]

Sleep disruption can be a consequence or a cause of some mood disorders.[70] In light of the high prevalence of sleep deprivation in medical students, it can be hypothesized that mental health may also be compromised. Therefore, in this population of students, periodic sleep assessment, complemented with psychiatric evaluation in sleep-deprived subjects, might lead to considerable improvements in quality of life and academic performance, as will be discussed in the next paragraphs.

Indeed, our meta-analysis showed that poor sleep quality and excessive daytime sleepiness were mildly but significantly associated with impaired academic performance. Interestingly, a recent meta-analysis in children and adolescents showed essentially similar results.[13] Furthermore, the strength of associations was also similar, with equally high levels of heterogeneity. This suggests that both meta-analyses of sleep and cognitive performance might have been affected by similar problems, mainly non-standardized assessments of sleep and academic performance, which will be discussed later.

Our findings that sleep quality but not sleep duration were associated with poor performance are intriguing. It should be mentioned that in a meta-analysis in children and adolescents, sleep duration correlated significantly with performance, but much more mildly as compared to sleep quality.[13] Furthermore, some studies suggest that sleep duration is not connected with cognitive performance,[1] which is in line with our results. Notwithstanding, in another study, sleep duration became relevant for cognitive performance in high-demanding tasks.[71] The workload is usually heavy in medical curricula, which suggests that adequate sleep duration may be an important feature of sleep hygiene. This result might also be connected with imprecision in the assessment of sleep duration by subjective diaries, as was done in all studies included in this meta-analysis. A subgroup analysis showed significantly stronger correlation coefficients between sleep duration and academic performance in studies with sample size < 150 students, which is compatible with publication bias. Notwithstanding, our results are not affected by this possible bias, as the observed overall correlation was already not statistically different from 0.

A direct effect of sleep disruption in cognitive function can not be denied, in the light of current evidence.[4, 7, 11, 72, 73] Notwithstanding, another hypothesis may be considered. Indeed, both can result from a third factor, such as personal or familial problems, general adverse socioeconomic context, or mood disorders. In any case, medical students would greatly benefit from periodic assessment of sleep quality. Furthermore, the importance of adequate sleep hygiene should be reinforced in this population, and misbeliefs eradicated. It should also be mentioned that sleepiness may increase the chance of errors during hands-on tasks related to patient health, thus compromising patients' safety.

As mentioned earlier, sleep is essential for learning and memory consolidation, with molecular changes in synaptic plasticity at the hippocampus as the probable mechanism.[1, 7] Notwithstanding, there might be other yet unexplored mechanisms. For example, in teenagers, we have shown that short sleep duration led to daytime sleepiness, which in turn was associated with reduced attention, ultimately leading to poor academic performance.[74] Attention, reaction times and other psychological variables have not been extensively studied in relation to sleep in this population. Further studies are warranted. In particular, what do students do with the time they gain from restricting nighttime sleep, and its relationship with hobbies and work schedules, need to be investigated.

This systematic review and meta-analysis suffered from some limitations. In the first place, female medical students may have been overrepresented. Significant heterogeneity was noticed in the relationship between sleep quality and duration with performance. This may reflect heterogeneity in the assessment of these variables, which calls for standardization. Furthermore, objectives measures of sleep characteristics were not employed in any study. Therefore, further research employing objective sleep assessment and standardized performance evaluations are warranted. Importantly, these assessments should include chronotype and bed and rise times. We also observed that the correlation between sleep quality and academic performance was significantly stronger in the Middle East and Asia/Oceania regions, in studies conducted in 2012 or after, and in those in which women comprised > 50% of the sample. Further research is needed to understand the meaning and importance of these differences.

Another important limitation is that we were not able to extract sufficient data on demographics and comorbidities to allow for moderator analyses. In particular, organic sleep disorders were not assessed in any of the included studies.

In summary, we observed sleep disruption in about 40% of a worldwide sample of 14,000 medical students. Furthermore, better academic performance was significantly associated with greater sleep quality and lower daytime sleepiness scores. Sleep should be systematically and routinely assessed in medical students. When sleep disruption is detected, it should be treated, and psychiatric assessment may also be warranted. Finally, more education about sleep hygiene is needed among medical students. Common misbeliefs, such as that sleepiness can be overcome by will, should be chased away.

Practice Points

- Poor sleep quality, insufficient sleep duration, and excessive diurnal somnolence affected a high proportion of a worldwide sample of 14,170 medical students.

- Poor sleep quality and excessive diurnal somnolence, but not insufficient sleep duration, were significantly associated with worse academic performance.
- Sleep should be systematically and routinely assessed in medical students.

Research Agenda

- Prospective studies are needed to further study the relationship between sleep deprivation and academic performance in medical students.
- Studies about the consequences of sleep disturbances in this population are needed.
- It is also necessary to assess how sleep deprivation during medical courses correlates with students' future abilities to provide health care.
- How sleep affects cognitive function also remains to be fully elucidated.

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Legend to figures

Figure 1. Flow of information through the different phases of a systematic review. SD= Sleep Disruption; AP= Academic Performance

Figure 2. Correlation between sleep quality scores, sleep duration, daytime sleepiness, and Academic Performance. Fixed and random-effects model are shown. In cases were significant heterogeneity could be detected by the Q-test, random-effects models should be used, if not fixed effects model can be accepted.

Figure 3. Funnel plots of the correlation between sleep quality, sleep duration or daytime sleepiness with academic performance.

Table 1. Characteristics of included studies

Study	Country	Academic Performance		Sleep Quality		Sleep Duration		Daytime Sleepiness	
		Assessment	Failure	Assessment	Poor	Assessment	Insufficient	Assessment	Excessive
Abdulah 2018[21]	Iraq	-	-	Sleep-50	Not identified	Own questionnaire	<6hs	-	-
Abdulghani 2012[22]	Saudi Arabia	GPA	<3.75	-	-	Own questionnaire	<6hs	EES	>10
Ahrberg 2012[23]	Germany	GPA	Not identified	PSQI	>5	PSQI	Not identified	-	-
Albhlal 2017[24]	India	-	-	-	-	Own questionnaire	<6hs	ESS	Not identified
Almojali 2017[25]	Saudi Arabia	GPA	<4.25	PSQI	>5	PSQI	<7hs	-	-
Alsaggaf 2016[26]	Saudi Arabia	GPA	<3.50	PSQI	>5	PSQI	<8hs	ESS	≥10
Alvaro-Monterrosa 2015[27]	Colombia	GPA	<3.50	AIQ	>5	AIQ	<6hs	AIQ	Not identified
Brick 2010[28]	United States	-	-	PSQI	Not identified	-	-	-	-
Cardoso 2009[29]	Brazil	-	-	PSQI	>5	PSQI	<6hs	ESS	>10
Correa 2017[30]	Brazil	-	-	PSQI	≥5	PSQI	<6hs	-	-
Cvejic 2018[31]	Australia	GPA	Not identified	PSQI	>5	PSQI	Not identified	-	-
Escobar-Córdoba 2011[33]	Colombia	Surgery Grade	<4.00	PSQI	>5	-	-	ESS	>10
Ezelarab 2014[32]	Egypt	GPA and attitudes	-	ISS	>3	-	-	ESS	>10
Fawzy 2017[34]	Egypt	GPA	<3.25	PSQI	>5	PSQI	<6hs	-	-
Genzel 2013[35]	Germany	Average Grade at the end of the semester	<4.00	PSQI	>5	Munich Chronotype Questionnaire	Not identified	-	-
Giri 2013[36]	India	-	-	PSQI	-	PSQI	<6hs	ESS	>10
Granados 2013[37]	Peru	-	-	PSQI	>5	PSQI	<6hs	-	-
Hamed 2015[38]	Arab Emirates	GPA	-	-	-	Own questionnaire	<6hs	-	-
Huen 2007[39]	China	-	-	Own questionnaire	Not identified	Own questionnaire	-	-	-
Israel 2016[40]	India	-	-	PSQI	>6	PSQI	<6hs	-	-
Lapinski 2015[41]	United States	-	-	-	-	Own questionnaire	<6hs	-	-
Loayza 2001[42]	Brazil	-	-	Own questionnaire	Not identified	-	-	-	-
Medeiros 2013[43]	Brazil	GPA	-	PSQI	>5	PSQI	<6hs	-	-

Mirghani 2015[44]	Sudan	Average Grade at the end of the semester	C	PSQI	>5	PSQI	Not identified	-	-
Morgan 2017[45]	Brazil	-	-	Own questionnaire	Bad/Regular	Own questionnaire	<6hs	-	-
Patricio 2013[46]	Chile	Approval of courses	Fail	Own questionnaire	Insufficient	-	-	-	-
Perez-Olmos 2006[47]	Colombia			-	-	Own questionnaire	≤6hs	-	-
Priya 2017[48]	India	-	-	PSQI	>5	PSQI	≤6hs	ESS	>10
Purim 2016[49]	Brazil	-	-	PSQI	>5	-	-	ESS	>10
Rathi 2018[50]	India	-	-	PSQI	>5	-	-	-	-
Rodrigues 2002[51]	Brazil	GPA	≤2.45	-	-	-	-	ESS	≥10
Rosales 2007[52]	Peru	-	-	PSQI	>5	-	-	ESS	>10
Sawah 2015[53]	United States	GPA	Not identified	PSQI	>5	PSQI	<6hs	ESS	>10
Saygin 2016[54]	Turkey	-	-	PSQI	>5	Own questionnaire	Not identified	ESS	>10
Sitticharoon 2014[55]	Thailand	Overall Average Grade	Not identified	-	-	Own questionnaire	<6hs	-	-
Veldi 2005[56]	Estonia	Self-reported academic progress	Insufficient	Questionnaire on sleep and daytime habits	Poor/Very poor	-	-	Questionnaire on sleep and daytime habits	Not identified
Vilchez-Cornejo 2016[57]	Peru	All courses approval	Fail	PSQI	>5	PSQI	<6hs	-	-
Wang 2016[58]	China	GPA	<3.00	PSQI	>5	PSQI	<6hs	-	-
Yaset-Caicedo 2015[59]	Colombia	GPA	Not identified	-	-	-	-	ESS	>10
Yeung 2008[60]	China	GPA	<25%	Own questionnaire	Not identified	Own questionnaire	<6hs	ESS	>10
Zailinawati 2009[61]	Malaysia	-	-	Own questionnaire	Not identified	Own questionnaire		ESS	>10

AIQ= Athens Insomnia Questionnaire; ESS: Epworth Somnolence Scale, GPA: Grade Point Average, hs: hours, N/A: Not Available, PSQI: Pittsburg Sleep Quality Index; SRSS=Self-Rating Sleeping State Scale. All studies were cross-sectional.

Table 2. Samples' characteristics

Study	Sample size	Men	Comorbidities	Medical students	Study years*	Smokers	Hypno sedatives	Stimulants	Alcohol	Coffee	Overweight
Abdulah 2018[21]	317	137 (43%)	0 (0%)	317 (100%)		36 (11%)	29 (9%)		37 (12%)		
Abdulghani 2012[22]	491	307 (63%)	68 (14%)	491 (100%)	2.0±1.6						
Ahrberg 2012[23]	144	49 (34%)		144 (100%)							
Albhlal 2017[24]	128			128 (100%)		17 (13%)					111 (87%)
Almojali 2017[25]	263	181 (69%)		263 (100%)	2.2±2.0			39 (15%)		80 (30%)	
Alsaggaf 2016[26]	305	127 (42%)		305 (100%)	4.9±4.5		27 (9%)			232 (76%)	
Alvaro-Monterrosa 2015[27]	210	103 (49%)	31 (15%)	210 (100%)	3.0±2.9	11 (5%)		38 (18%)	94 (45%)	67 (32%)	
Brick 2010[28]	314	175 (56%)		314 (100%)		37 (12%)			177 (56%)		57 (18%)
Cardoso 2009[29]	276	151 (55%)		234 (85%)	3.7±3.7		24 (9%)				
Correa 2017[30]	372	138 (37%)		372 (100%)	3.3±3.2						
Cvejic 2018[31]	59	24 (41%)	0 (0%)		1.8±1.4						
Escobar -Córdoba 2011[33]	83	48 (58%)	83 (100%)	83 (100%)							
Ezelarab 2014[32]	435	211 (49%)		435 (100%)	3.6±3.4						
Fawzy 2017[34]	700	248 (35%)		248 (35%)	3.7±3.6	25 (4%)	70 (10%)			96 (14%)	
Genzel 2013[35]	31	7 (23%)		31 (100%)							
Giri 2013[36]	50	20 (40%)		50 (100%)							
Granados 2013[37]	247	53 (21%)		57 (23%)			33 (13%)				
Hamed 2015[38]	200	50 (25%)									
Huen 2007[39]	419	166 (40%)		419 (100%)	2.8±2.7						
Israel 2016[40]	250	120 (48%)	0 (0%)								109 (44%)
Lapinski 2015[41]	1294	681 (53%)			2.1±1.8						
Loayza 2001[42]	302	184 (61%)	67 (22%)	302 (100%)							
Medeiros 2013[43]	36	21 (58%)		36 (100%)							
Mirghani 2015[44]	140	38 (27%)		140 (100%)							
Morgan 2017[45]	196	78 (40%)		196 (100%)	2.5±2.2	15 (8%)	31 (16%)	113 (58%)		129 (66%)	

Patricio 2013[46]	90	38 (42%)		38 (42%)	5.2±4.8						
Perez-Olmos 2006[47]	318	118 (37%)		318 (100%)	2.3±2.2						
Priya 2017[48]	307	235 (77%)		307 (100%)	2.5±2.2						
Purim 2016[49]	101	52 (51%)	0 (0%)	101 (100%)							
Rathi 2018[50]	166	89 (54%)		166 (100%)							
Rodrigues 2002[51]	172				6.5±6.0						
Rosales 2007[52]	127	72 (57%)		127 (100%)	1.5±1.0	6 (5%)	8 (6%)			49 (39%)	
Sawah 2015[53]	98	57 (58%)		98 (100%)	1.3±0.8			48 (49%)		79 (81%)	
Saygin 2016[54]	337	141 (42%)		337 (100%)	3.3±3.2	38 (11%)					
Sitticharoon 2014[55]	100	49 (49%)		100 (100%)							17 (17%)
Veldi 2005[56]	413	95 (23%)		413 (100%)							
Vilchez-Cornejo 2016[57]	892	431 (48%)		892 (100%)	3.0±2.9						
Wang 2016[58]	6085	1660 (27%)		6085 (100%)	2.0±1.8		95 (2%)				
Yaset-Caicedo 2015[59]	131	62 (47%)		131 (100%)	3.2±3.1						
Yeung 2008[60]	249			249 (100%)	2.9±2.5						
Zailinawati 2009[61]	799	487 (61%)		799 (100%)			30 (4%)				
TOTAL	**17647**	**6093 (40%)**	**249 (14%)**	**14936 (95%)**	**2.5±2.5**	**185 (8%)**	**347 (4%)**	**238 (31%)**	**308 (37%)**	**732 (39%)**	**294 (37%)**

* Means±SD are shown.

Table 3. Pooled prevalence of poor sleep quality, insufficient sleep duration and daytime sleepiness

Study	Sleep Quality		Sleep Duration		Daytime sleepiness	
	Mean±SD[a]	Poor (%)	Mean±SD	Insufficient (%)	Mean±SD[b]	Excessive (%)
Abdulah 2018[21]			6.4±6.0	118 (37%)		
Abdulghani 2012[22]			6.0±1.4	249 (51%)	7.7±3.9	179 (36%)
Ahrberg 2012[23]	4.6±2.3		7.5±1.0			
Albhlal 2017[24]				59 (46%)		
Almojali 2017[25]	7.1±3.8	200 (76%)	5.8±1.3	193 (73%)		
Alsaggaf 2016[26]		91 (30%)	5.8±2.0	256 (84%)		118 (39%)
Alvaro-Monterrosa 2015[27]		98 (47%)	4.6±1.3	146 (70%)		
Brick 2010[28]	6.4±2.6	160 (51%)				
Cardoso 2009[29]		79 (29%)				138 (50%)
Correa 2017[30]		126 (34%)	6.5±6.1	60 (16%)		
Cvejic 2018[31]	5.2±2.6	18 (31%)	7.5±0.9			
Escobar -Córdoba 2011[33]		66 (80%)				50 (60%)
Ezelarab 2014[32]		300 (69%)	7.1±1.5			125 (29%)
Fawzy 2017[34]		390 (56%)	6.8±6.3	125 (18%)		
Genzel 2013[35]			8.2±0.1			
Giri 2013[36]	5.3±2.4		6.5±6.0	8 (16%)		10 (20%)
Granados 2013[37]	7.2±2.6	158 (64%)	3.3±2.9	198 (80%)		
Hamed 2015[38]						
Huen 2007[39]		277 (66%)	6.6±1.2			
Israel 2016[40]	6.7±6.6	128 (51%)	6.0±5.5	150 (60%)		
Lapinski 2015[41]			6.8±6.3	240 (19%)		
Loayza 2001[42]		85 (28%)				
Medeiros 2013[43]		14 (39%)	6.9±1.6			
Mirghani 2015[44]	7.5±3.6	95 (68%)	6.6±2.0			
Morgan 2017[45]		27 (14%)	6.5±1.1	32 (17%)		
Patricio 2013[46]		63 (70%)				
Perez-Olmos 2006[47]			5.6±5.2	226 (71%)		
Priya 2017[48]		207 (67%)		241 (79%)		114 (37%)
Purim 2016[49]	5.9±2.4				9.1±3.5	
Rathi 2018[50]	3.6±2.3	54 (33%)				
Rodrigues 2002[51]					10.7±4.0	
Rosales 2007[52]		74 (58%)	6.0±1.1	38 (30%)		43 (34%)
Sawah 2015[53]	7.3±5.9	67 (68%)	5.9±1.1	50 (51%)	8.6±4.7	44 (45%)
Saygin 2016[54]	9.0±4.2	268 (80%)	6.6±1.3			60 (18%)
Sitticharoon 2014[55]			6.4±0.1	55 (55%)		
Veldi 2005[56]		29 (7%)				
Vilchez-Cornejo 2016[57]		693 (78%)	6.0±1.0			
Wang 2016[58]	4.5±2.2	1698 (28%)	6.7±6.2	827 (14%)		
Yaset-Caicedo 2015[59]					9.4±9.5	54 (41%)
Yeung 2008[60]		53 (21%)	5.9±0.9	100 (40%)	9.7±4.2	106 (43%)
Zailinawati 2009[61]		129 (16%)	6.6±1.3	390 (49%)		284 (36%)

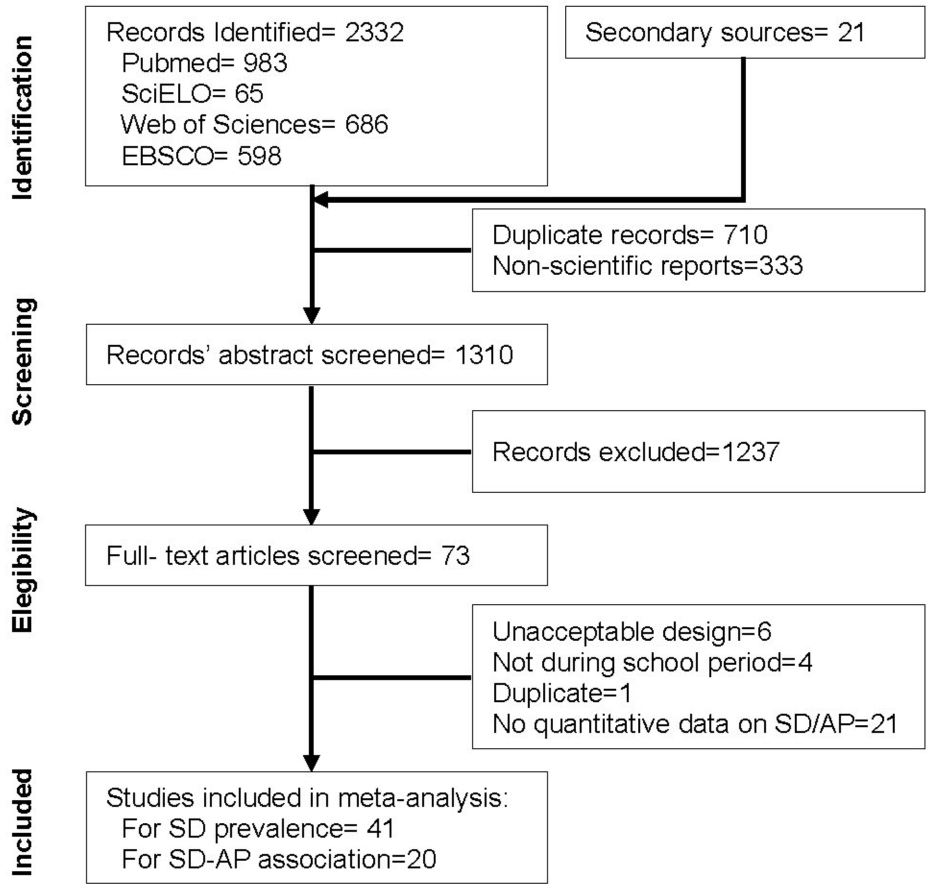
TOTAL	**5.1±2.7**	**5646/14170 (40%)**	**6.5±4.9**	**3762/12906 (29%)**	**8.9±4.9**	**1324/3688 (36%)**

[a] only in studies using Pittsburg Sleep Quality Index. [b] only in studies using Epworth Sleepiness scale.

Table 4. Subgroup analyses

	Sleep quality		Sleep duration	
	Pooled correlation coefficient (95% CI)	Between groups p-value	Pooled correlation coefficient (95% CI)	Between groups p-value
Region				
Middle East	0.23 (-0.16;0.57)	<0.01	-0.03 (-0.36;0.30)	0.53
Europe	0.12 (-0.10;0.32)		0.14 (-0.24;0.48)	
Asia/Oceania	0.23 (-0.14;0.55)		-0.03 (-0.15;0.10)	
Americas	0.07 (-0.02;0.17)		0.12 (-0.36;0.54)	
Year				
< 2012	0.07 (-0.01;0.14)	<0.01	-0.04 (-0.26;0.18)	0.19
≥ 2012	0.24 (0.02;0.44)		0.13 (-0.15;0.39)	
PSQI				
Not used	0.12 (-0.05;0.28)	0.52	0.09 (-0.05;0.22)	0.69
Used	0.17 (0.02;0.31)		0.05 (-0.30;0.38)	
Sample size				
<150	0.20 (-0.23;0.57)	0.69	0.21 (-0.05;0.43)	0.01
≥150	0.13 (0.07;0.19)		-0.04 (-0.20;0.13)	
Males proportion				
<50%	0.21 (0.01;0.40)	0.03	0.00 (-0.24;0.25)	0.62
≥50%	0.07 (-0.04;0.17)		0.08 (-0.34;0.46)	
Careers				
Medicine + Others	0.13 (0.06;0.20)	0.69	-	-
Only medicine	0.16 (0.04;0.27)		0.03 (-0.12;0.17)	

CI=confidence interval. Between group comparisons were performed by ANOVA.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Secondary sources= 21
Duplicate records= 710
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Screening
Records' abstract screened= 1310
Records excluded=1237
Eligibility
Full- text articles screened= 73
Unacceptable design=6
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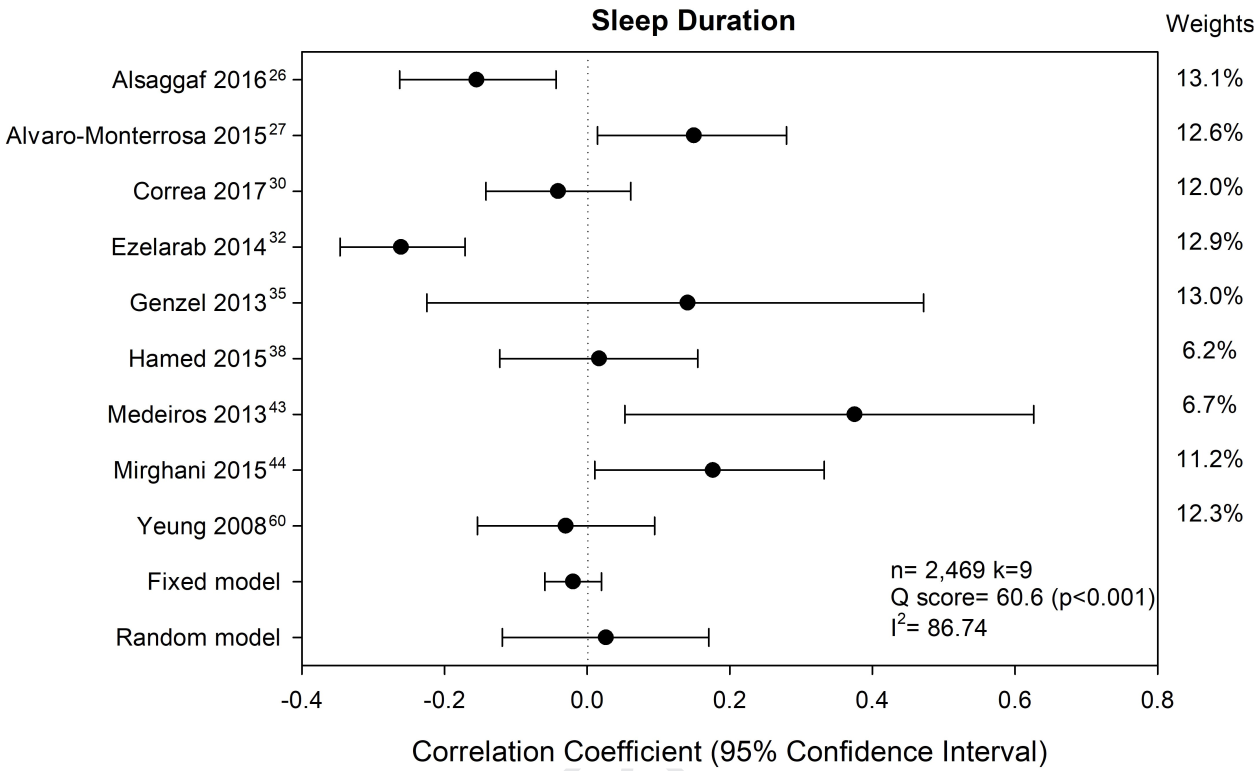
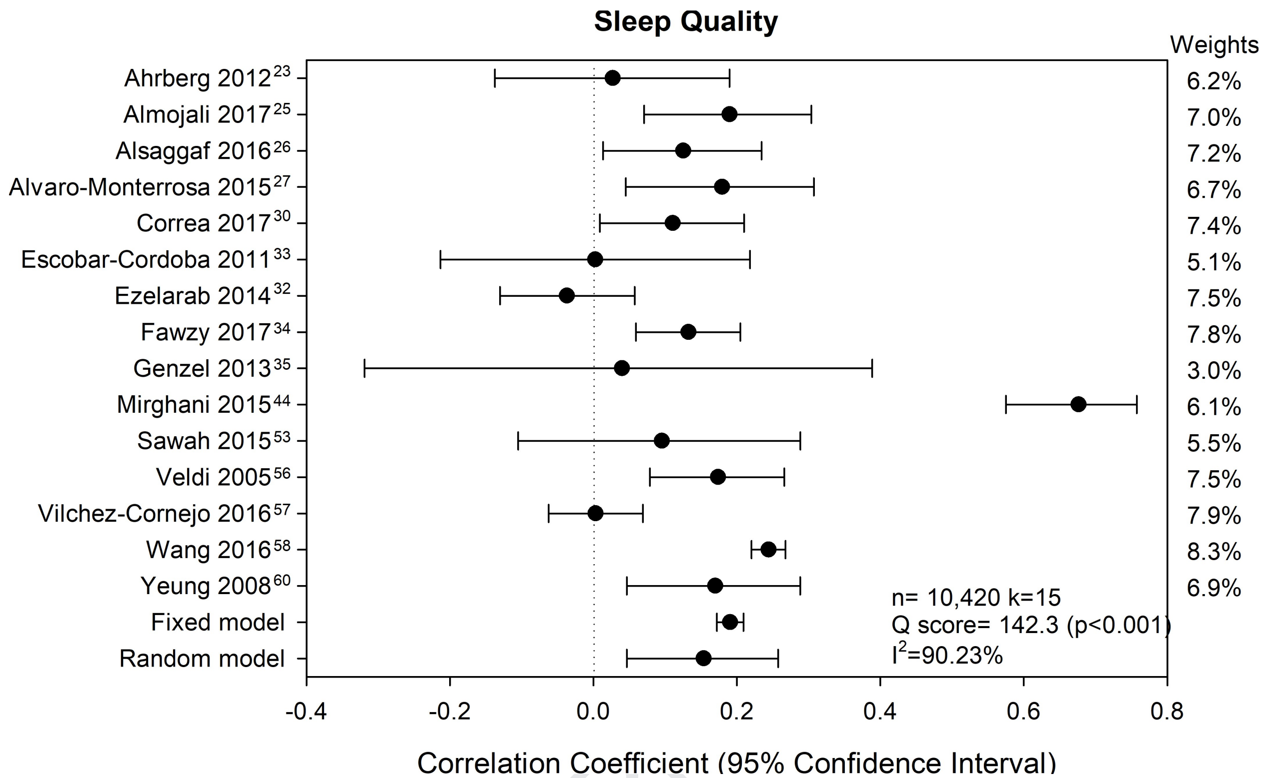
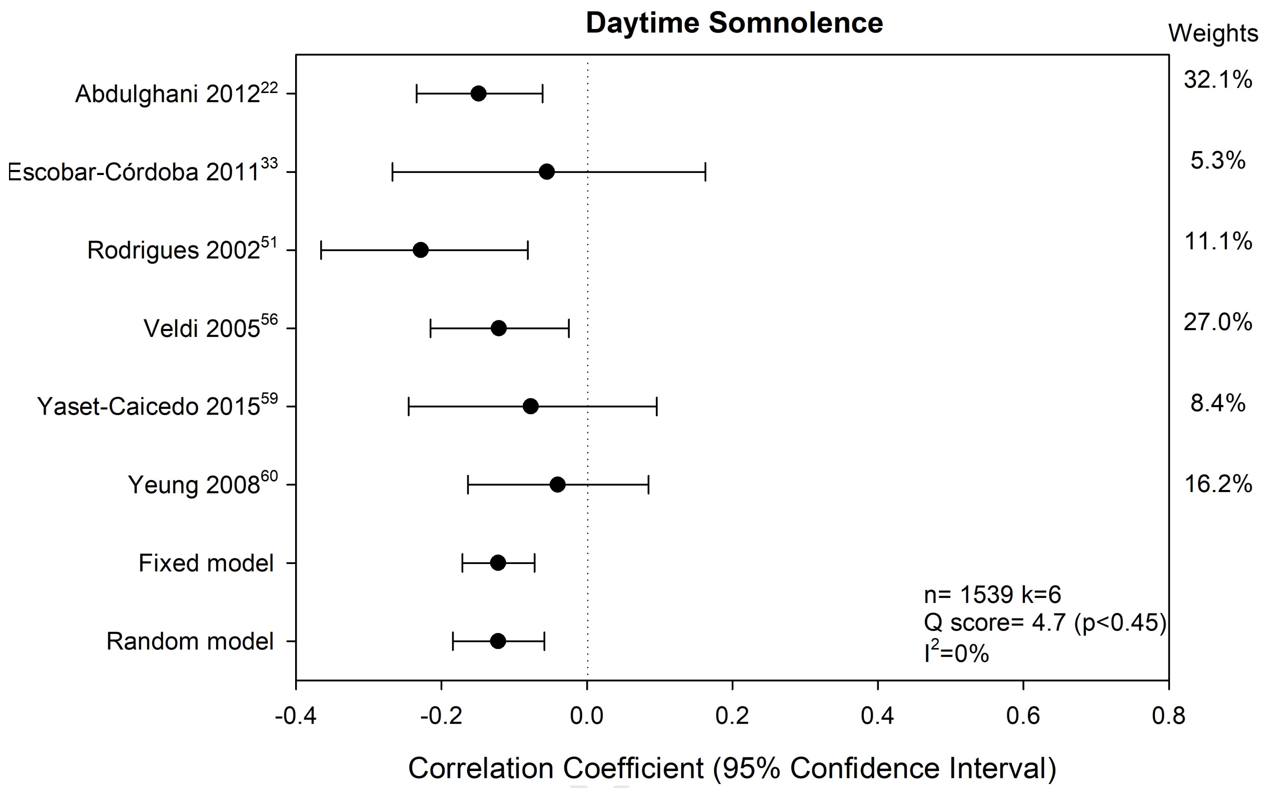
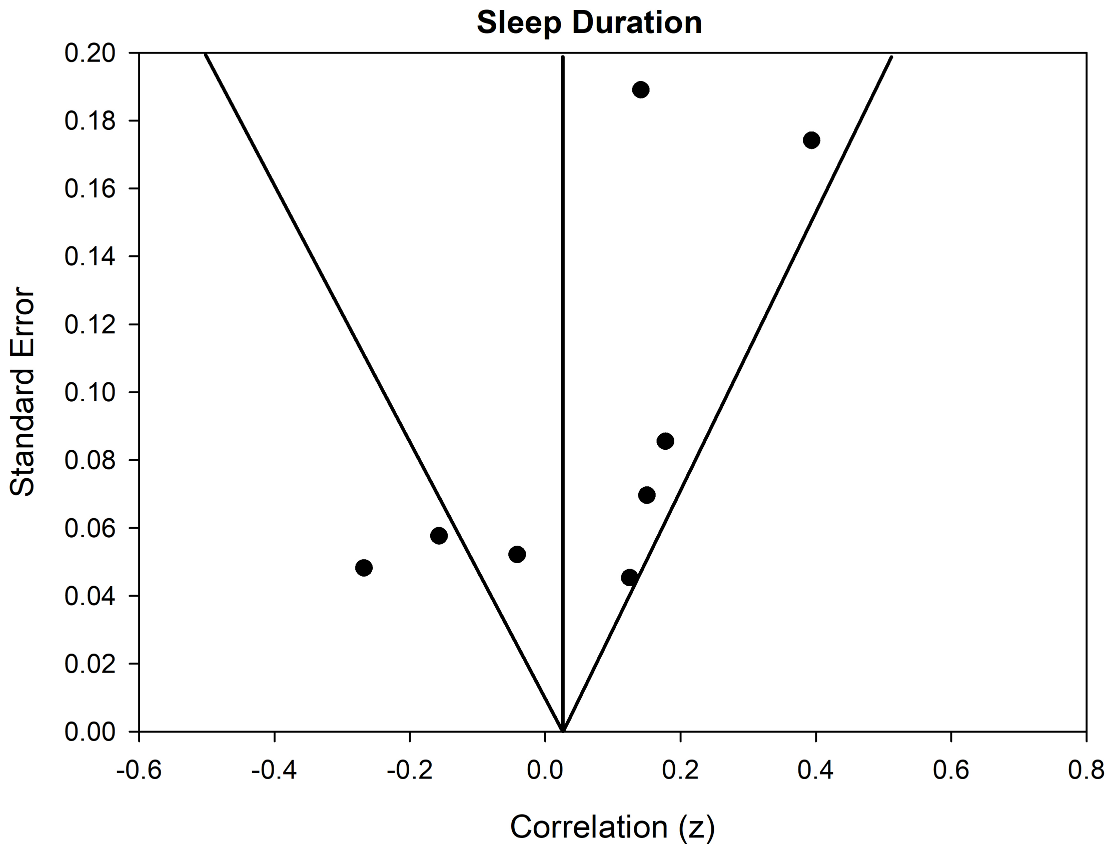
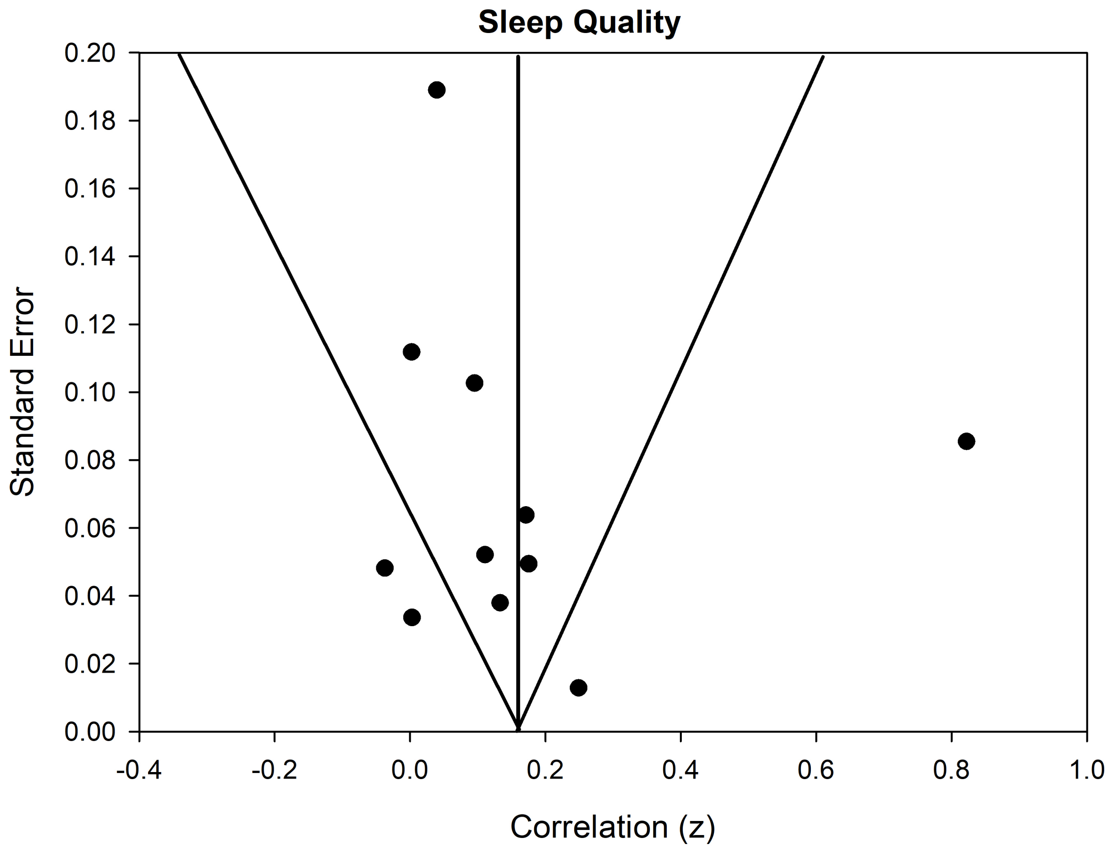
Duplicate=1
No quantitative data on SD/AP=21
Included
Studies included in meta-analysis:
For SD prevalence= 41
For SD-AP association=20

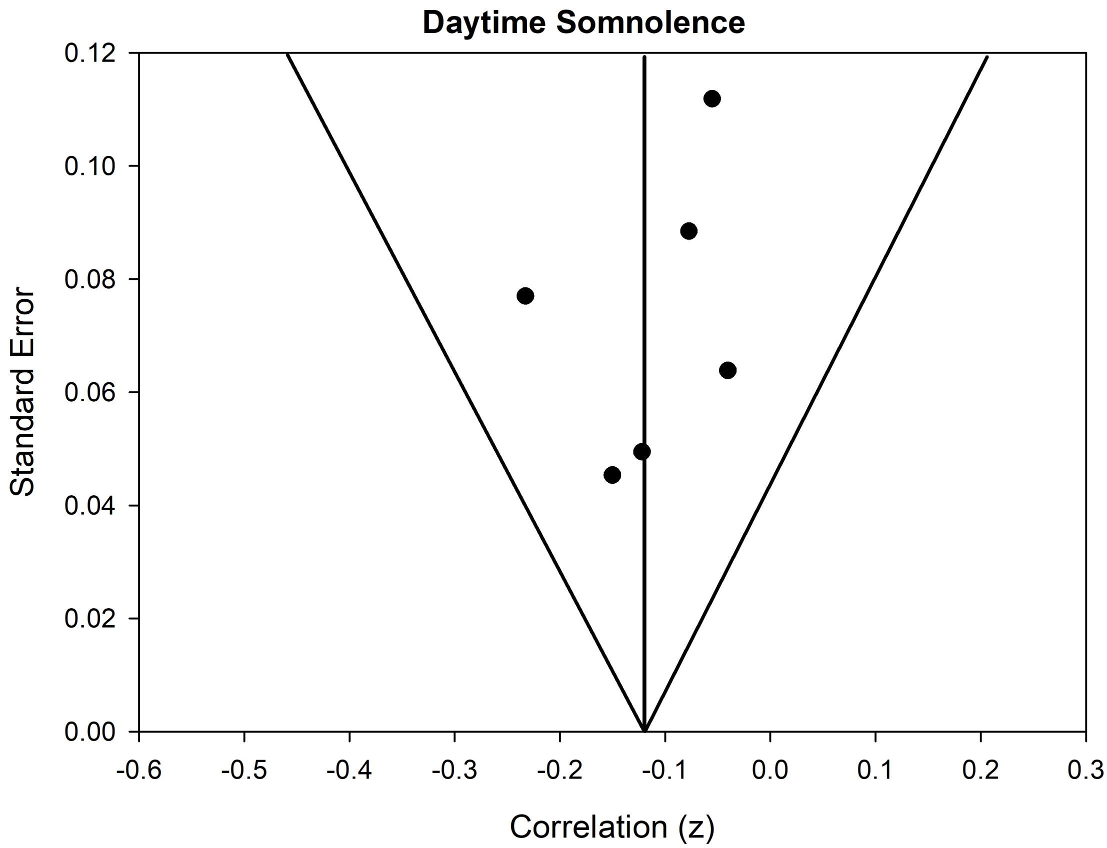

Sleep Duration
Weights
Alsaggaf 2016 26
Alvaro-Monterrosa 2015 27
Correa 2017 30
Ezelarab 2014 32
Genzel 2013 35
Hamed 2015 38
Medeiros 2013 43
Mirghani 2015 44
Yeung 2008 60
Fixed model
Random model
13.1%
12.6%
12.0%
12.9%
13.0%
6.2%
6.7%
11.2%
12.3%
n= 2,469 k=9
Q score= 60.6 (p<0.001)
I2= 86.74
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
Correlation Coefficient (95% Confidence Interval)


Sleep Quality
Weights
Ahrberg 2012[23]
Almojali 2017[25]
Alsaggaf 2016[26]
Alvaro-Monterrosa 2015[27]
Correa 2017[30]
Escobar-Cordoba 2011[33]
Ezelarab 2014[32]
Fawzy 2017[34]
Genzel 2013[35]
Mirghani 2015[44]
Sawah 2015[53]
Veldi 2005[56]
Vilchez-Cornejo 2016[57]
Wang 2016[58]
Yeung 2008[60]
Fixed model
Random model
6.2%
7.0%
7.2%
6.7%
7.4%
5.1%
7.5%
7.8%
3.0%
6.1%
5.5%
7.5%
7.9%
8.3%
6.9%
n= 10,420 k=15
Q score= 142.3 (p<0.001)
I^2=90.23%
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
Correlation Coefficient (95% Confidence Interval)


Daytime Somnolence
Weights
Abdulghani 2012[22]
Escobar-Córdoba 2011[33]
Rodrigues 2002[51]
Veldi 2005[56]
Yaset-Caicedo 2015[59]
Yeung 2008[60]
Fixed model
Random model
32.1%
5.3%
11.1%
27.0%
8.4%
16.2%
n= 1539 k=6
Q score= 4.7 (p<0.45)
I^2=0%
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
Correlation Coefficient (95% Confidence Interval)


Sleep Duration
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Standard Error
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
Correlation (z)


Sleep Quality
Standard Error
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Correlation (z)


Daytime Somnolence
Standard Error
0.12
0.10
0.08
0.06
0.04
0.02
0.00
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
Correlation (z)