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REVIEW ARTICLE

Prevalence of sleep problems among medical students: a systematic review and meta-analysis

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Abstract

Aim Several studies have shown high prevalence rates of sleep problems among medical students, including insufficient sleep duration, poor sleep quality, and excessive daytime sleepiness. This review aims to systematically summarize the existing literature on sleep problems among medical students and consequently estimate the prevalence of these disturbances.

Subject and Methods The MEDLINE, EMBASE, ScienceDirect, and ProQuest Medical databases, the Google Scholar engine, and reference lists of retrieved articles were systematically searched and evaluated for quality.

Results Forty–three studies involving a total of 18,619 students from 13 countries were included in the analyses. Results showed that the mean pooled sleep duration (K = 16, *N* = 10,512) was 6.3 h per night for medical students, [95% confidence interval (CI) 6.0–6.6]. The results also indicated that 55% [95% CI 48.0%–62.0%] of students reported poor sleep quality (K = 33, *N* = 15,462) according to the Pittsburgh Sleep Quality Index (PSQI); the mean pooled score of 6.3. Excessive daytime sleepiness (K = 18, *N* = 5688) was reported by 31.0% [95% CI 24.4%–37.7%] of students according to the Epworth Sleepiness Scale (ESS). Age and gender were not significant moderators for sleep quality or excessive daytime sleepiness. Some differences were obtained between countries, suggesting that cultural values, local conditions, and environment all have an impact on sleep practices and attitudes.

Conclusion Sleep problems are highly prevalent among medical students and are therefore a severe problem. Prevention and intervention programs targeting these are therefore highly recommended for future studies.

Keywords Sleep disturbance · Pittsburgh sleep quality index · Epworth Sleepiness Scale

Introduction

Research evidence indicates that sufficient sleep duration and good sleep quality are essential for neurocognitive functioning (Tononi and Cirelli 2006), psychomotor performance (Huber et al. 2004), and physical and mental health (AlDabal and BaHammam 2011). Epidemiological studies have found that sleep problems are associated with an increased risk for cardiovascular disease (US Institute of Medicine Committee on Sleep Medicine and Research 2006), psychiatric problems, particularly mood and anxiety disorders (Hidalgo and Caumo 2002; Krystal 2012), social problems (Eller et al. 2006), road traffic accidents (Stutts et al. 2003; Drake et al. 2010), and reduced academic performance (Belenky et al. 2003; Medic et al. 2017).

The American Academy of Sleep Medicine and the Sleep Research Society jointly recommend 7 hours of sleep per night for adults, and up to 9 hours of sleep per night for

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adolescents and younger adults to promote optimal health (Watson et al. 2015). However, research has shown that the prevalence of short sleepers, defined as those who get less than 6 hours of sleep per night, increased from 7.6% in 1975 to 9.3% in 2006 (Knutson et al. 2010). In addition, average sleep duration decreased among adults between 1985 and 2012 (Ford et al. 2015). Similarly, sleep duration for adolescents decreased between 1991 and 2012, with an increasing proportion of adolescents getting less than 7 hours of sleep per night (Keyes et al. 2015). Additionally, a recent review showed that 70% of college students get less than 7 hours of sleep per night and have irregular sleep schedules, and that 50% report daytime sleepiness (Hershner and Chervin 2014).

The overall prevalence rate of sleep problems has been estimated to be 20.4% among adults (Hublin et al. 2001) and 25% among adolescents (Ohayon et al. 2000). The higher prevalence rate of sleep problems among adolescents is attributed to an interaction of biological factors, such as changes in chronotype, and environmental factors, such as social evening activities and media use. A combination of these factors may cause later bedtimes while getting-up times remain early in the morning (Carskadon et al. 1993). University students, who represent an age group experiencing the transition from adolescence to adulthood, appear to be a high-risk group for sleep problems (Buboltz et al. 2001). This vulnerability can be explained by changes in lifestyle factors, including increased independence, new relationships, academic responsibilities, more night-time activities, and access to alcohol and other substances (Taylor et al. 2013). It is therefore not surprising that approximately 50% of university students exhibit poor sleep quality and/or excessive daytime sleepiness compared to 36% of the general population (Oginska and Pokorski 2006; Lund et al. 2010), and that they suffer from more disturbed sleep than individuals from the general population (Jiang et al. 2015). The above-mentioned sleep problems can negatively affect students' daytime functioning and academic achievement. A recent study showed, for example, that chronic sleep reduction affected students' academic performance and predicted the students' concentration level, even when other lifestyle factors were controlled for (van der Heijden et al. 2018).

Medical students represent a university cohort which appears to be highly vulnerable to sleep problems (Azad et al. 2015). They have increased rates of insufficient sleep duration, poor sleep quality, and excessive daytime sleepiness. For a narrative review, see Azad et al. 2015. Possible explanations for these elevated prevalence rates of sleep problems are the long duration and intensity of academic study, clinical duties that include overnight and on-call shifts, and dealing with illness and death, which can be emotionally challenging (Azad et al. 2015). It is also well established that pre-sleep worries, rumination, and stress-related hyperarousal can negatively affect sleep (Harvey 2000; Thomsen et al. 2003; Akerstedt et al. 2007). All of these are commonly experienced by medical students as their study is very demanding and time-consuming, consequently reducing students' free-time activities and life–work balance (Yu et al. 2017). In many countries, getting a place at medical school requires high grades, leading to pressure and competition among students, both prior to and after admission. Although multiple studies have investigated sleep problems among medical students, prevalence rates vary greatly between them. This may be the result of cross-cultural diversity, and different assessment methods and/or definitions of what constitutes sleep disturbance (Azad et al. 2015). There is currently no published meta-analysis of sleep problems in medical students. Thus, the present study aims to examine the pooled prevalence of sleep problems in medical students around the world using English language research studies (Medeiros et al. 2001; Lima et al. 2002; Bahammam et al. 2005; Kang and Chen 2009; Zailinawati et al. 2009; Brick et al. 2010; Sahraian and Javadpour 2010; James et al. 2011; Abdulghani et al. 2012; Mazurkiewicz et al. 2012; ElArab et al. 2014; Giri et al. 2013; Pagnin et al. 2014; Rique et al. 2014; Ramamoorthy et al. 2014; Prashanth et al. 2015; Mirghani et al. 2015; Surani et al. 2015; Waqas et al. 2015; Alsaggaf et al. 2016; Elwasify et al. 2016; Kumar and Vandana 2016; Mohammadbeigi et al. 2016; Rasekhi et al. 2016; Saygın et al. 2016; Siddiqui et al. 2016; Wang et al. 2016; Yazdi et al. 2016; Almojali et al. 2017; AlQahtani et al. 2017; Asiri et al. 2018; Corrêa et al. 2017; Fawzy and Hamed 2017; Gladius et al. 2017; Ibrahim et al. 2017; Johnson et al. 2017; Mokros et al. 2017; Najafi Kalyani et al. 2017; Priya et al. 2017; Sarbazvatan et al. 2017; Alnomsi et al. 2018; Nadeem et al. 2018; Rathi et al. 2018).

Sleep problems and their daytime consequences include a wide range of complaints, such as insufficient sleep duration, poor sleep quality, excessive daytime sleepiness, and difficulty initiating and/or maintaining sleep (Azad et al. 2015; Kalmbach et al. 2017). In the current review, sleep problems were defined as including one of three components, namely insufficient sleep duration, poor sleep quality, or excessive daytime sleepiness. Due to the differences in the definition of each of these components as well as used, measurement tools and cut-off values used, each one was meta-analysed separately.

Methods

This systematic review and meta-analysis was guided by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement (Liberati et al. 2009).

Data sources and searches

Two members of our review team (MT and NA) independently conducted an electronic literature search using four databases; namely, MEDLINE, EMBASE, ScienceDirect, and

ProQuest Medical and Google Scholar engine. The following keywords were used: 'medical students' plus 'sleep disturbance' or 'sleep problems' or 'sleep quality' or 'sleep duration' or 'excessive daytime sleepiness' or 'sleep disorder' or 'sleep habit' or 'sleep hygiene'. The search was limited to English language research papers published from inception of the databases until the second week of September 2018. The review team manually screened the references of the identified papers for potential inclusion in the review.

Study selection

Our review included observational studies that aimed to study the prevalence of sleep problems among medical students. To be included, research studies had to meet the following criteria: (1)published in the English language, (2) date of publication before the second week of September 2018, (3) medical students assessed as the target population, and (4) reported data on the prevalence of sleep disturbance using a validated, commonly utilized measurement tool. Specifically, we included studies that reported sleep duration per night and/or used the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al. 1989) for sleep quality or the Epworth Sleepiness Scale (ESS) (Johns 1991) for excessive daytime sleepiness. Exclusion criteria were: (1) case reports and case series, (2) studies that reported results for medical students with non-medical students in the same group, but without providing a subgroup analysis, (3) lack of study availability and inability to obtain the full text after contacting the authors, and (4) studies that focused on specific sleep disorders (e.g., sleep apnea) among medical students. The flow diagram of study inclusion is shown in Fig. 1.

Outcomes and measures

The anticipated outcome of this systematic review and meta-analysis was to report the prevalence of sleep problems among medical students. The specific measures were to: (1) report the pooled mean duration of sleep per night, (2) determine the average PSQI score and corresponding prevalence of poor sleep quality as measured by the index, (3) determine the prevalence of excessive daytime sleepiness as measured by the ESS, and (4) investigate age, gender, and country as covariates/factors of sleep quality and excessive daytime sleepiness among medical students. Two members of the review team (HJ and MF) independently screened titles, abstracts, and full texts and assessed studies for eligibility criteria, as well as performing the data extraction and research summary. Any disagreements were resolved through discussion with a third reviewer (AA) to reach consensus.

Data extraction

Data were independently extracted by two reviewers (HJ and MT), and checked by a third reviewer (NA or MF). The following information was extracted and tabulated systematically: study authors, study country, study period, sampling method, age, proportion of male gender, sample size, assessment instruments and cut-offs of sleep quality (PSQI) and excessive daytime sleepiness (ESS), and the main key results of sleep prevalence.

Quality evaluation

Two reviewers (HJ and MF) independently assessed the methodological quality of the studies using a standardized checklist consisting of six items in terms of sample size and sampling technique, utilized measurement tools, and statistical analyses. The item scores ranged between zero and six, with scores of zero to two corresponding to low quality, three or four to medium quality, and five or six to high quality. Disagreements between the two reviewers were resolved by consensus after discussion with a third reviewer (AA). See Supplementary Material 1.

Data synthesis and analysis

Data were pooled using random-effects model according to the DerSimonian–Laird method. Results reported prevalence and corresponding 95% confidence intervals (CIs). Furthermore, data were presented graphically using forest plots. An assessment of study heterogeneity using the I^2 statistic was performed, with a value of 75–100% considered to represent high heterogeneity. Between-study heterogeneity was also assessed by the Cochran (Q) statistic test and tau^2 (τ^2). A leave-one-out sensitivity analysis was performed by iteratively removing one study at a time to confirm that our findings were not driven by any single study. The meta-regression technique was applied to examine covariates of sleep quality and daytime sleepiness among medical students, with subgroup analysis being conducted to analyse for the country-of-origin factor among students. Funnel plots were used to visually assess publication bias, and rank-order correlations were also computed. Funnel plots are a visual tool for examining publication bias in meta-analysis. In the present study, we used the funnel plot of precision to produce scatterplots of logit event rate, which is a derivative of prevalence estimate from individual studies (horizontal axis) against a measure of study precision (vertical axis). Standard error was used as a measure of study precision in our plots. Duval and Tweedie's trim-and-fill procedure was used to calculate adjusted point estimates. Meta-analyses were performed using OpenMetaAnalyst software

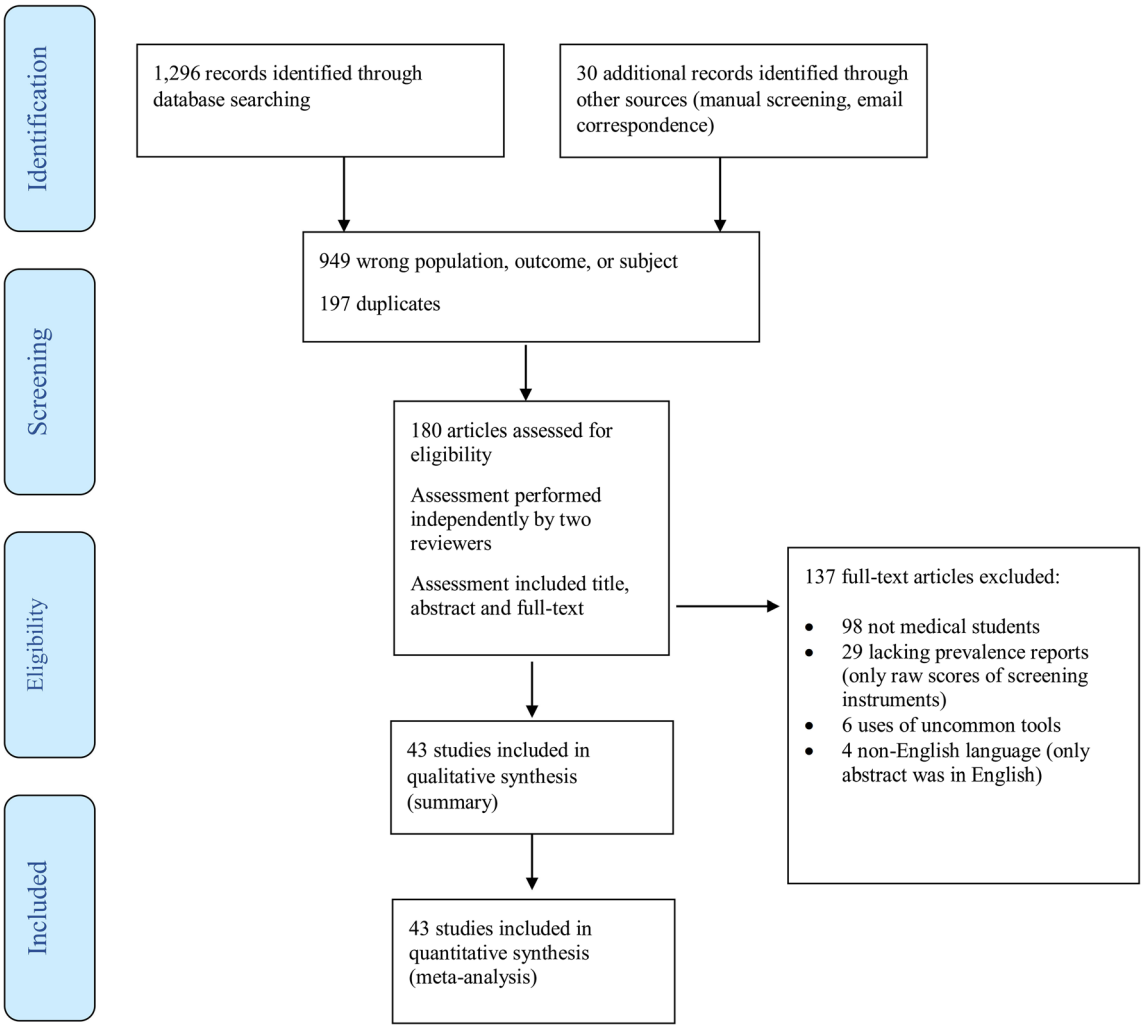

Fig. 1 Flow diagram of study inclusion

provided by the Centre for Evidence Synthesis in Health, School of Public Health at Brown University. Funnel plots and related publication bias tests were performed using Comprehensive Meta-Analysis, version 2.0 (Borenstein et al. 2005). Other descriptive statistical analyses were carried out using STATA 14.0 (StataCorp 2015).

Results

Characteristics of included studies

Forty-three studies, involving a total of 18,619 respondents from 13 countries, contributed to the analyses (see Table 1). All of the studies were published after the year 2001, and approximately two-thirds of the literature had been published within the past 5 years. The median number of respondents per study was 278 (range: 27–6085), and their median age was 21 years (range: 19–28 years). Approximately 60% of the participants were females. Table 2 provides a systematic summary of the studies included in this review. The mean score of the quality assessment was 4.2, ranging from 3.0 to 6.0.

All of the 43 studies had an observational, cross-sectional research design. K represents the number of the studies and N represents the number of participants in that particular analysis. Sixteen studies (K = 16, N = 10,512) reported sleep duration. Thirty-three studies (K = 33, N = 15,462) reported the prevalence of poor sleep quality, using the number of events (participants with PSQI $\geq$ 5) and total study sample size. Twenty-three studies (K = 23, N = 13,403) reported mean PSQI scores and corresponding standard deviations (SD). Finally, 18 studies (K = 18, N = 5688) reported the prevalence of excessive daytime sleepiness, using the number of events (participants with ESS $\geq$ 10) and total study sample size. All of the studies included in this meta-analysis reported their prevalence rates primarily using standard cut-offs of 5 or 10 points or greater for PSQI and ESS respectively.

Table 1 Selected characteristics of studies examining sleep problems among medical students included in systematic review and meta-analysis

Study	Country	Number of respondents	Mean age in years*	Male %	Sleep duration (hours/night) *
Medeiros et al. (2001)	Brazil	36	20.7 ± 2.2	58.33	6.7 ± 1.3
Lima et al. (2002)	Brazil	27	20.2 ± 2.0	48.15	7.0 ± 1.0
James et al. (2011)	Nigeria	255	24.45 ± 2.32	49.02	NR
BaHammam et al. 2005)	Saudi Arabia	129	21.2 ± 0.8	NR	5.9 ± 1.6
Kang and Chen (2009)	China	160	20.3 ± 1.9	50.62	6.7 ± 1.3
Zailinawati et al. (2009)	Malaysia	792	20.8 ± NR	41.04	6.6 ± 1.3
Brick et al. (2010)	USA	314	27.8 ± 4.22	42.36	NR
Sahraian and Javadpour (2010)	Iran	159	21.52 ± 2.67	49.69	NR
Mazurkiewicz et al. (2012)	USA	86	NR	25.58	NR
Abdulghani et al. (2012)	Saudi Arabia	491	24.4 ± 1.9	37.47	NR
Giri et al. (2013)	India	50	22.4 ± 0.5	40.00	NR
Rique et al. (2014)	Brazil	221	22.3 ± 3.8	55.66	NR
Pagnin et al. (2014)	Brazil	127	21.3 ± 2.3	44.88	NR
ElArab et al. (2014)	Egypt	435	21.4 ± 1.88	48.51	NR
Ramamoorthy et al. (2014)	India	121	NR	53.72	NR
Waqas et al. (2015)	Pakistan	263	21.1 ± 1.78	43.73	NR
Surani et al. (2015)	Pakistan	504	20 ± 1.4	40.48	6.4 ± 1.5
Mirghani et al. (2015)	Sudan	140	22.8 ± 1.8	27.86	7.0 ± 1.9
Prashanth et al. (2015)	India	503	NR	48.11	NR
Wang et al. (2016)	China	6085	NR	27.28	7.0 ± 1.0
Mohammadbeigi et al. (2016)	Iran	363	21.8 ± 3.2	30.30	NR
Alsaggaf et al. (2016)	Saudi Arabia	305	22 ± 1.3	41.64	5.5 ± 2.0
Siddiqui et al. (2016)	Saudi Arabia	318	22.35 ± 1.4	64.78	6.0 ± 1.94
Kumar and Vandana (2016)	India	308	21.4 ± 1.85	57.14	NR
Yazdi et al. (2016)	Iran	285	22.8 ± 1.74	47.37	NR
Saygin et al. (2016)	Turkey	337	21.3 ± 2.1	42.09	6.6 ± 1.3
Elwasify et al. (2016)	Egypt	1182	21.4 ± 1.5	32.32	NR
Rasekhi et al. (2016)	Iran	177	20.99 ± 2.12	46.89	6.0 ± NR
Mokros et al. (2017)	Poland	140	NR	NR	NR
Corrêa et al. (2017)	Brazil	372	NR	37.10	6.0 ± 1.0
Najafi Kalyanii et al. (2017)	Iran	278	19.88 ± 1.52	34.89	NR
Almojali et al. (2017)	Saudi Arabia	263	21.9 ± 1.4	68.82	5.8 ± 1.3
Fawzy and Hamed (2017)	Egypt	700	21.22 ± 1.623	35.43	6.0 ± 1.0
Ibrahim et al. (2017)	Saudi Arabia	576	21 ± 1.46	35.76	NR
Sarbazvatan et al. (2017)	Iran	80	19.2 ± 1.04	NR	NR
Gladius et al. (2017)	India	203	NR	40.39	NR
Johnson et al. (2017)	USA	307	26.4 ± NR	35.83	NR
Priya et al. (2017)	India	307	20.5 ± NR	76.54	NR
AlQahtani et al. (2017)	Saudi Arabia	237	22 ± 2.37	61.18	NR
Asiri et al. (2018)	Saudi Arabia	286	22.4 ± 1.6	63.64	NR
Alnomsi et al. (2018)	Saudi Arabia	169	22.9 ± 1.27	48.52	60.5 ± 1.52
Nadeem et al. (2018)	Pakistan	362	19.57 ± 1.45	40.05	NR
Rathi et al. (2018)	India	166	20.93 ± 1.86	53.61	NR

NR = not reported

* Mean ± standard deviation

Table 2 Systematic summary of studies of sleep problems among medical students included in review

Study	Design; sampling method; response rate	Research tool(s)	Key findings	Quality score
Medeiros et al. (2001)	Cross-sectional survey; convenience sampling; NR	PSQI	• 38.9% had poor sleep quality according to PSQI.	4
Lima et al. (2002)	Cross-sectional survey; convenience sampling; NR	PSQI, MEQ	• During early or standard schedule (7:00–8:00 am), 42.3% had a value > 5 according to PSQI. • Study included change of class timing (10:00 am); the prevalence of sleep disturbance decreased to 11.5% based on this change.	3
James et al. (2011)	Cross-sectional survey; convenience sampling; 91%	PSQI, ESS, FACE, FSS, GHQ-12	• 32.5% of medical students reported poor quality sleep according to PSQI. • Presence of a chronic illness, adverse childhood experience, and irregular sleep schedule significantly predicted poor sleep quality.	4
BaHammam et al. (2005)	Cross-sectional survey; convenience sampling; 44.4%	ESS	• 22.4% had EDS based on ESS. • Mean sleep duration 5.9 ± 1.6.	4
Kang and Chen (2009)	Cross-sectional survey; simple random sampling; 81.2%	PSQI, ESS, FSS	• 33.8% had poor sleep quality according to PSQI. • 14.4% had EDS based on ESS. • A significant positive correlation between irregular bedtime frequency and PSQI scores.	6
Zailinawati et al. (2009)	Cross-sectional survey; convenience sampling; 69.5%	ESS, GHQ-12	• EDS in 35.5% of students. • Psychological distress in 41.8%, and 16.1% reported bad sleep quality according to GHQ-12.	4
Brick et al. (2010)	Cross-sectional survey (web-based); convenience sampling; 61%	PSQI	• 148 (47%) of students above PSQI clinical cut-off.	4
Sahraian and Javadpour (2010)	Cross-sectional survey; convenience sampling; 79%	PSQI, GHQ-28	• 57.2% of students poor sleepers according to PSQI. • Statistically significant correlation between sleep quality and general health status.	3
Mazurkiewicz et al. (2012)	Cross-sectional survey; convenience sampling; 70%	ESS, MBI-GS	• 33% of students had EDS.	4
Abdulghani et al. (2012)	Cross-sectional survey; convenience sampling; 55%	ESS	• 36.6% had EDS according to ESS; with a statistically significant increased incidence in female students ($p < 0.001$).	4
Giri et al. (2013)	Cross-sectional survey; convenience sampling; NR (50 medical students only, 100 were interns/postgraduates)	PSQI, ESS	• The prevalence is NR according to PSQI. • PSQI mean of 5.28 (SD 2.39). • 20% had EDS according to ESS. • Sleep quality in females was better than in the males.	3
Rique et al. (2014)	Cross-sectional survey; convenience sampling; 86.7%	PSQI, ESS	• 61.5% had poor quality of sleep according to PSQI. • 42.1% had EDS according to ESS.	5
Pagnin et al. (2014)	Cross-sectional survey; convenience sampling; NR	PSQI, ESS, MBI, BDI, BAI	• 65% prevalence of poor sleep quality according to PSQI. • 63% had EDS according to ESS. • Poorer academic performance associated with poor sleep quality.	4
ElArab et al. (2014)	Cross-sectional survey; convenience sampling; 72%	ESS, ISS, GHQ-28	• 28.7% had EDS according to ESS. • Different parasomnias prevalent.	4
Ramamoorthy et al. (2014)	Cross-sectional survey; convenience sampling; NR	ESS	• 30.57% had EDS according to ESS.	3
Waqas et al. (2015)	Cross-sectional survey; convenience sampling; 94%	PSQI, PSS	• 77% prevalence of poor sleep quality according to PSQI. • Very high prevalence of academic stress associated with poor sleep quality.	4
Surani et al. (2015)	Cross-sectional survey; convenience sampling; 77.7%	PSQI, ESS	• 39.5% prevalence of poor sleep quality according to PSQI. • 26.1% had EDS according to ESS. • Poor sleep quality associated with female gender ($p < 0.05$), EDS ($p < 0.05$), total hours slept ($p < 0.001$) and sleep disturbances ($p < 0.001$).	4

Table 2 (continued)

Study	Design; sampling method; response rate	Research tool(s)	Key findings	Quality score
			• Mean sleep duration 6.4 ± 1.5.	
Mirghani et al. (2015)	Case-control study*; convenience sampling; 81.6% *Excellent grade medical students versus average grade medical students	PSQI	• Poor sleep detected in 36% of excellent group, and 94.6% of average group, with significant difference seen between groups ($p < 0.001$).	4
Prashanth et al. (2015)	Cross-sectional survey; convenience sampling; NR	ESS	• 11.33% had EDS according to ESS.	3
Wang et al. (2016)	Cross-sectional survey; data collected in 2011 and 2013; convenience sampling *Data on prevalence rates reported by authors for 2013 only	PSQI	• 27.8% poor sleepers according to PSQI. • Poor sleep quality associated with: poor academic performance, exercise frequency less than three times a week, skipping breakfast.	4
Mohammadbeigi et al. (2016)	Cross-sectional survey; convenience sampling; 95.5%	PSQI, COS	• Prevalence of poor sleep quality 61.7% according to PSQI. • Overuse of internet and screens related to poor sleep quality and quantity.	3
Alsaggaf et al. (2016)	Cross-sectional survey; convenience sampling; 95%	PSQI, ESS, PSS	• Prevalence of poor sleep quality 30% according to PSQI. • 39% of students had EDS according to ESS. • Poorer academic performance and stress associated with poor sleep quality.	4
Siddiqui et al. (2016)	Cross-sectional survey; convenience sampling; 84.5%	PSQI	• Poor sleep quality reported by 74.2% of students.	4
Kumar and Vandana (2016)	Cross-sectional survey; probability sampling; 96.3%	PSQI	• 39.6% classified as "poor sleepers". • More analgesic use among "poor sleepers" compared to "normal sleepers".	5
Yazdi et al. (2016)	Cross-sectional survey; probability sampling; 87.7%	PSQI	• 57.5% had poor sleep quality according to PSQI. • Mean global PSQI score and average score of four subscales significantly higher in male than female students.	4
Saygin et al. (2016)	Cross-sectional survey; probability sampling; 46.8%	PSQI, ESS, BSAST	• 79.6% prevalence of poor sleep quality according to PSQI. • 17.9% had EDS according to ESS. • Five individuals (1.5%) suffered sleep apnea according to BSAST.	5
Elwasify et al. (2016)	Cross-sectional survey (multi-university study); convenience sampling; NR	PSQI	• Mean PSQI score 6.01 (SD ± 2.73). • According to PSQI, 46.7% students had good sleep quality and 53.3% had poor sleep quality.	5
Rasekhi et al. (2016)	Cross-sectional survey; convenience sampling; 74%	PSQI	• 66.6% of students had poor sleep quality according to PSQI.	4
Mokros et al. (2017)	Cross-sectional survey; convenience sampling; 94%	PSQI, BDI, HCL-32, CQ, EPQ-R	• 42.8% of students had poor sleep quality according to PSQI. • Poor sleep quality predicted depressive symptoms.	4
Corrêa et al. (2017)	Cross-sectional survey; probability sampling; 68.9%	PSQI	• 39.5% of students had poor sleep quality according to PSQI.	5
Najafi Kalyani et al. (2017)	Cross-sectional survey; probability sampling; NR	PSQI, DASS-21	• 46.4% of students had poor sleep quality according to PSQI. • 73% of students had moderate or severe stress. • Mean sleep quality score 4.65 ± 2.37, and their stress score 8.09 ± 5.14. • Statistically significant relationship was found between student stress levels and sleep quality ($p < 0.001$).	4
Almojali et al. (2017)	Cross-sectional survey; Convenience sampling; 86%	PSQI, KPDS	• 76% of students had poor sleep quality according to PSQI.	5

Table 2 (continued)

Study	Design; sampling method; response rate	Research tool(s)	Key findings	Quality score
			• 53% of the students had severe stress. • A statistically significant relationship was found between the students' stress levels and sleep quality ($p < 0.001$).	
Fawzy and Hamed (2017)	Cross-sectional survey; convenience sampling; 100%	PSQI, DASS-21	• 55.7% of students had poor sleep quality according to PSQI. • Poor sleep quality associated with stress.	5
Ibrahim et al. (2017)	Cross-sectional survey; probability sampling; NR	PSQI, ESS, HADS	• Prevalence of poor sleep quality and EDS among medical students 70.4% according to PSQI and 37.3% according to ESS.	6
Sarbazvatan et al. (2017)	Cross-sectional survey; convenience sampling; sample size 645 from medical sciences, only 80 were medical students.	PSQI	• 72.5% poor sleepers according to PSQI.	4
Gladius et al. (2017)	Cross-sectional survey; probability sampling; NR	PSQI, PSS	• 72.4% of study students had poor sleep quality. • 66.5% had moderate stress.	6
Johnson et al. (2017)	Cross-sectional survey; two cohorts (included all enrolled students); 68%	ESS, MBI, PSS	• 26.9% had excessive daytime sleepiness according to ESS. • 34.3% reported fewer than 7 h of sleep on typical week nights.	5
Priya et al. (2017)	Cross-sectional survey; convenience sampling; NR	PSQI, ESS	• 67.4% had poor sleep quality according to PSQI. • 37.1% had EDS according to ESS.	4
Al Qahtani et al. (2017)	Cross-sectional survey; convenience sampling; NR	ESS	• 57% had EDS according to ESS.	4
Asiri et al. (2018)	Cross-sectional survey; convenience sampling; NR	PSQI	• 29.7% poor sleepers according to PSQI. • Quality of sleep differed significantly according to academic year.	5
Alnomsi et al. (2018)	Cross-sectional survey; convenience sampling; NR	PSQI	• 83.4% had poor sleep quality according to PSQI. • No correlation found between cumulative grades (GPA), sleep quality, chronotype, body mass index, or sleep duration during weekdays and weekends.	5
Nadeem et al. (2018)	Cross-sectional survey; convenience sampling; 63.8%	PSQI	• 38.9% had poor sleep quality according to PSQI. • Females reported more significant impact due to poor sleep quality.	5
Rathi et al. (2018)	Cross-sectional survey; census; 69%	PSQI, EPQ-R	• 32.5% had poor sleep quality according to PSQI. • Students with poor sleep quality had higher scores on neuroticism.	5

Abbreviations:

FACE family-related adverse childhood experiences*BAI* Beck anxiety inventory*BDI* Beck depression inventory*BSAST* Berlin sleep apnea screening tool*COS* cell-phone over-use scale*CQ* chronotype questionnaire*DASS-21* depressionanxietystress scale*EDS* excessive daytime sleepiness*EPQ-R* Eysenck personality questionnaire revised*ESS* Epworth Sleepiness Scale*FSS* fatigue severity scale*GHQ-12* general health questionnaire—12 items*GHQ-28* general health questionnaire—28 items*HADS* hospital anxiety and depression scale*HCL-32* hypomania checklist-32 items*ISS* insomnia severity scale*KPDS* Kessler psychological distress scale*MBI-GS* Maslach Burnout Inventory—General Survey*MEQ* morningness/eveningness questionnaire*PSQI* Pittsburgh Sleep Quality Index*PSS* perceived stress scale*SD* standard deviation*NR* not reported

Sleep problems among medical students

Sleep duration

Meta-analytic pooling of the point estimates of sleep duration per night yielded that medical students sleep about 6.3 h per night [95% CI 6.0–6.6], with statistically significant evidence of between-study heterogeneity ($Q = 1413$, $\tau^2 = 0.32$, $I^2 = 98.93\%$, $P < 0.001$). Figure 2 demonstrates the results of sleep duration per night. Sensitivity analysis indicated that no study influenced the results by more than 0.1 h of sleep per night analysis. Publication bias was assessed via visual inspection of the funnel plot (Kendall's τ without continuity correction = 0.21, $P = 0.30$). This visual inspection of the plot (see Fig. 3) indicated no bias. Duval and Tweedie's procedure showed that if the point estimate was to be adjusted for bias left or right of the mean, it would remain unchanged for the random effects model.

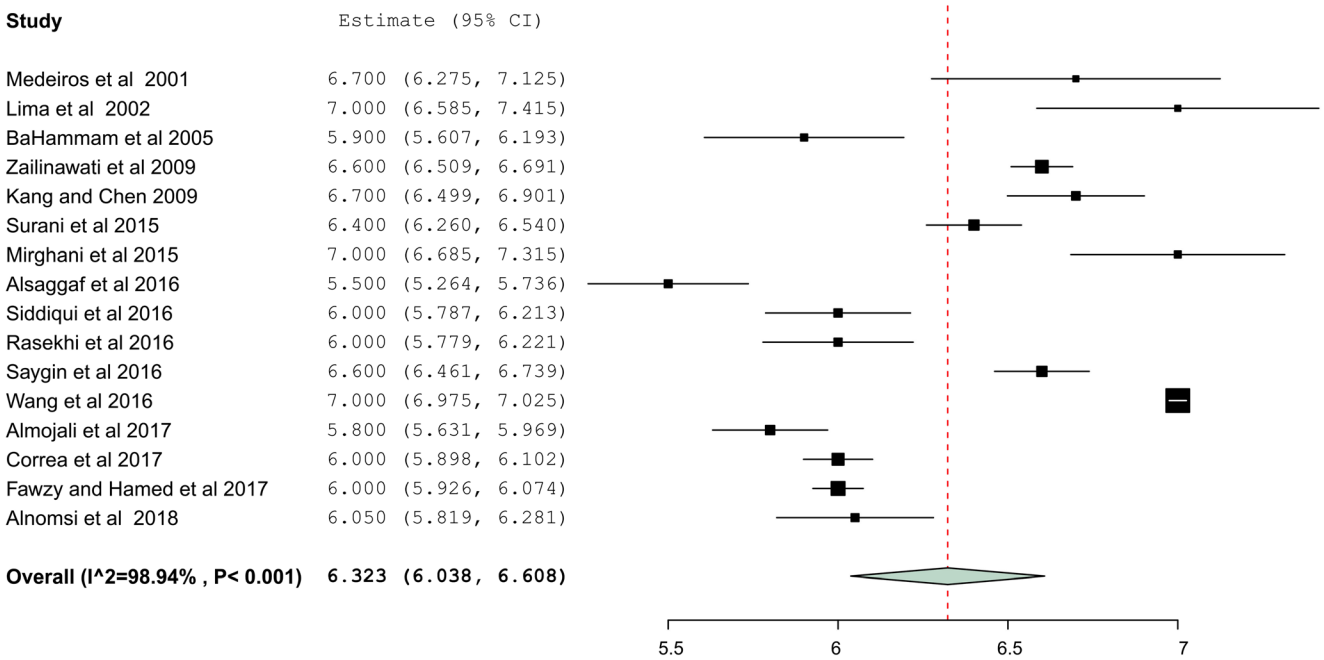

Fig. 2 Meta-analysis of sleep duration per night (in hours). Notes: 95% CI = 95% confidence Intervals

Sleep quality

Meta-analytic pooling of the point estimates of the PSQI values yielded that medical students scored 6.3 on the PSQI [95% CI 5.7–6.8], with statistically significant evidence of between–study heterogeneity (Q = 2734, $\tau^2 = 1.6$, $I^2 = 99\%$, $P < 0.001$). The meta-analytic pooling of the prevalence estimates of poor sleep quality according to the PSQI yielded a pooled prevalence rate of 55%, [95% CI 48.0%–62.0%], with statistically significant evidence of between-study heterogeneity (Q = 2538, $\tau^2 = 0.04$, $I^2 = 98.7\%$, $P < 0.001$). The raw prevalence estimates of poor sleep quality reported among

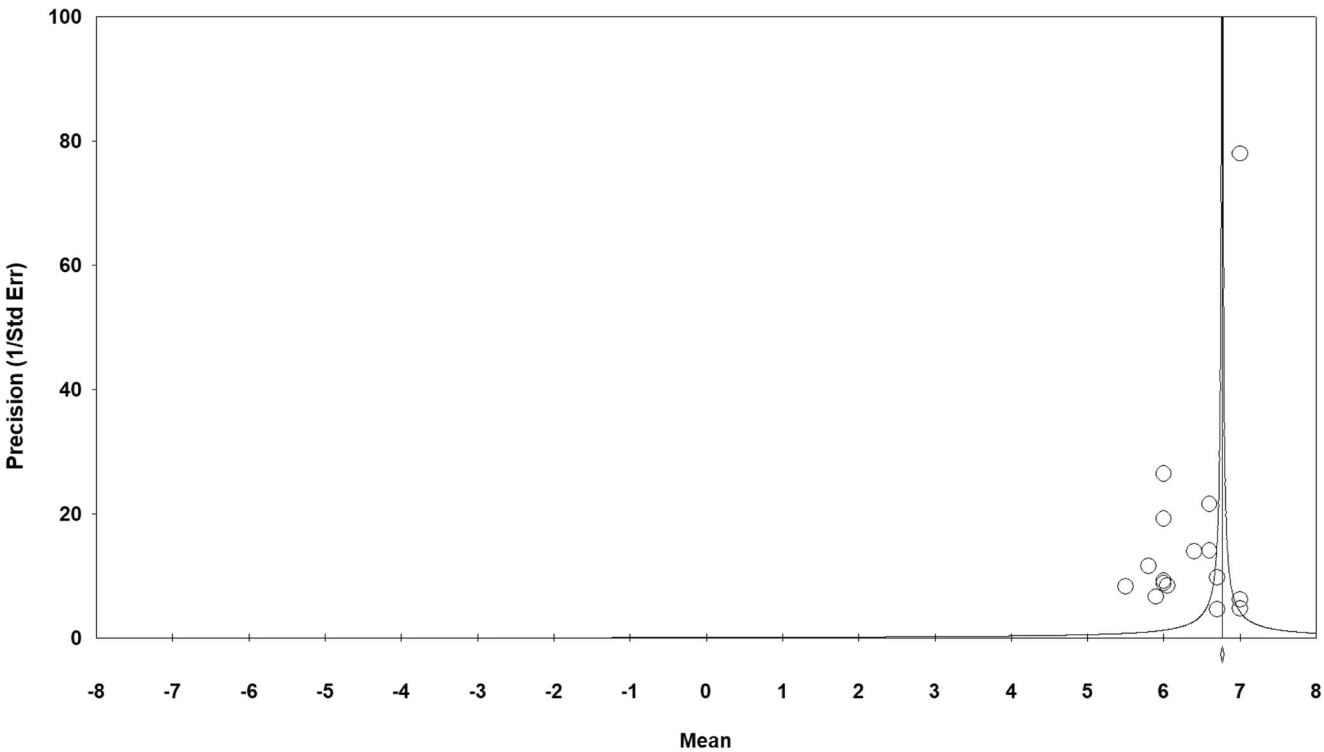

Fig. 3 Precision plot for random-effects meta-analysis of studies estimating sleep duration per night. Notes: study precision is measured using standard error

medical students using the PSQI ranged from 27.8% to 83.4%. Figure 4 demonstrates the meta-analysis of poor sleep quality. Sensitivity analysis indicated that no study affected the prevalence estimate by more than 1%. A visual inspection of the funnel plot (Kendall's τ without continuity correction = 0.01, $P = 0.09$) (see Fig. 5) indicated no publication bias. Duval and Tweedie's procedure indicated that if the point estimate was to be adjusted for bias left or right of the mean, it would remain unchanged for random effects model.

As a measure of heterogeneity, I^2 was 99%, indicating that heterogeneity characterized the studies investigating sleep quality in medical students. In order to explain this figure, covariate analyses were conducted for age and gender. Results revealed that age ($\beta = -0.007$, $P = 0.721$) and gender ($\beta = 0.1$, $P = 0.694$) were not significant moderators for the prevalence of poor sleep quality.

Furthermore, a subgroup analysis of the pooled prevalence of poor sleep quality by country was conducted (see Fig. 6). Results showed that the heterogeneity index as measure by I^2 showed an improvement for some countries, with a lower pooled prevalence rate for Brazil 49.9% (95% CI 37.1%–62.8%, $I^2 = 90.94\%$, $P < 0.001$), a higher pooled prevalence rate for Iran 59.9% (95% CI 53.2%–66.6%, $I^2 = 84\%$, $P < 0.001$), and a similar pooled rate to the overall prevalence for Egypt 54.2% (95% CI 51.9%–56.5, $I^2 = 3.5\%$, $P = 0.3$).

Some countries did not show an in improvement in the heterogeneity index; however, their pooled prevalence of poor sleep quality increased by approximately 5%. This included Pakistan with 60.8% (95% CI 38.2%–83.4% $I^2 = 98.5\%$, $P < 0.001$) and Saudi Arabia with 60.5% (95% CI 42.3%–78.8% $I^2 = 98.8\%$, $P < 0.001$).

Excessive daytime sleepiness

The meta–analytic pooling of the estimates of excessive daytime sleepiness yielded a crude prevalence rate of 31.0%,

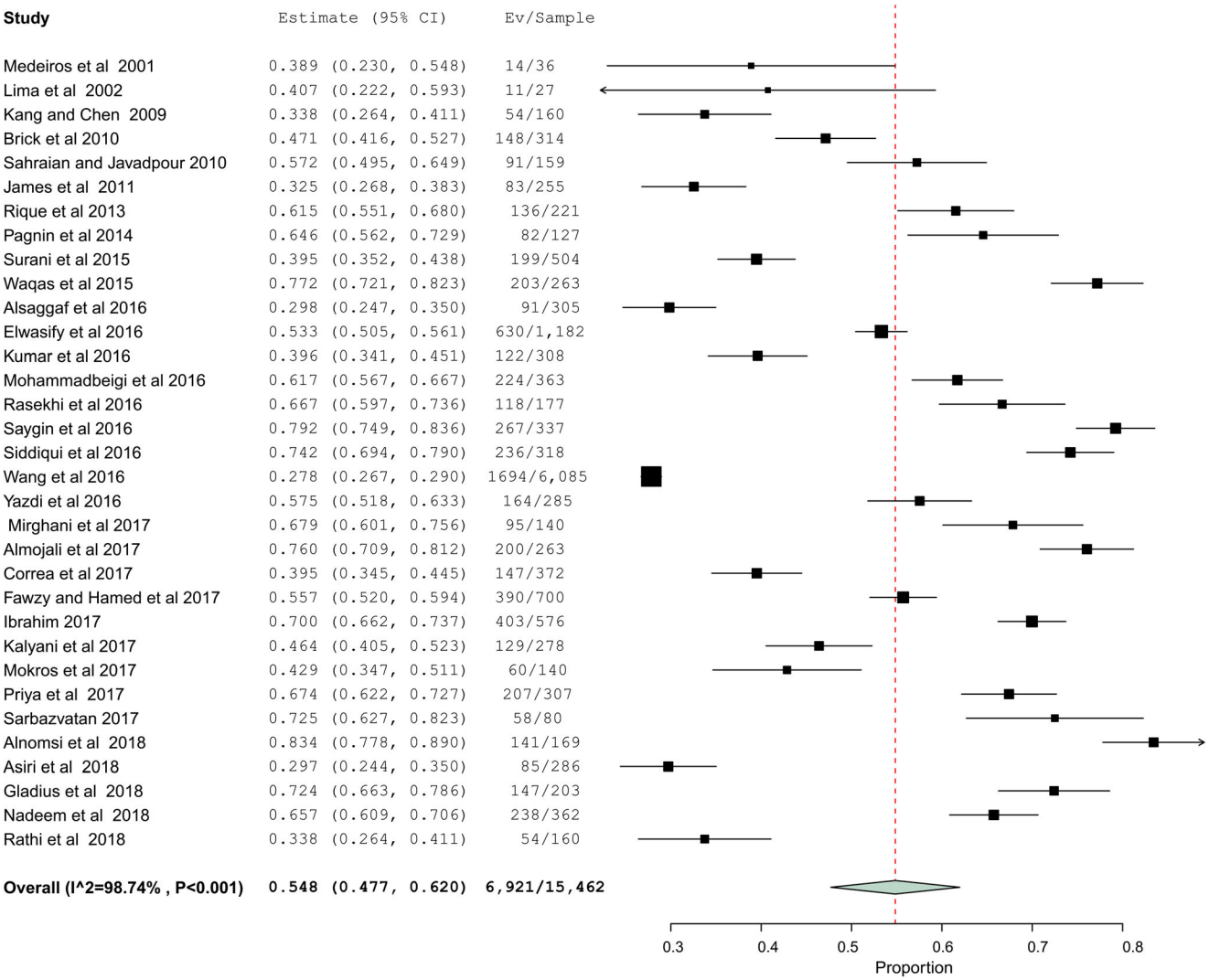

Fig. 4 Meta-analysis of prevalence of poor sleep quality measured by PSQI. Notes: *Ev/Sample* represents cases /total sample size per study. Events are defined as individuals scored > 5 on PSQI

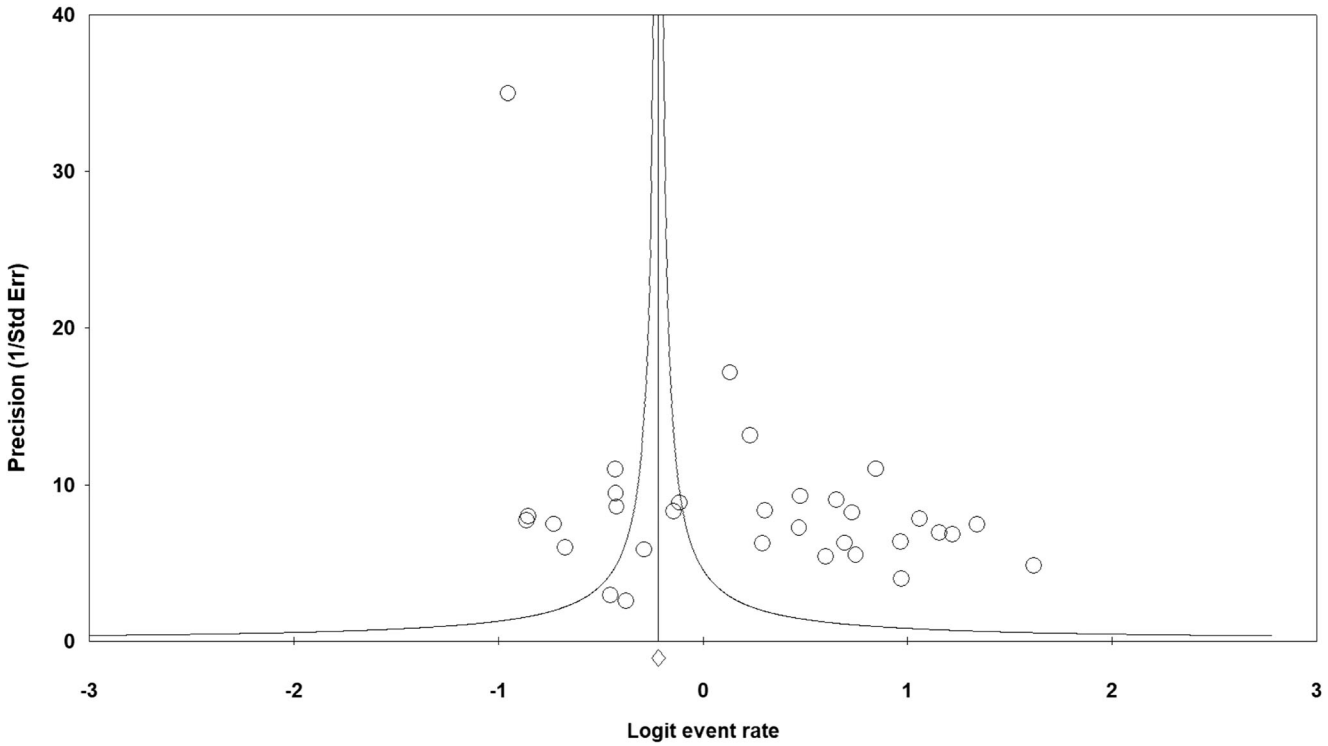

Fig. 5 Precision plot for random-effects meta-analysis of studies estimating prevalence of poor sleep quality. Notes: logit event rate is the derivative of prevalence in each study and study precision is measured using standard error

[95% CI 24.4%–37.7%], with statistically significant evidence of between-study heterogeneity ($Q = 603$, $\tau^2 = 0.02$, $I^2 = 97\%$, $P < 0.001$). The raw prevalence estimates of excessive daytime sleepiness reported among medical students using the ESS ranged from 10.3% to 63%, as demonstrated in Fig. 7. Sensitivity analysis indicated that no study affected the prevalence estimate by more than 1%, suggesting that the overall prevalence estimate was powered to the methodological quality of each research study included. A visual inspection of the funnel plot (Kendall's τ without continuity correction = −0.25, $P = 0.13$) (see Fig. 8) indicated no publication bias. Duval and Tweedie's procedure revealed that if the point estimate were to be adjusted for bias left or right of the mean, it would remain unchanged for the random effects model.

I^2 was 97%, indicating that heterogeneity characterized the studies investigating excessive daytime sleepiness in medical students. In order to explain this figure, covariate analyses were conducted for age and gender. Results indicated that age ($\beta = 0.12$, $P = 0.589$) and gender ($\beta = 0.27$, $P = 0.377$) were not significant moderators.

Furthermore, a subgroup analysis of the pooled prevalence of excessive daytime sleepiness by country was conducted (see Fig. 9). Results showed that the heterogeneity index as measured by I^2 showed an improvement in the heterogeneity index for some countries: with lower pooled prevalence for USA with 28.1% (95% CI 23.7%–32.6%, $I^2 = 0\%$, $P = 329$) and India with 24.7% (95% CI 9.6%–39.8%, $I^2 = 96\%$, $P < 0.001$), or with higher pooled prevalence in the case of Saudi Arabia with 38.4% (95% CI 29.9%–46.8%, $I^2 = 92.5\%$, $P < 0.001$) and Brazil with 52.4% (95% CI 31.9%–72.9, $I^2 = 93\%$, $P < 0.001$).

Discussion

Results of the current meta-analysis demonstrate that insufficient sleep duration is a common problem among medical students, as they slept on average only 6.3 h per night, which is less than the recommended amount. Additionally, 55% of the students reported poor sleep quality (PSQI≥5) with an average PSQI score of 6.3, and 31.0% reported excessive daytime sleepiness (ESS ≥ 10). Age and gender were not significant moderators for poor sleep quality or excessive daytime sleepiness. Subgroup analysis revealed some differences between countries. The prevalence of poor sleep quality was lower in Brazil, but higher in Iran, Pakistan, and Saudi Arabia, compared to the overall estimate. For excessive daytime sleepiness, India and USA showed a lower prevalence, while Brazil and Saudi Arabia exhibited higher prevalence compared to the overall estimate.

Our results indicate that the sleep duration of medical students is deficient by at least 1, and up to 3 hours, as the sleep duration recommendation is 7 to 9 hours for young adults and adults (Watson et al. 2015). An experiment by van Dongen

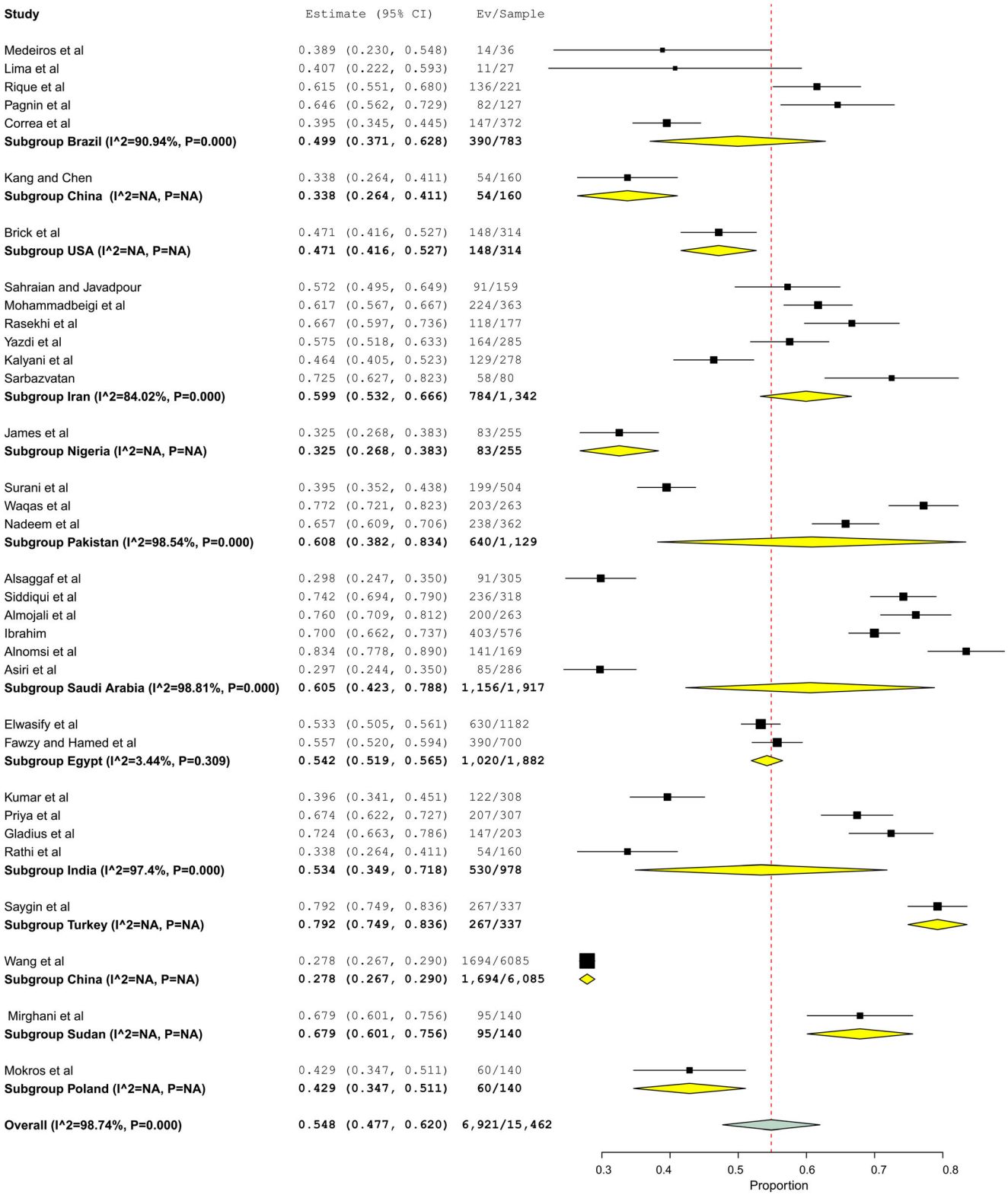

Fig. 6 Subgroup meta-analysis of prevalence of poor sleep quality by country

and colleagues demonstrated that a 2-week restriction of sleep (6 or fewer hours per night) produced cognitive performance deficits comparable to 2 nights of complete sleep deprivation (Dongen et al. 2003). The study concluded that even relatively moderate sleep restriction can seriously impair waking neurobehavioral functions in healthy adults (Dongen et al. 2003). This indicates that insufficient sleep in medical students may severely impair their work. Despite these alarming results, one

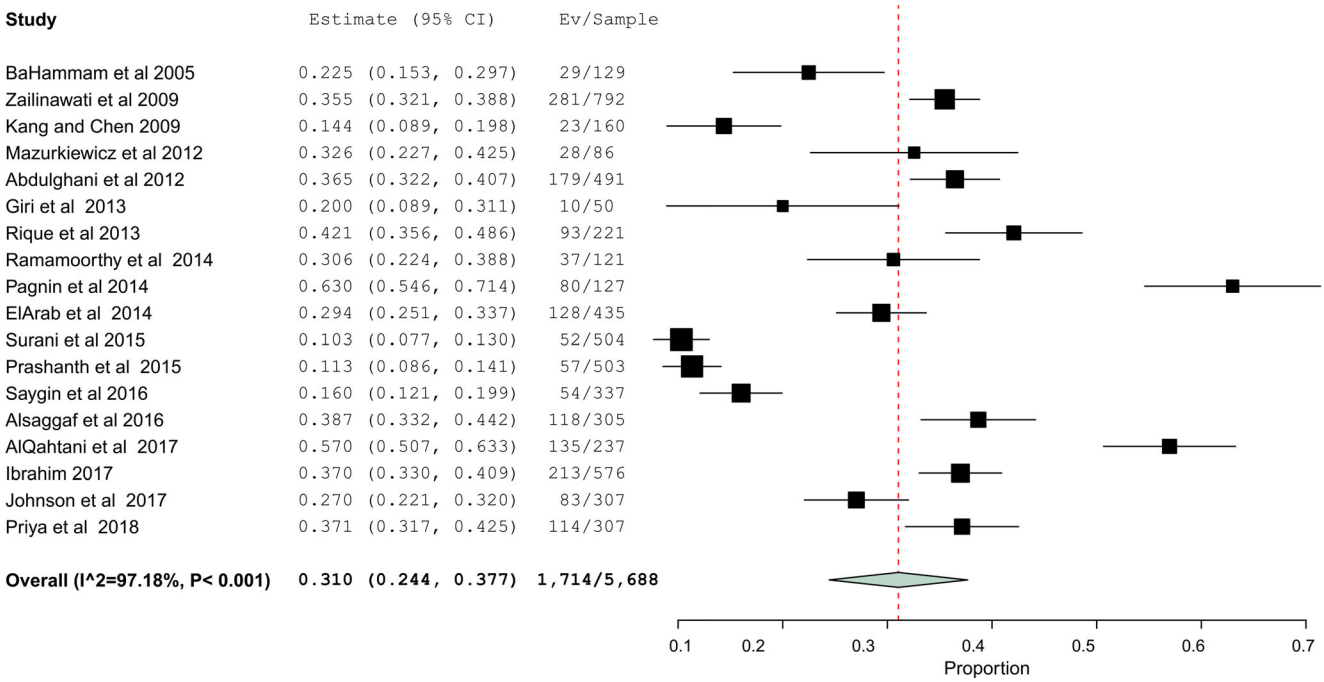

Fig. 7 Meta-analysis of prevalence of excessive daytime sleepiness measured by ESS. Notes: *Ev/Sample* represents cases /total sample size per study. Events are defined as individuals scored > 10 on ESS

has to be aware that there are individual differences in sleep need and vulnerability to sleep loss (Dongen et al. 2003). This suggests that some students can function well with this amount of sleep, whereas others may be severely impaired. Therefore, assessing sleep debt, which reflects an individual's amount of sleep relative to his/her sleep need, might be a better indication of problematic sleep. Additionally, it should be mentioned that the included studies on sleep durations did not address the problem of individuals' chronotype and sleep regularity. It has been shown that chronotype changes over a lifetime, and individuals become more evening-types during adolescence and young adulthood, peaking at the age of 20 years (Roenneberg et al. 2004), which is in line with the median age of 21 years of the participants in the studies in this

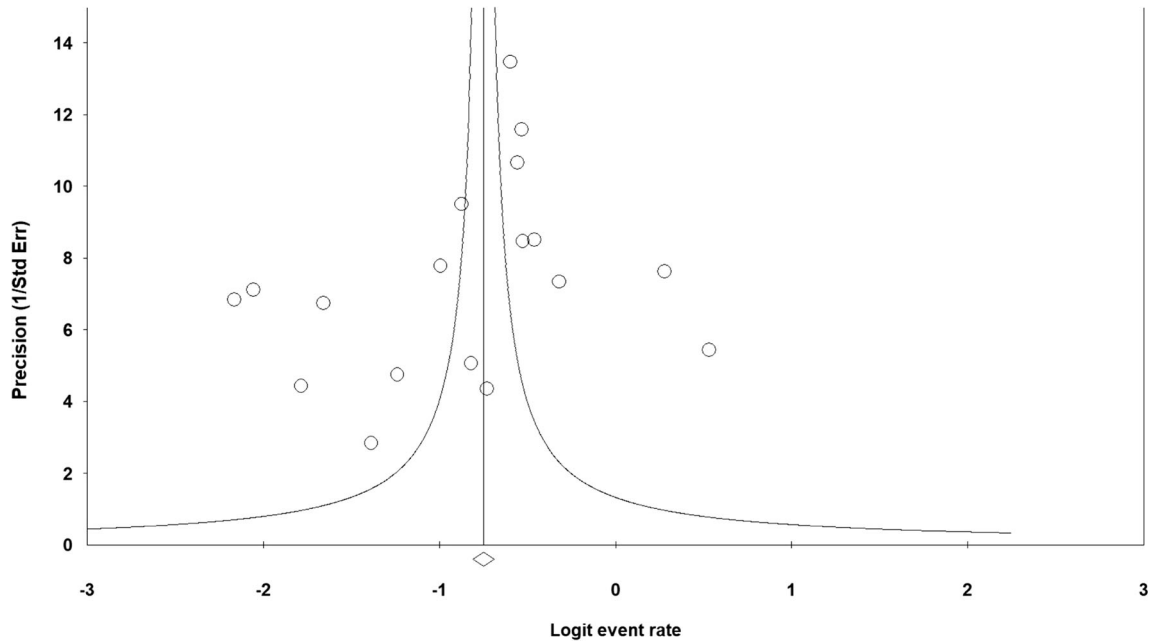

Fig. 8 Precision plot for random-effects meta-analysis of studies estimating prevalence of excessive daytime sleepiness. Notes: logit event rate is the derivative of prevalence in each study and study precision is measured using standard error

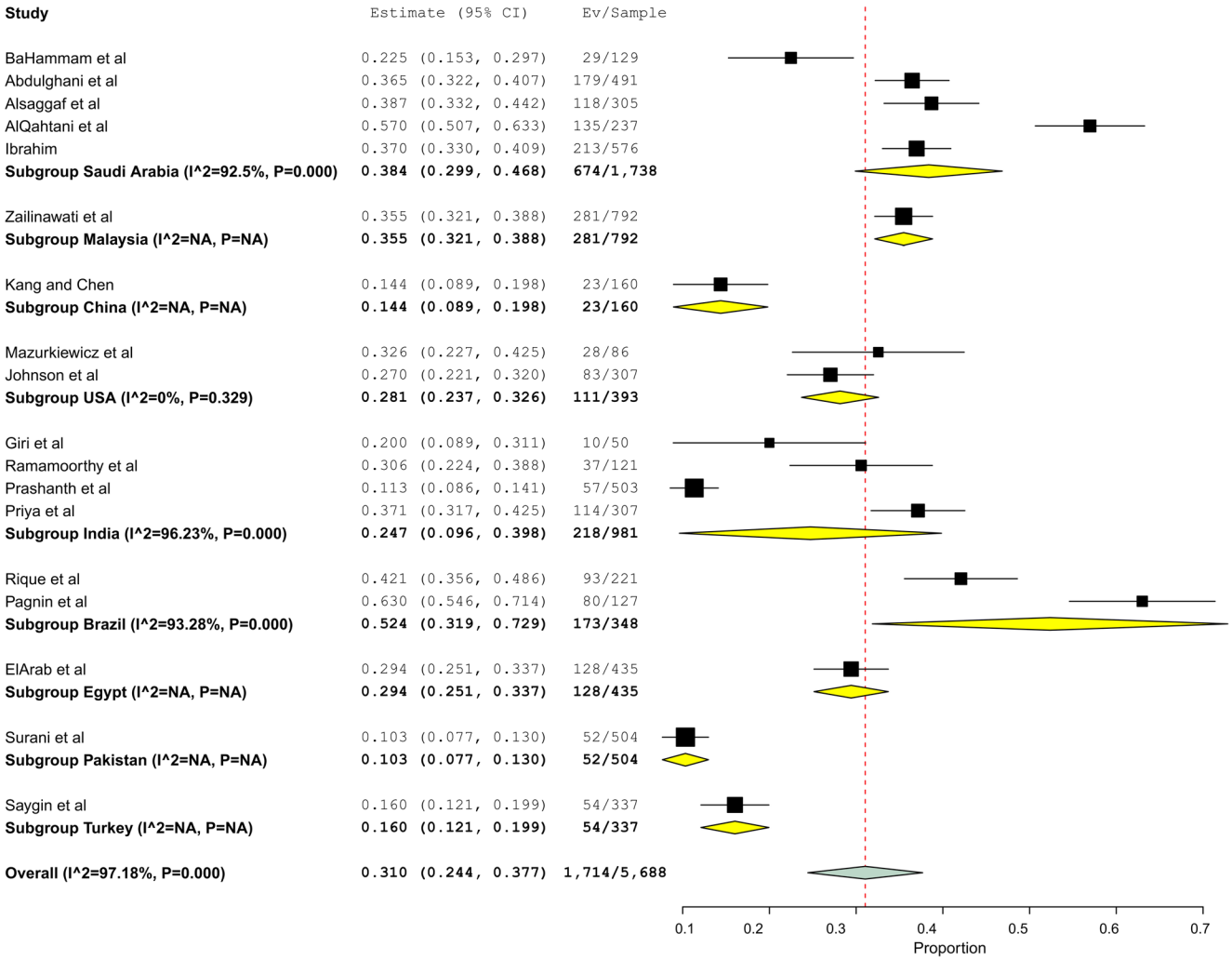

Fig. 9 Subgroup meta-analysis of prevalence of excessive daytime sleepiness

meta-analysis. These changes in chronotype imply that adolescents and young adults tend to go to bed late, they still have to get up early in the morning to attend their classes, which leads to an intense sleep debt during the week. Often, individuals compensate this sleep debt at the weekends by sleeping in on Saturday and Sunday mornings. This chronic misalignment between a person's preferred sleep/wake schedule and sleep/wake timing imposed by his/her work schedule has been referred to as social jetlag (Roenneberg et al. 2004). Supporting the idea that such sleep problems severely affect students' functioning, it has been shown that students with early chronotypes have better academic achievement (Haraszti et al. 2014; Enright and Refinetti 2017; Zerbini and Merrow 2017; Mirghani 2017) but less psychological well-being (Dimitrov et al. 2018).

A comprehensive meta-analysis of sleep duration and sleep patterns among Chinese university students (including medical students) showed that the pooled mean sleep duration was seven hours per night [95% CI 6.8–7.3] (Li et al. 2017). The same meta-analysis demonstrated that the percentage of students with sleep duration shorter than 7 hours per night was 43.9% [95% CI 36.9%–51.1%] (Li et al. 2017). The variation in sleep duration between our meta-analysis and the meta-analysis from China may indicate that medical students are even more affected by insufficient sleep than other students. On the other hand, the differences may point to discrepancies in socio-economic and cultural factors. Divergent attitudes towards academic achievement and performance are another important cultural aspect. As mentioned before, pre-sleep worries and rumination, which are likely to be associated with academic attitudes and performance pressure, negatively affect students' sleep (Harvey 2000; Thomsen et al. 2003; Akerstedt et al. 2007).

The present meta-analysis indicates that the majority of medical students experienced poor sleep quality with an average PSQI score of 6.3, which is above the cut-off score used to differentiate good from poor sleepers. Interestingly, the mean global PSQI score of Chinese medical students was around 6.16 in most of the studies included in a Chinese meta-analysis (Yu et al. 2017). These results are of high importance,

as they indicate that our findings can be generalized to medical students. Previous studies have shown that poor sleep quality negatively affects students' academic performance (Veldi et al. 2005; van der Heijden et al. 2018) as well as their psychological well-being, thereby increasing anxiety and depressive symptoms (Abdussalam et al. 2013; Sawyer et al. 2015; Choueiry et al. 2016) and further highlighting the importance of sleep quality for students' daytime functioning.

Approximately one-third of the medical students experienced excessive daytime sleepiness, which may be the consequence of insufficient sleep duration and/or poor sleep quality. A meta-analysis in adolescents showed that the relationship between excessive daytime sleepiness and academic performance was stronger than the relationship between sleep duration and academic performance or sleep quality and academic performance (Dewald et al. 2010), highlighting the relevance of this problem.

Moderator analyses indicated that age and gender were not significantly associated with sleep quality or excessive daytime sleepiness. The relationship between gender and sleep problems has been controversial among university-age students. For example, results from India (Giri et al. 2013) and Pakistan (Surani et al. 2015) showed that female students had a higher prevalence of sleep problems compared to male students, whereas findings from Iran (Yazdi et al. 2016) and Saudi Arabia (Siddiqui et al. 2016), showed that male students had a higher rate of sleep problems compared to female students. Finally, studies from the USA (Mazurkiewicz et al. 2012) and China (Li et al. 2017) suggested no statistically significant gender difference between males and females. The absence of effect for age may be explained by the narrow age range of the samples included in this meta-analysis. Investigating an age-by-gender interaction may be interesting for future studies, as research has generally shown developmental variation between males and females. Subgroup analyses showed some differences between countries, suggesting that cultural values, local conditions, and environment all play a role in sleep practices and attitudes. This aspect could be explored further by future reviews once a viable number of studies is available.

Based on our results, it can be concluded that the high prevalence of sleep issues among medical students requires ongoing monitoring and accurate diagnosis. Further, management interventions may reduce these problems and possibly prevent the development of sleep disorders such as insomnia, or physical or mental health problems. One approach to improving individuals' sleep, especially in relatively young samples, is to supply sleep hygiene knowledge, including information on bedtime routines, regular sleep schedules, electronic media use, etc. This approach has the advantage of being relatively cost-effective, since many students can be reached at the same time. However, it has also been shown that sleep hygiene knowledge does not necessarily improve sleep hygiene practice (Brown et al. 2002). Evaluating and applying more individually tailored sleep intervention or treatment programs is therefore recommended for future studies.

Limitations

Findings from the current meta-analysis should be interpreted in light of four main limitations. First, high heterogeneity (as measured by I^2) is unavoidable in epidemiological meta-analyses (Sedov et al. 2018; Li et al. 2018). In our meta-analysis, substantial heterogeneity remained despite conducting moderator analyses using meta-regression techniques or after performing subgroup analyses. Due to limited common information in the studies, additional sources of heterogeneity, such as lifestyle factors and stress, could not be explored.

Second, the studies included in this review were all cross-sectional surveys. However, longitudinal research of changes in sleep quality during medical education is needed to understand the factors associated with sleep problems among this population. Third, the prevalence rates were based on self-report instruments. Both the PSQI and the ESS are important clinical and research tools, but they only represent specific aspects of sleep, sleep quality, and excessive daytime sleepiness. Thus, future research is encouraged to investigate other sleep characteristics such as objective sleep quality measurement, including polysomnography. Fourth, most included studies did not differentiate between students with and without sleeping disorders (e.g., insomnia), although this may be relevant for estimating prevalence rates of sleep problems.

Conclusions

Findings from this systematic review and meta-analysis show that medical students experience insufficient sleep duration, with a mean 6.3 h per night. More than half (55%) of the students had poor quality of sleep as measured by the PSQI, and one third (31.0%) experienced excessive daytime sleepiness as measured by the ESS. Future studies are needed to identify, prevent, and treat sleep problems in this population.

Authors Contribution HJ and AA designed the study. MT, NA and MF conducted electronic and manual literature search. HJ performed statistical analyses and wrote the first draft along with JDF. AA and MF provided intellectual contributions to strengthening the manuscript and suggested additional data analyses. All authors provided critical revisions of manuscript and approved the final version.

Compliance with ethical standards

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

Informed consent For this type of study, formal consent is not required.

Conflict of interest statement The authors declare that there is no conflict of interest regarding the publication of this article.

Declaration of competing interests The authors declare that they have no competing interests.

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