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CLINICAL REVIEW

A systematic review and meta-analysis of poor sleep, insomnia symptoms and stress in undergraduate students

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SUMMARY

University students experience high prevalence of mental health problems and exacerbation of mental health difficulties, including sleep disturbances and stress during their studies. Stress and poor sleep quality and/or insomnia are interlinked outcomes for this population. The aim was to conduct a systematic review, and meta-analyses, of the relationships between sleep quality and/or insomnia with stress in students.

Full-text articles of studies exploring the associations of stress with poor sleep quality and/or insomnia in undergraduate students using validated tools and published in peer-reviewed journals were eligible for inclusion.

Thirty-four studies, resulting in 37 effect sizes, included and all were suitable for meta-analysis. The weighted pooled effect size between sleep quality and stress was for 0.39 (25 studies, n = 10,065), whereas a slightly higher pooled association of 0.41 was demonstrated for insomnia and stress (12 studies, n = 5564.5).

Pooled associations show moderate effects for associations between sleep quality, insomnia and stress in undergraduate students. High heterogeneity in meta-analyses was found, suggesting the findings should be considered cautiously. Future research should focus on longitudinal studies exploring sleep difficulties across the academic year, whilst university services should consider psychoeducation for stress and sleep in university students, especially during transition to university.

Introduction

University and college students are particularly vulnerable to psychological distress and the exacerbation, or first onset, of mental health difficulties [1]. In individuals that are studying for a degree in higher education stress levels were associated with poorer quality of life and well-being [2]. Over the past five y, poor mental well-being and distress appear to be rising in this population [3] with the most prominently reported difficulties including stress, anxiety, depression, suicidal ideation, and insomnia symptoms [1]. University and college students report insufficient sleep or poor subjective sleep quality [4], with recent evidence showing that approximately 30% of students meet criteria of insomnia [5]. Considering how poor sleep or lack of sleep opportunity negatively affects cognitive functions [6], it is no surprise that poor sleep is associated with decreased academic performance in young adults [7]. Recent evidence highlights the importance of longer, regular sleep as a positive contributor to academic performance in university students [8].

Sleep and stress are closely linked, at multiple levels, with current evidence supporting a bidirectional association between sleep and stress [9]. Experiences of stress are linked to appraisals of potential environmental threat and the stress reaction involves the autonomic nervous system and hypothalamic-pituitary-adrenocortical (HPA) activity [10]. Hyperactivity of HPA is evident in several clinical conditions including depression and insomnia [11]. Transitions between wakefulness and sleep states involve

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Abbreviations

AIS	Athens insomnia scale
BDI	Beck's depression inventory
CES	Center for epidemiologic studies depression scale
DASS	Depression anxiety stress scale
ESM	Experience sampling methodologies
ESS	Epworth sleepiness scale
GAD	General anxiety disorder
HPA	Hypothalamic-pituitary-adrenocortical
ICSRLE	Inventory of college students' recent life experiences
ISI	Insomnia severity index
MeSH	Medical Subject Headings
MSQ-I	Mini sleep questionnaire – insomnia
SCI	Sleep condition indicator
STAI	State trait anxiety inventory
PHQ	Patient health questionnaire
PSS	Perceived stress scale
PSQI	Pittsburgh sleep quality index
USQ	Undergraduate stress questionnaire
QIDS	Quick inventory of depressive symptomatology

sleep- and wake-promoting networks, such as the ascending arousal system [12], which are altered in insomnia and are primarily linked to hyperarousal [13].

Stress is the mental or emotional pressure experienced when an individual is faced with adverse or demanding circumstances that are perceived to or exceed their ability to cope [14]. Stressful events are considered as precipitating factors for the onset of insomnia [15] alongside the individual's resources to manage the stressor encountered [16]. These observations have driven several theoretical models on the onset and maintenance of insomnia in variations of the initial stress-diathesis model, also known as “3P model” put forward by Spielman et al. [15]. Specifically, this model describes predisposing, precipitating, and perpetuating factors in the development and maintenance of insomnia. These factors may be biological, behavioural, environmental, or psychological in nature. Perlis et al., (1997) links transient stress to acute insomnia via the psychophysiological activation of the hyperarousal system [17], whereas the attention-intention-effort pathway links stress system activation to sleep disruption which becomes an attentional focus [18]. These models account for the development of chronic insomnia following instances of acute insomnia and early insomnia, which develops as a biopsychosocial response to a perceived or actual stressor [19]. Several factors have been identified to contribute to the transition from acute to chronic insomnia [20], including markers linked to the stress response such as blood pressure, respiratory rate, and activation of the HPA axis in those with a predisposition for insomnia [21,22].

The majority of student population face many stressors that may contribute to the experience of poor sleep quality, insomnia and stress, including the ever-increasing cost of living and tuition fees that expose students to financial strain which may be related to socioeconomic status [23]. Transitioning to university level study in some cases is perceived as a stressor in its own right as it is accompanied by a higher degree of academic independence (e.g., less structured methods of learning) and expectations (e.g., capability, quality) [24]. Furthermore, personal independence may be associated with late night social and activities related to university culture could provide an opportunity for (increased) alcohol intake and possible substance abuse [24] that is associated with poor sleep quality in this population cohort [25]. Finally, the experience of overlapping deadlines and late working hours, albeit study or part-time work, inherently contributes to circadian disruption. Taken together, these factors likely contribute to an environment that precipitates not only the experience of stress, but also disturbed sleep [1].

To date no systematic review has explored the association of poor sleep quality and/or insomnia with stress in undergraduate students. Despite the plethora of studies investigating the presence of sleep disturbances in student populations, no single study has systematically evaluated the findings and attempted to synthesise and report a pooled level of association. The current review aims to systematically evaluate the quality of this evidence base, summarize methodological features, and conduct meta-analyses of poor sleep quality and insomnia associations with stress in undergraduate university students.

Methods

The protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO; registration CRD42018111665) and the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) [26] was followed as guidance for the searching and reporting. Searches were performed by MG. MG and DB independently screened titles and abstracts. Hand searches were carried out by MG and KR on the reference lists of the included studies with the full texts of any new studies screened against the inclusion exclusion criteria. Each full text was screened by two authors blindly (so all papers were reviewed in combinations of the authors in pairs MG, DB, KR, UA, SA). Any disagreements were settled by discussion between reviewers or the decision by the first author (MG). KR, LB and SA performed quality assessment. Results were synthesised by MG and meta-analyses were conducted by DB.

Search strategy

In consultation with a librarian a concept-based literature search was conducted using keywords relating to sleep and stress in undergraduate students. The literature search was conducted on five electronic databases [Medline (Ovid), Web of Science (Core), Embase (Ovid), PsychInfo (Ebsco) and PsychArticles (Ebsco)] up to 13th January 2020. The search strategy was developed by the research team using keywords and medical subject heading terms (MeSH) to encompass sleep disturbances and insomnia and stress alongside population specific keywords for university and college undergraduate students (see supplementary material).

Study inclusion criteria

Pre-registered eligibility criteria, as per our systematic review protocol (https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=111665), were applied throughout the screening process to determine eligibility of articles for inclusion in the review, based on P(IC)OS (see below). When reviewers were unable to determine eligibility directly from the publication, they contacted the study authors to request further clarifications.

Population

Only studies that included participants that were undergraduate students were eligible for inclusion. When studies reported mixed student cohorts, e.g., comprised of undergraduate and postgraduate students or not enough information was reported, the authors of the study were contacted for clarification. Studies were excluded if authors did not respond or could not provide a detailed breakdown of sample demographics.

Outcome measures

The main outcome of interest of this review is the association of sleep quality and insomnia (diagnosis or symptoms) with stress in undergraduate students. Only studies that investigated these associations were included in the review. When the effects of the associations were not reported in the full-text, the authors contacted the study authors for further details. Studies were included only if they used validated measures for all outcomes of interest (sleep quality, insomnia, and stress).

Type of study

Only full-text original empirical studies published in English in peer-reviewed journals were eligible for inclusion in the review. Reviews, meta-analyses, comments, replies, clinical guidelines, conference abstracts, theses, editorial letters, and book chapters were excluded from the review as well as grey literature.

Study design

All studies that explored an association between sleep quality, insomnia and stress were included in the review. When studies collected data using a longitudinal or interventional design only data at baseline were considered.

Data extraction

A template was designed and piloted for the data extraction by the first author to ensure that all important findings to inform the data synthesis and meta-analyses were captured. Data extraction was done by all the authors. Extracted data included 1) citation details (authors, publication year), 2) study setting, 3) sample characteristics (age, gender, size), 4) outcome measures for sleep quality, insomnia and stress, 5) outcome measures for comorbidities when reported (anxiety and depression), and 6) effect sizes and type of statistical analyses reported (correlation/association coefficient or simple linear regression coefficient within the range ±0.50 as per scott recommendations) [27].

Assessment of risk of bias

To critically appraise the studies, an adapted version of the Newcastle Ottawa Scale was employed. The scale was modified in order to reflect the inclusion criteria so that the quality was determined with relevance to the research designs of the potentially identified studies.

Firstly, as the decision was taken to only include studies that utilised validated measures of sleep and stress, the scale items assessing “ascertainment of exposure” and “assessment of the outcome” were removed. Secondly, as correlation/association coefficients were the effect size estimates chosen for the meta-analysis, the scale item pertaining to adjusting for confounding factors was also excluded. Assessment criteria relating to the methodological quality of the studies was based on a framework that has been utilised in previous work [28]. This instrument has two sets of criteria (methodology and analysis) and is included in the supplementary material of this review. Quality ratings ranging from 0 to 2 indicated low quality, 3–5 moderate quality, and 6–8 high quality. Agreement between reviewers was very high (Kappa = 0.87).

Data analysis

The primary approach was to produce a systematic narrative review of the results from the included studies, accompanied by tabulated details of the included studies as well as the quality ratings for the included studies. Meta-analysis techniques, as detailed below, were used to pool the reported associations. The main group analyses focus on associations of 1) insomnia and stress and 2) sleep quality and stress, based on the outcome measures employed by the respective studies.

To estimate a pooled effect size across all included studies, the correlation/association coefficients were extracted from each study along with the sample size. When multiple effect sizes were reported for the same construct within a primary study (e.g., where two measures of stress were used) they were averaged. One study [29] used the reverse-scored Sleep Condition Indicator so the sign of sleep-related effect sizes extracted from this study was multiplied by −1. When correlation/association coefficients had a skewed distribution, effect sizes were converted to Fisher's Z scores to achieve a normal distribution. All effect sizes extracted from primary studies and used in the meta-analysis were continuous (correlation, association, or linear regression coefficients). Meta-analyses were carried out using R v.3.6.3 [30] and a random effects model fitted using the *metafor* package [31]. Weighted pooled effect sizes (and 95 CIs) are reported as Pearson's correlation coefficients which have been back-transformed from Fisher's Z scores. The data were inspected for outliers and influential studies. Heterogeneity was assessed using the I^2 statistic. An I^2 was classed to indicate low (25%), medium (50%) or large (75%) heterogeneity [32]. Subgroup analyses were performed to investigate potential sources of heterogeneity. Publication bias was assessed using Egger's regression test and Kendall's rank correlation coefficient.

Results

A total of 3910 studies were identified and following removal of duplicates using Endnote (Version X8.2) 2432 studies were screened independently by two authors using Rayann [33]. Following hand searching of the final included studies, six additional studies were added in the full screening database resulting in a total of 2438 studies. Title screening resulted in 2182 studies were excluded leaving 256 papers for full text screening. Of the 256 available papers, 222 were excluded based on the *a priori* criteria. Of note, 76 studies were excluded as at least one measure used was not validated and sleep or stress was explored via single item questions or Likert scale responses, such as “How do you rate your sleep quality?”. In total 18 studies were not available despite various attempts to source manuscripts, leaving a remaining 34 studies for inclusion in the data synthesis (Fig. 1). Agreement between reviewers on title screening was calculated at 92%. Crude collated inter-rater agreement between all pairs of reviewers was 96.3%; Cohen's Kappa = 0.85; Scott's Pi = 0.85 [34].

Study authors were emailed to request supplementary results or data where clear associations were not reported, or if clarification was required as per the inclusion criteria (e.g., confirming whether samples referred to as “students” exclusively comprised undergraduate students. Ten of the 34 [29,35–43] studies were included after study authors provided clarifications, statistics, or additional data by email.

Study characteristics

Details of study characteristics are presented in Table 1 and included a total of n = 14,704 undergraduate student participants.

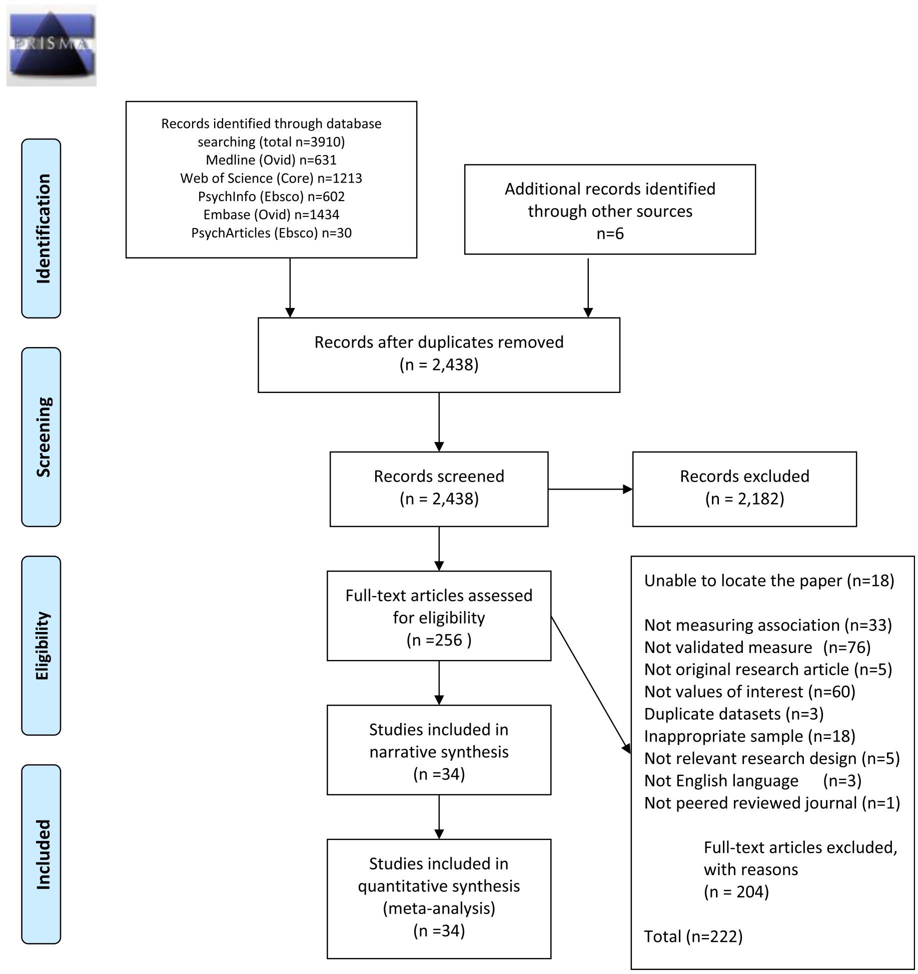

Fig. 1. PRISMA 2009 flow diagram.

The majority of the studies were cross-sectional (n = 32) with only two longitudinal studies [37,42] including one intervention study [37]. All studies except one [44] reported mean age and standard deviation of the participants. The weighted mean age across studies (excluding [44], n = 14,245) was 21.7y (range 18.4–26.9). The weighted mean percentage of females across all studies (including [44]) was 69.2% (range 24–93).

Study setting

The studies included were recent, ranging from 2010 to 2020 [45]. The geographical location of the studies varied widely with the majority of (n = 15) studies conducted in North America [37,44,46–58]. The remaining studies were based in Iran (n = 3) [39,41,59], Saudi Arabia (n = 2) [35,36], India (n = 2) [59,60], and one taking place in each of Australia, Canada, China, Egypt, Germany, Poland, South Korea, Sweden and the UK (n = 9) [29,42,43,61–66].

Outcomes of sleep quality, insomnia and stress

Six studies used multiple sleep measures; four of these used two sleep measures [46–48,54] and two studies used three [29,50]. Most of the studies [29,35,37–40,42–52,54–56,58,61–63,65] (n = 25) used the Pittsburgh Sleep Quality Index (PSQI) [67]. Ten (n = 10) studies [29,41,47,50,53,54,57,59,60,68] used the Insomnia Severity Index (ISI) [69], and one for each of the Athens Insomnia Scale (AIS) [70], Mini Sleep Questionnaire – Insomnia (MSQ-I) [71], and Sleep Condition Indicator (SCI) [72] were reported.

One study measured stress using two instruments [47] whereas all others used a single measurement for stress. Across the 44 reported associations of sleep and stress – where by sleep here indicated measures of sleep quality and insomnia combined, variants of the Perceived Stress Scale (PSS) [73] were most commonly employed (n = 28) with PSS-10 used in 15 studies (n = 15) [36,38,43,45–49,52,53,57–59,64,66], PSS-14 in four studies (n = 4) [29,40,50,51] and the PSS-4 in two (n = 2) [37,55]. Different versions of the Depression Anxiety Stress Subscale (DASS) [74] were used in ten studies (n = 10) with the DASS-21 used in nine (n = 9) [35,39,41,42,44,54,62,63,68] and the DASS-42 in one (n = 1) [60]. Two studies (n = 2) used the Inventory of College Students' Recent Life Experiences (ICSRLE) [47,56], one (n = 1) used the Undergraduate Stress Questionnaire (USQ) [61], and another (n = 1) used the stress component of the Patient Health Questionnaire- Deutsche (PHQ-Deutsche) [65].

Sleep quality and stress main results

Twenty-six effect sizes relating sleep quality to stress (range 0.19–0.55) all using the PSQI were generated across 25 studies (as above) with one study [47] reporting two effect sizes (as these

Table 1
Study characteristics.

Study	Country	Sample Characteristics N, mean age, SD, % Gender	Sleep Disturbance Outcome(s)	Stress Outcome Mean score, SD, % of severity	Associations Analysis	Comorbidity	Comorbidity Associations	Study Quality
Al-Khani et al, 2019 [35]	Saudi Arabia	n = 95, mean age 20.8, (SD = 1.95), age range 18–28 y, 24% Female	PSQI, mean score 5.68, (SD = 3.19)	DASS-21 Stress, mean score 12.38, (SD = 9.73)	Kendall's rank tau (PSQI- DASS-21 Stress), 0.42***	DASS-21 Depression, mean score 10.63, (SD = 9.79) DASS-21 Anxiety, mean score 9.73, (SD = 8.54)	Kendall's rank tau (PSQI- DASS-21 Depression), 0.37*** Kendall's rank tau (DASS-21 Depression-Stress), 0.54*** Kendall's rank tau (PSQI- DASS-21 Anxiety), 0.44*** Kendall's rank tau, (DASS-21 Anxiety – Stress), 0.56***	3
Alsaggaf et al, 2016 [36]	Saudi Arabia	n = 305, mean age 22, (SD = 1.3), age range NR, 58.3% Female	ESS, mean score 8.7, (SD = 4.47)	PSS-10, mean score 17.4, (SD = 5.4), 65% of students were found to have high stress	Simple linear regression (standardised coefficient) 0.33***	NR	NR	3
Barnes et al, 2011 [61]	UK	n = 117, mean age 22.3, (SD = 5.3), age range NR, 64.1% Female	PSQI, mean score 6.35, (SD = 3.6)	Undergraduate Stress Questionnaire , mean score 26.3, (SD = 11.4)	Pearson's correlation, 0.461**	NR	NR	4
Benham 2010 [46]	USA	n = 218, mean age 22.6, (SD = 5.2), age range 18–48, 74% Female	PSQI (n = 209), mean score 6.2, (SD = 3) ESS (n = 217), mean score 8.7, (SD = 4.3)	PSS-10 (n = 218), mean score 18, (SD = 7.1)	Spearman's correlation (PSQI-PSS), 0.37** Spearman's correlation (ESS-PSS), 0.41**	NR	NR	3
Benham 2019 [47]	USA	n = 416, mean age 22.69, (SD = 5.51), age range 18–59, 76% Female	PSQI, mean score 6.8, (SD = 3.2) ISI, mean score 9.9, (SD = 6)	PSS-10, mean score 20.1, (SD = 6.9) Inventory of College Students' Recent Life Experiences (ICSRLE), mean score 228.1, (SD = 76)	Pearson's correlation (PSQI-PSS-10) 0.51*** Pearson's correlation (PSQI-ICSRLE), 0.49*** Pearson's correlation, (ISI-PSS-10) 0.55*** Pearson's correlation, (ISI-ICSRLE), 0.5***	NR	NR	2
Benham & Charak 2019a [48]	USA	n = 460, mean age 22.69, (SD = 5.51), age range 18–59, 69.6% Female	PSQI, mean score 6.17, (SD = 3.1), 55.4% > 5 ESS, mean score 7.81, (SD = 4.21), 26.1% > 10	PSS-10, mean score 18.7, (SD = 6.56)	Pearson's correlation (PSQI-PSS), 0.31*** Pearson's correlation (ESS-PSS) 0.23***	NR	NR	4
Briones et al, 2016 [49]	USA	n = 363, mean age 22.9, (SD = 4.9), age range 18–50, 78.5% Female	PSQI, mean score 6.94, (SD = 3.48)	PSS-10, mean score 20.06, (SD = 6.16)	Nonspecific correlation coefficient (PSQI-PSS-10) 0.45***	NR	NR	4
Caldwell et al, 2010 [37]	USA	n = 166, mean age 21.29, (SD = 3.32), age range 18–41), 84.90% Female	PSQI, NR	PSS-4, NR	Pearson's correlation (PSQI-PSS-4, n = 76), 0.519**	NR	NR	8

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Table 1 (*continued*)

Study	Country	Sample Characteristics N, mean age, SD, % Gender	Sleep Disturbance Outcome(s)	Stress Outcome Mean score, SD, % of severity	Associations Analysis	Comorbidity	Comorbidity Associations	Study Quality
Chen et al, 2018 [62]	China	n = 443, median age 20.61, (SD = 1.32), age range 17–26, 54.4% Female	PSQI (8 cut off point), mean score 5.93, (SD = 2.88), 25.5% > 8	DASS-21 Stress, mean score 10.6, (SD = 7.08), 22.3% ≥ 8 characterised as stressed	Pearson's correlation (PSQI-DASS-21), 0.41***	DASS-21 Depression, mean score 7.9, (SD = 6.98), 15.3% ≥ 8 DASS-21 Anxiety, mean score 8.12, (SD = 6.64), 14.4% ≥ 8	Pearson's correlation (PSQI- DASS-21 Depression), 0.33** Pearson's correlation (DASS-21 Depression-PSS-10), 0.68** Pearson's correlation (PSQI- DASS-21 Anxiety), 0.33** Pearson's correlation (DASS-21 Anxiety- PSS-10), 0.75**	3
Dietch et al, 2016 [50]	USA	n = 866 mean age 20.4, (SD = 4.1), age range NR, 71.8% Female	PSQI (n = 865), mean score 5.64, (SD = 2.79), 43.82% > 5 ISI (n = 852), mean score 7.2, (SD = 5.09), 42.37% ≥ 8 ESS (n = 860), mean score 8.62, (SD = 3.67), 40.70% ≥ 10	PSS-14, mean score 18.06, (SD = 7.29),	Kendal's (PSQI-PSS-14, n = 846), 0.23*** Kendall's (ISI-PSS-14, n = 833), 0.33*** Kendall's (ESS-PSS-14, n = 841), 0.18***	QIDS, mean score 6.58, (SD = 3.9), 30.52% ≥ 11 STAI	Kendall's (PSQI-QIDS, n = 865), 0.35*** Kendall's (ISI-QIDS, n = 852), 0.44*** Kendall's (ESS-QIDS, n = 860), 0.21*** Kendall's (QIDS-PSS-14, n = 846), 0.47***	3
Fawzy & Hamed, 2017 [63]	Egypt	n = 700, mean age 21.22, (SD = 1.62), age range 18–25, 65.6% Female	PSQI, mean score 6.13, (SD = 2.69), 55.7% > 5	DASS-21 Stress, mean score 22.82, (SD = 6.69), 59.9% scored mild or worse	Pearson's correlation (PSQI-Stress), 0.193***	DASS-21 Depression, mean score 17.94, (SD = 5.16), 65% scored mild or worse DASS-21 Anxiety, mean score 16.04, (SD = 5.09), 73% scored mild or worse	Pearson's correlation (PSQI-DASS-21 Depression), 0.153*** Pearson's correlation (DASS-21 Stress-Depression), 0.379*** Pearson's correlation (PSQI- DASS-21 Anxiety), 0.169*** Pearson's correlation (DASS-21 Stress-Anxiety) 0.306***	5
Furman et al, 2018 [51]	USA	n = 131 mean age 19.1, (SD = 1.11), age range NR, 60.3% Female	PSQI, mean score 6.3, (SD = 2.4)	PSS-14, mean score 27.3, (SD = 7.1)	Pearson's correlation (PSQI-PSS-14), 0.35**	NR	NR	4
Graham and Streitel 2010 [52]	USA	n = 362, mean age 20.58, (SD = 1.56), age range NR, 73.2% Female	PSQI (N = 359), mean score 6.92, (SD = 3.25)	PSS-10 (N = 342), mean score 18.68, (SD = 6.19)	Pearson's correlation (PSQI-PSS-10, n = 342), 0.36***	CES-D (n = 334), mean score 15.72, (SD = 10.01)	Pearson's correlation (n = 334), (PSQI-CES-D), 0.39*** Pearson's correlation, (CESD-PSS-10, n = 334), 0.66***	4

Gress-Smith et al, 2015 [53]	USA	n = 447, mean age 19.2, (SD = 1.3), age range 18−23, 64% Female	ISI (n = 390), mean score 8.4, (SD = 5.5), 69.3% endorsed mild or severe insomnia (≥8 on ISI)	PSS-10 (n = 409), mean score 17.4, (SD = 6.2)	Pearson's correlation (ISI-PSS-10, n = 390), 0.37**	Depression Scale of Adult Self-Report (n = 446), mean score 4.9, (SD = 4.1), 33.8% reported mild or worse depression	Pearson's correlation (ISI-ASR, n = 390), 0.55** Pearson's correlation (ASR-PSS-10, n = 409), 0.54**	3
Gupta et al, 2018 [60]	India	n = 430, mean age 20.52, (SD = 2.26), age range 18−37, 57.7% Female	ISI, mead score 6.84, (SD = 4.84), moderate to severe insomnia was 9.10% (95% CI 6.5%−12.2%)	DASS-42 Stress, mean score 12.9, (SD = 7.92)	Spearman's correlation (ISI- DASS-42 Stress), 0.416***	DASS-42 Depression, mean score 10.26, (SD = 8.21) DASS-42 Anxiety, mean score 10.34, (SD = 6.75)	Spearman's correlation (ISI- DASS-42 Depression), 0.367*** Spearman's correlation (DASS-42 Depression - Stress), 0.783*** Spearman's correlation (ISI- DASS-42 Anxiety), 0.354*** Spearman's correlation (DASS-42 Stress-Anxiety), 0.819***	5
Haghighi & Gerber, 2019 [59]	Iran	n = 207, mean age 22.04, (SD = 2.75), age range NR, 49% Female	ISI, mean score 9.6, (SD = 5.59), 18.4% reported moderate (or worse) insomnia	PSS-10, mean score 16.7, (SD = 6.5)	Pearson's correlation (ISI− PSS-10), 0.48***	BDI-2, mean score 11.74, (SD = 8.85) 18.8% had moderate or worse depression STAI, mean score 43.05, (SD = 10.78), 88.5% reported moderate or above anxiety	Pearson's correlation (BDI-2 −ISI), −0.4*** Pearson's correlation (BDI-2 −PSS-10), 0.62*** Pearson's correlation (STAI-ISI), 0.48*** Pearson's correlation (STAI- PSS-10), 0.72***	6
Haidar et al, 2018 [38]	Lebanon	n = 266, mean age 20.56, (SD = 3.07), age range NR, 66.5% Female	PSQI, mean score 6.65, (SD = 3.24)	PSS-10, mean score 19.64, (SD = 6.18)	Pearson's correlation, (PSQI-PSS-10), 0.378***	NR	NR	3
Hellberg et al, 2019 [54]	USA	n = 253, mean age 19.99, (SD = 1.84), age range 18−33, 62.8% Female	PSQI, mean score 6.19, (SD = 2.8) ISI, mean score 6.19, (SD = 2.8), 42% report sub-threshold or clinically significant symptoms	DASS-21 Stress, mean score 10.64, (SD = 7.08)	Pearson's correlation, (PSQI- DASS-21 Stress), 0.43*** Pearson's correlation, (ISI − DASS-21 Stress), 0.48***	DASS-21 Depression, mean score 8.6, (SD = 8.74) DASS-21 Anxiety, mean score 3.13, (SD = 2.9)	Pearson's correlation (PSQI- DASS-21 Depression), 0.44*** Pearson's correlation (ISI- DASS-21 Depression), 0.44*** Pearson's correlation (Depression − Stress), 0.6*** Pearson's correlation (PSQI- DASS-21 Anxiety), 0.38*** Pearson's correlation (ISI − DASS-21 Anxiety), 0.41*** Pearson's correlation (DASS-21 Anxiety − Stress), 0.68***	4

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Table 1 (*continued*)

Study	Country	Sample Characteristics N, mean age, SD, % Gender	Sleep Disturbance Outcome(s)	Stress Outcome Mean score, SD, % of severity	Associations Analysis	Comorbidity	Comorbidity Associations	Study Quality
Hellstrom et al, 2019 [29]	Sweden	n = 634, mean age 26.9, (SD = 7.4), age range NR 83.1% Female	PSQI (n = 548), mean score 7.09, (SD = 3.9) ISI (n = 590), mean score 8.33, (SD = 6.46) SCI (n = 614), mean score 21.3, (SD = 7.95)	PSS-14 (n = 593), mean score 27.52, (SD = 8.55)	Pearson's correlation (PSQI-PSS-14, n = 548), 0.492*** Pearson's correlation (ISI– PSS-14, n = 590), 0.551*** Spearman's correlation (SCI – PSS-14, n = 593), −0.5***	NR	NR	4
John-Henderson et al, 2019 [55]	USA	n = 89, mean age 21.47, (SD = 3.92), age range NR 62.2% Female	PSQI (n = 84), mean score 6.46, (SD = 2.83)	PSS-4 (n = 89), mean score 6.04, (SD = 2.22)	Pearson's correlation (PSQI- PSS-4 n = 84), 0.36**	NR	NR	4
Kalyani Najafi, 2017 [39]	Iran/Participants from 3 geographical locations	n = 278 Medical Sciences students, mean age 19.88, (SD = 1.53), age range NR, 65.1% Female	PSQI, mean score 4.65, (SD = 2.37), 46.4% ≥ 5	DASS-21 Stress, mean score 16.18, (SD = 10.28), 47.5% moderate stress and 24.8% severe stress	Pearson's correlation (PSQI- DASS-21 Stress), 0.206*	DASS-21 Depression, mean score 11.88, (SD = 10.44), 36.3% moderate depression and 14.7% severe depression DASS-21 Anxiety, mean score 9.34, (SD = 8.3), 32.4% moderate anxiety and 7.9% severe anxiety	Pearson's correlation (PSQI- DASS-21 Depression) 0.116* Pearson's correlation (DASS-21 Depression – Stress), 0.657* Pearson's correlation (PSQI- DASS-21 Anxiety), 0.198* Pearson's correlation (DASS-21 Anxiety-Stress), 0.375*	2
Kim 2017 [64]	South Korea	n = 470 mean age 21.40 (SD = 1.98), age range 19–36, 93% Female	Mini-Sleep Questionnaire for insomnia (timeframe the past month), mean score 7.23, (SD = 3.31)	PSS(10-item validated Korean version), mean score NR	Pearson's correlation (MSQ-I – PSS-10), 0.31***	NR	NR	2
Liffman et al, 2012 [43]	Australia	n = 71, mean age 20.68, (SD = 5.38), 70.4% Female	PSQI, mean score 6.86, (SD = 3.18), 61.97% > 5	PSS-10, mean score 19.27, (SD = 3.18)	Kendall's (PSQI- PSS-10), 0.25**	CES-D, mean score 18.62, (SD = 10.69) STAI-40, mean score 81.48, (SD = 22.67)	Kendall's (PSQI- CES-D), 0.36*** Kendall's (PSS-10 – CES-D), 0.49*** Kendall's (PSQI- STAI-40), 0.27** Kendall's (PSS-10 – STAI-40), 0.49***	4
MacNeil et al, 2017 [42]	Canada	n = 106, mean age 21.25 (SD = 2.25), 81.13% Female	PSQI, mean score 4.87, (SD = 2.22) 36.79% ≥ 5	DASS-21 Stress, mean score 8.76, (SD = 7.78)	Kendall's tau (PSQI-DASS-21 Stress), 0.47***	DASS-21 Depression, mean score 6.13, (SD = 6.86) DASS-21 Anxiety, mean score 4.99, (SD = 5.28)	Kendall's tau (PSQI-DASS-21 Depression), 0.4*** Kendall's tau, (DASS-21 Depression- Stress), 0.53*** Kendall's tau, (PSQI-DASS-21 Anxiety), 0.39*** Kendall's tau, (DASS-21 Anxiety-Stress),0.61***	5

Markarian et al, 2013 [44]	USA	N = 459, mean age NR, 79.1% Female	PSQI, mean score 7.99, (SD = 3.33), 53.8% ≥ 8	DASS-21 Stress, mean score 25.6, (SD = 9)	Pearson's correlation, (PSQI − DASS-21 Stress), 0.42*	DASS-21 Depression, mean score 22.2, (SD = 9.4) DASS-21 Anxiety, mean score 21, (SD = 7.6)	Pearson's correlation, (PSQI- DASS-21 Depression), 0.39* Pearson's correlation, (DASS-21 Depression Stress), 0.75* Pearson's correlation, (PSQI- DASS-21 Anxiety), 0.31* Pearson's correlation, (DASS-21 Anxiety-Stress), 0.76*	3
Najem et al, 2020 [45]	Lebanon	n = 644, mean age 20.22, (SD = 1.83), 70.3% Female	PSQI (n = 609), mean score 5.62, (SD = 3.15)	PSS-10 (n = 644), mean score 18.97, (SD = 6.9)	Pearson's correlation, (PSQI- PSS-10,n = 609), 0.32***	NR	NR	2
Rebello et al, 2018 [40]	India	n = 121 Medical Students, mean age 18.37, (SD = 0.8) 43% Female	PSQI, mean score 5.1, (SD = 2.24)	PSS-14, mean score 26.55, (SD = 5.4)	Spearman's correlation (PSQI- PSS-14), 0.37**	NR	NR	3
Schlarb et al, 2018 [65]	Germany	n = 2442, mean age 24, (SD = 3.8) 65% Female	PSQI, mean score NR, 36.9 ≥ 5	Stress component of PHQ-Deutsche, mean score NR	Pearson's correlation (PSQI- PHQ-D Stress), 0.454**	PHQ-9 (Depression), mean score NR GAD-7 (Anxiety), mean score NR	Pearson's correlation, (PSQI- PHQ-9), 0.588** Pearson's correlation (PSQI- GAD-7), 0.496**	4
Średniawa et al, 2019 [66]	Poland	n = 264, mean age 22.22, (SD = 1.5), 56.8% Female	AIS, mean score 7.14, (SD = 4.12), 19.7% ≥ 11 (AIS cut off)	PSS-10, mean score 19.04	Pearson's correlation (AIS- PSS-10), 0.44**	NR	NR	2
Vand Doos et al, 2014 [41]	Iran	n = 169, mean age 20.33, (SD = 1.62) 58% Female	ISI, mean score 10.05, (SD = 5.83, 68.6% ≥ 8	DASS-21 Stress, mean score 12.88, (SD = 8.96)	Kendall's tau (ISI − DASS-21 Stress), 0.38***	DASS-21 Depression, mean score 10.51, (SD = 9.36) DASS-21 Anxiety, mean score 8.42, (SD = 7.7)	Kendall's tau (ISI- DASS-21 Depression), 0.29*** Kendall's tau (DASS-21 Stress − Depression), 0.57*** Kendall's tau (ISI- DASS-21 Anxiety), 0.29*** Kendall's tau (DASS-21 Stress- Anxiety), 0.56**	2
Vargas et al, 2018 [56]	USA	n = 929, mean age 22.73, (SD = 5.62), 79.8% Female	PSQI, mean score 7.35, (SD = 3.34), 68.5% > 5	Inventory of College Students Recent Life Experiences, mean score 95.43, (SD = 23)	Non-specific correlation (PSQI- ICSRLE), 0.4448***	CES-D, mean score 15.89, (SD = 10.81), 42.8% of students showing some level of depression (CESD 16), and 18.3% scoring 26, suggestive of severe depression.	Non-specific correlation (PSQI- CES-D), 0.469***	2
Wilkerson et al 2012 [57]	USA	n = 941, mean age 20., (SD = 3.6), 65% Female	ISI, mean score 11.23, (SD = 5.46)	PSS-10, mean score 21.84, (SD = 4.21)	Non-specific correlation (ISI-PSS-10), 0.25**	Quick Inventory of Depressive Symptomology (QIDS-SR), mean score 15.52, (SD = 4.17)	Non-specific correlation (ISI- QIDS-SR), 0.55** Non-specific correlation (PSS-10-QIDS-SR), 0.56**	3

(*continued on next page*)

Table 1 (*continued*)

Study	Country	Sample Characteristics N, mean age, SD, % Gender	Sleep Disturbance Outcome(s)	Stress Outcome Mean score, SD, % of severity	Associations Analysis	Comorbidity	Comorbidity Associations	Study Quality
Younes 2016 [68]	Lebanon	n = 600 mean age 20.31 y, (SD = 1.64), 69.7% Female	ISI, mean score 9.3, (SD = 3.76), 9.8% ≥ 15	DASS-21 Stress, mean score 6.99, (SD = 4.46), 66.8% scored mild or above/49.0% scored moderate, or above/22% scored “severe” or “extremely severe"	Non-specific correlation (ISI- DASS-21 Stress), 0.404***	DASS-21 Depression, mean score 5.43, (SD = 4.43), 8% scored “severe" or “extremely severe" DASS-21 Anxiety, mean score 4.77, (SD = 3.79), 21.8% scored “severe" or “extremely severe"	Non-specific correlation (ISI-DASS-21 Depression), 0.366*** Non-specific correlation (DASS-21 Depression- Stress), 0.366*** Non-specific correlation (ISI- DASS-21 Anxiety), 0.367*** Non-specific correlation (DASS-21 Anxiety- Stress), 0.669***	2
Zhang et al 2018 [58]	USA	n = 242, Nursing students, mean age 19.8, (SD = 1.7), 91.3% Female	PSQI, mean score 7.3, (SD = 3.4), 66.2% scored > 5	PSS-10, mean score 20.9, (SD = 7.2)	Spearman's correlation (PSQI-PSS-10), 0.55**	CES-D, mean score 10.9, (SD = 6.5), 54.5% ≥ 10 PROMIS Emotional Distress Anxiety Short Form (EDA-SF), mean score 60.7, (SD = 9.7)	Spearman's correlation (PSQI-CES-D), 0.59** Spearman's correlation (PSS-10 − CES-D), 0.78** Spearman's correlation (EDA-SF- PSQI), 0.45** Spearman's correlation (EDA-SF- PSS-10), 0.76**	3

Note: M, mean; SD, standard deviation; %, percentage; NR, not reported; *p < 0.05, **p < 0.01, ***p < 0.001; AIS, Athens Insomnia Scale; BDI, Beck's Depression Inventory; CES, Center for Epidemiologic Studies Depression Scale; DASS, Depression Anxiety Stress Scale; ESS, Epworth Sleepiness Scale; GAD, General Anxiety Disorder; ICSRLE - Inventory of College Students' Recent Life Experiences; ISI, Insomnia Severity Index; MSQ-I, Mini Sleep Questionnaire − Insomnia; SCI, Sleep Condition Indicator, STAI, State Trait Anxiety Inventory; PHQ, Patient Health Questionnaire; PSS, Perceived Stress Scale; PSQI, Pittsburgh Sleep Quality Index; USQ, Undergraduate Stress Questionnaire; QIDS, Quick Inventory of Depressive Symptomatology.

authors collected two stress measures, PSS-10 and ICSRLE). Stress was measured using variants of the PSS and resulting in 15 effect sizes (PSS-10 = 9 [38,43,45–49,52,58], PSS-14 = 4 [29,40,50,51], PSS-4 = 2 [37,55]), DASS 21 stress subscale in seven effect sizes [35,39,42,44,54,62,63], ICSRLE in two effect sizes [47,56], USQ in one effect size [61], and the stress component of the PHD-Deutsche in one effect size [65].

Insomnia and stress main results

Fourteen effect sizes for insomnia and stress were reported across 12 studies (range 0.25–0.55) [29,41,47,50,53,54,57,59,60,64,66,68] (with Benham, 2019 [47] and Hellstrom et al., 2019 [29], including two effect sizes each). Insomnia was measured by the ISI in 11 effect sizes [29,41,47,50,53,54,57,59,60,68], with the remaining three effect sizes using the AIS [66], SCI [29], and MSQI [64]. Stress was measured by variants of the PSS in nine effect sizes (PSS-10 = 6 [47,53,57,59,64,66], PSS-14 = 3 [29,50]), variants of the DASS stress subscale in four effect sizes (DASS21 = 3 [41,54,68], DASS-42 = 1 [60]), and the ICSRLE in one effect size [47].

Outcomes of comorbidities

Nineteen studies (n = 19) included measures of anxiety and/or depression [35,39,41–44,50,52–54,56–60,62,63,65,68]. Of these, 10 studies used variants of the DASS to measure stress and also reported the subscales of anxiety and depression [35,39,41,42,44,54,60,62,63,68] (See Table 1).

Associations of comorbidities

A total of 41 combinations of associations (effect sizes) between the outcomes of interest such as: sleep quality, insomnia, sleepiness, depression and anxiety were reported from 19 studies (as above): 13 for sleep quality and depression [35,39,42–44,50,52,54,56,58,62,63,65], 11 for sleep quality and anxiety [35,39,42–44,50,54,58,62,63,65], eight (n = 8) for insomnia and depression [40,49,52,53,56 58,59,68], seven (n = 7) for insomnia and anxiety [41,50,54,57,59,60,68], one for sleepiness and depression [50], and one for sleepiness and anxiety [50]. Results of the meta-analysis of these comorbidities are presented in Table 2. Associations between stress and depression were reported by 22 effect sizes from 19 studies (as above) and between stress and anxiety were reported by 15 studies [35,39,41–44,50,54,57–60,62,63,68].

Assessment of bias/study quality

Quality scores ranged from 2 to 8 (M = 3.47). Eight studies were rated as low quality [39,41,45,47,56,64,66,68], twenty-four were rated as moderate quality [29,35,36,38,40,42–44,46,48–55,57,58,60,61,63,65,75] and two were rated as high quality [37,59] indicating that most of the available evidence is of moderate quality. Most of the evidence (n = 32) relies on cross-sectional research designs, which prevents the assessment of temporal precedence and limits any inferences regarding causality. Furthermore, most studies did not detail their hypotheses (n = 20), nor did they provide a power calculation or indicate whether sufficient power was achieved (n = 27).

Meta-analyses

Sleep quality and stress

The weighted pooled effect size (25 studies, n = 10,065) for sleep quality and stress was r = 0.39 (95% CI: 0.35, 0.43, $p < 0.001$; $I^2 = 80.03\%$; $tau^2 = 0.010$; Q [24] = 133.7216, $p < 0.001$). A forest plot of the pooled effect sizes is shown in Fig. 2. Both regression and rank correlation tests for asymmetry were not statistically significant (Egger's p = 0.650, Kendall's tau = 0.02, p = 0.908). Fig. 3 shows the related funnel plot.

Insomnia and stress

The weighted pooled effect size (12 studies, n = 5564.5) for insomnia and stress was r = 0.41 (95% CI: 0.36, 0.46, $p < 0.001$; $I^2 = 80.96\%$; $tau^2 = 0.009$; Q [11] = 67.72, $p < 0.001$). A forest plot of the pooled effect sizes is shown in Fig. 4. Both regression and rank correlation tests for asymmetry were not statistically significant (Egger's p = 0.179, Kendall's tau = 0.33, p = 0.153). Fig. 5 shows the related funnel plot.

Co-morbidities

Results of the meta-analyses for combinations of the outcomes of interest and the reported comorbidities are presented in Table 2. The pooled effect sizes for stress and anxiety, as well as stress and depression, are also reported. The studies included in these meta-analyses are reported in the supplementary material.

Discussion

The aim of this review was to systematically identify studies that explore the associations of sleep quality, insomnia and stress in undergraduate students. This systematic review is the first to synthesise peer-reviewed scientific evidence from 34 studies across thirteen countries and empirically assess the pooled associations between sleep quality (25 studies) or insomnia (12 studies) and stress in a total of n = 14,704 undergraduate university students. We also provide estimates of effect sizes using random effects model meta-analyses techniques. Included studies used various measures of sleep quality, insomnia and stress and in some studies, researchers used multiple measures of both sleep quality and insomnia [29,47,54]. The effect sizes for the associations between outcomes of interest were uniformly positive effect sizes reported in the included studies. The effect size ranged from small to moderate (0.19–0.55) for sleep quality and stress with similar range for insomnia and stress (0.25–0.53). The weighted pooled effect size between sleep quality and stress was 0.39 (25 studies, n = 10,065), whereas a slightly higher pooled association of 0.41 was found for insomnia and stress (12 studies, n = 5564.5). These effect sizes should be considered with caution given the high heterogeneity

Table 2
Pooled effect sizes for comorbidities using random effects models.

	r	95% CI	I^2 (%)	tau^2	N studies	N total PP
Insomnia/Depression	0.44	(0.38, 0.50)	81.82	0.001	8	3842
Insomnia/Anxiety	0.38	(0.36, 0.41)	0.01	0.000	7	3426
Sleep Quality/Depression	0.39	(0.31, 0.47)	92.66	0.025	13	7217
Sleep Quality/Anxiety	0.34	(0.27, 0.40)	85.66	0.013	11	5928
Stress/Depression	0.62	(0.57, 0.67)	92.67	0.031	18	7512
Stress/Anxiety	0.64	(0.57, 0.71)	95.10	0.052	15	5814

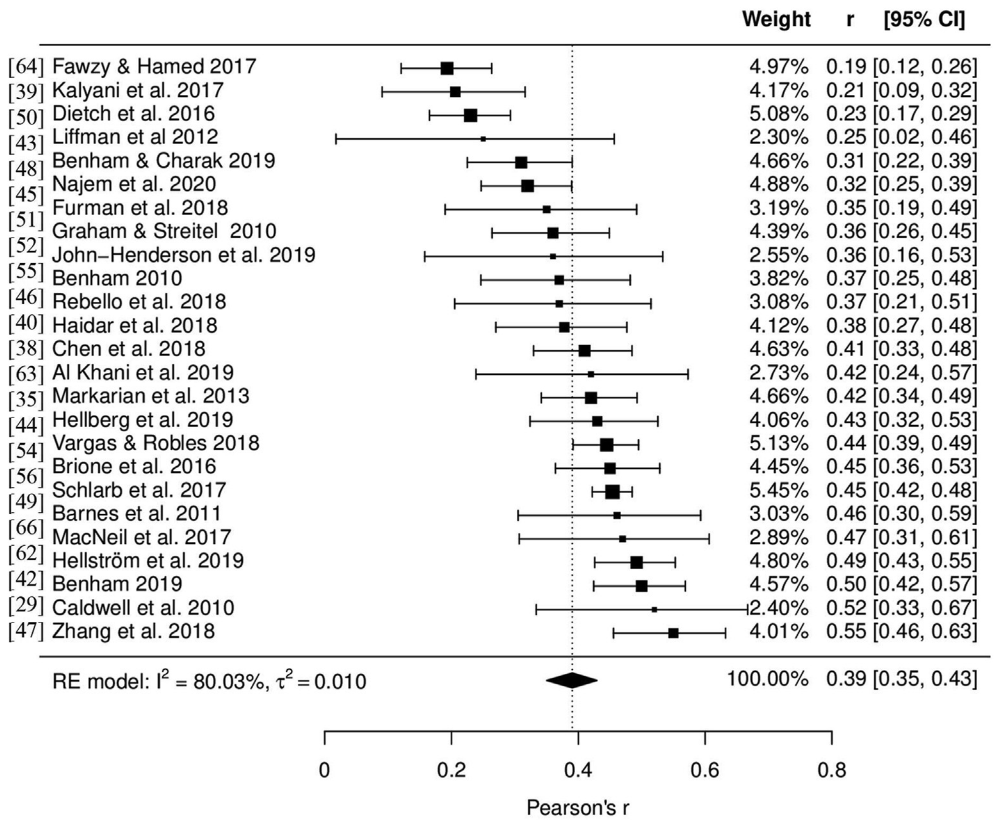

Fig. 2. Forest plot of effect sizes for sleep quality and stress. Size of filled squares indicates weight, whiskers show 95% CI, dashed line and filled diamond centred on pooled effect size and width of the diamond reflects 95% CI for pooled effect size.

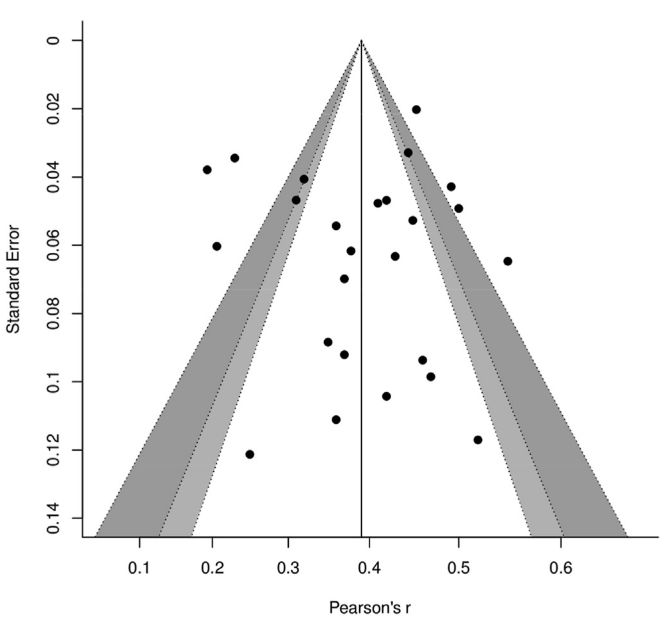

Fig. 3. Funnel plot of effect sizes for sleep quality and stress. Vertical line centred on pooled effect size (r = 0.39), light grey = 90–95% confidence region, dark grey = 95–99% confidence region.

identified (80.03% and 80.96% respectively) in the meta-analyses [32]. However, heterogeneity is fairly typical in epidemiological sleep meta-analyses [76]. Methodological limitations notwithstanding, the results of this review indicate a significant interplay of stress and sleep and/or insomnia in undergraduate students.

With the increase of mental health problems in student groups, there is evidence of a surge of studies published investigating sleep and stress in students. This is reflected in the included studies as the earliest studies in this review have been published in 2010 [37,46,52]. Most studies included in this review were comprised of rather small sample sizes ranging from 71 to 941 students and, despite some diversity in study location, sampling was disproportionately limited to North America (n = 15) and Asia (n = 12). Very few studies were conducted in Europe (n = 4), Australia (n = 1), or Africa (n = 1). Most studies collected cross-sectional data (n = 32) with only two employing a longitudinal approach [37,42]. Moreover, a disproportionate preponderance of female participants was observed, and several of the included studies [n = 12] restricted their student population to include only those deemed as psychologically healthy. A variation was observed in the quality ratings of the included studies, where eight were considered low quality, twenty-four as moderate quality, and only two of high quality.

Stress and sleep interplay

Stress-sleep reactivity is the process by which a given cognitive, physiological, or environmental stressor results in a disruption of the sleep system [77]. Sleep reactivity itself is a predisposing factor for insomnia according to some researchers [77], with recent evidence demonstrating that stress-sleep reactivity was associated with poor psychological health, and this relationship was found to be moderated by perceived stress in normal sleepers [78]. In a recent study, stress-sleep reactivity was identified as a feature of acute insomnia but it was not implicated in the transition from acute to chronic insomnia [20]. Individual differences in the stress-induced sleep disturbances are considerable either in the severity

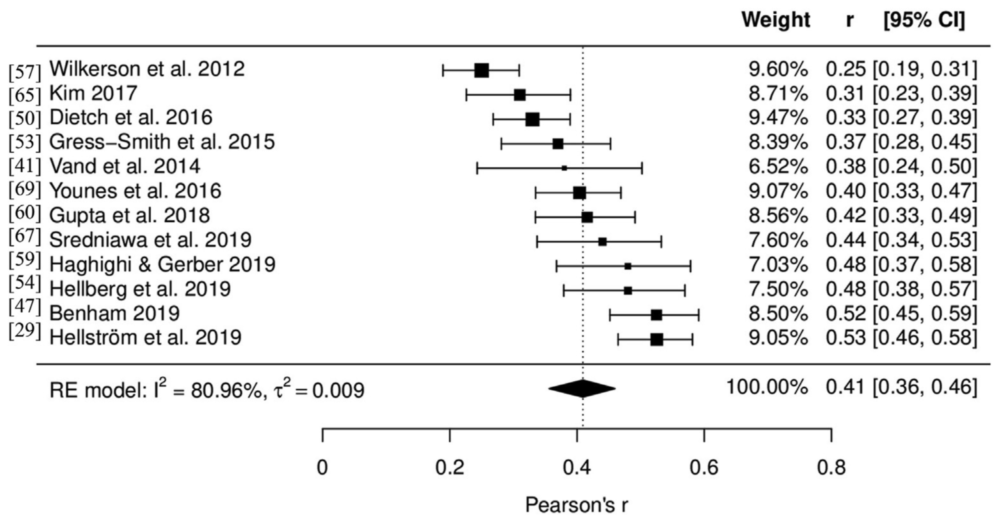

Fig. 4. Forest plot of effect sizes for insomnia and stress. Size of filled squares indicates weight, whiskers show 95% CI, dashed line and filled diamond centred on pooled effect size and width of diamond reflects 95% CI for pooled effect size.

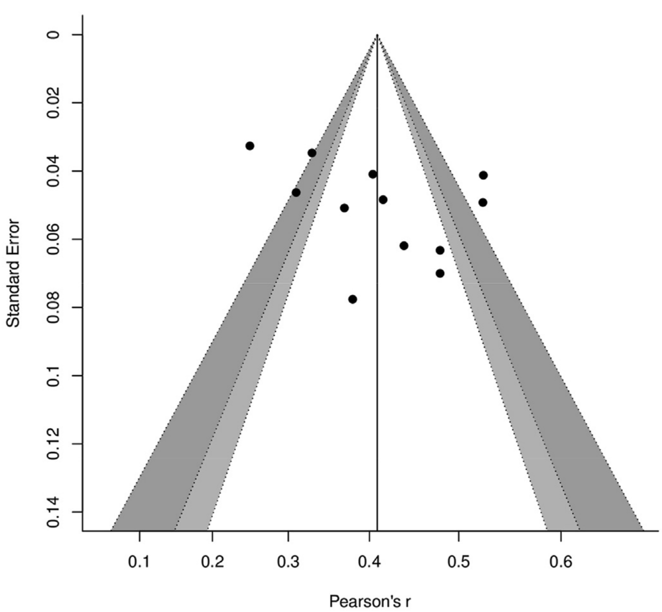

Fig. 5. Funnel plot of effect sizes for insomnia and stress. Vertical line centred on pooled effect size (r = 0.41), light grey region = 90−95% confidence, dark grey region = 95−99% confidence region.

or reporting, for review see [9]. However, the studies in the current review explored the associations of sleep quality and/or insomnia and stress using self-report measures of perceived stress.

The interaction between sleep and psychological stress is likely bidirectional in nature, where daytime stressors serve to impair the subsequent sleep process, and the experience of poor sleep impairs the adequacy of daytime functioning [79]. From the cognitive and neurocognitive perspectives, academic stress may contribute to the experience of insomnia due to increased worry and ruminative thinking when attempting to initiate sleep [17,80]. The initial temporal nature of this thinking may orient towards academic and psychosocial worry and rumination, consequently leading to delayed sleep-onset through a combination of negatively toned cognitive activity and physiological hyperarousal [81]. Over time, the subsequent daytime consequences of insomnia likely further impair the ability to cope with social, interpersonal, and academic stressors typically faced by students and thus contribute to stress. To compensate, individuals may employ behavioural strategies to compensate for the effects of their transient sleep loss (e.g., increased time in bed through napping or attempting sleep earlier than normal). Paradoxically, these strategies increase the likelihood that the initially acute experience of insomnia perpetuates into a chronic problem [18].

Sleep and stress in students

Sleep quality over the academic year is subject to the dynamic interplay of personal, academic, and environmental events. Indeed, negative family life events and academic stress both predict symptoms of insomnia, and poor sleep quality and stress before exams are associated with poorer academic performance [8]. For example, in a sample of college students, John-Henderson et al. [55], determined the incidence of significant life stressors in the preceding year to be associated with an increased number of sleep disturbances, but not sleep efficiency or latency, hypnotic medication use, daytime dysfunction or global scores as determined by the PSQI. Moreover, students appear to exhibit worse sleep in the 5 wk before their exams compared to the rest of the semester [82]. Future studies should also consider the influence of physical activity, caffeine intake or smoking which have been identified as potential confounds, mediators and/moderators f the relationships between stress and sleep [83,84].

In an academic setting, longitudinal studies or studies that account for variation in stress across an academic year would enable disentanglement of the effects of various stressors as mediating factors of sleep disturbances in this population. Indeed, one of the included studies demonstrated the expected increase in stress and self-reported sleep disturbances as the students progressed from periods of low to higher stress [42]. The students that demonstrated increased sleep disturbances during more demanding periods were characterised by higher trait worry paired with greater high-frequency heart rate variability. This suggests a possible profile of those more vulnerable to the effects of stress on sleep [42]. Studies exploring stress related to academic demands which exceed the capabilities of the students should differentiate amongst stressors and their subsequent effects on sleep. Similarly, these studies may benefit from using measures of academic stress that differentiate between specific academic experiences, such test anxiety which may affect sleep in the short term [85].

Whilst many institutions provide student-focused mental health and wellbeing services, the prevalence of mental health difficulties is increasing in this population [3]. Furthermore, limited funding of services results in long waiting lists with students having to wait up to three mo to receive support [3]. Systematic monitoring of student mental health would allow universities to appropriately allocate session availability and staffing, whilst determining the specific needs of students leading to a subsequent improvement in the efficacy of in-house treatment and assessment [86]. In the context of sleep, Holmen et al. (2020) recently examined the student perception of sleep-related uncertainties and the specific sleep-related interests of Norwegian students in the context of sleep-promotion. Here, screen-time, stress, shift-work, and sleep quality were identified as key areas of interest to students [87]. Sleep disturbance and insomnia are a less stigmatising mental health symptom even in the presence of comorbid mental health problems [88] and may, therefore, increase the likelihood of students requesting support. Currently a wealth of knowledge demonstrates the efficacy of Cognitive Behavioural Therapy for insomnia (CBTi) interventions to alleviate insomnia symptoms [89,90]. Furthermore, various methods of delivery and session structures have been shown to be efficacious, such as group interventions, online and a single shot [90]. Individuals in an acute phase of insomnia may be offered a single session CBTi and a self-help pamphlet which has been previously evidenced as effective in ameliorating acute insomnia [91].

Considering the above, it is therefore crucial for student wellbeing services to expand any programmes offered to reduce the negative consequences of disturbed sleep, drawing from the CBTi literature. Many sleep-based interventions have been demonstrated to improve subjective sleep amongst university students, using various methods involving sleep-education and monitoring, mindfulness and relaxation, and text message-based recommendations drawn from the National Sleep Foundation recommendations for good sleep practices [92,93]. Indeed, a recent review of psychological interventions targeting sleep in university students found: small to medium effect sizes in studies providing sleep hygiene; small to large effects for those employing relaxation techniques; and large effects in those providing CBT approaches [89]. While the experience of stress may be habitual of the university lifestyle, the interventional reduction of excessive stress appears another worthwhile target [94]. Indeed, several meta-analytic studies highlight the therapeutic role of cognitive behavioural and mindfulness relaxation techniques in reducing stress amongst university samples [94].

Limitations of current review

One limitation of this systematic review and meta-analysis is the high heterogeneity of the pooled effect sizes of the associations of sleep and stress. Following subgroup analysis, the instances of heterogeneity remained high. Thus, the current findings should be considered with caution. Furthermore, it should be noted that most studies were cross-sectional, which limits conclusions regarding temporal ordering in the context of theories as to insomnia development and maintenance.

Transition to university is a period of upset for some young students [24] that is associated with new onset or exacerbation of mental health difficulties [3]. Future studies should consider reporting these variables to enable characterization of those most vulnerable to sleep disturbances. The present review included a convenience exploratory meta-analysis of comorbidities as most studies included outcomes of comorbidities that relate to sleep and insomnia outcomes. These pooled associations were calculated using the effect sizes reported in the included studies and are not the outcome of a systematic exploration of the literature. Future systematic reviews and meta-analyses should systematically explore the associations of comorbid conditions in the student population.

Seventy-five studies were excluded from the final analysis due to the use of non-validated measures. The ongoing and problematic use of single item or bespoke in-house scales to measures sleep and stress fails to adequately capture the true extent of symptom experience in the student population, often leading to an altered prevalence statistics and misrepresentation of the captured problem. Future work should aim to consistently use validated measures of stress and sleep disturbances.

A number of studies were excluded as papers were not located despite the efforts to contact the corresponding authors or other members of the research team. As such, although a comprehensive search was undertaken the results may not be fully representative of the actual relationship due to missing manuscripts. Furthermore, the review included only studies published in English language, and thus studies in other languages may provide different results to the ones reported here.

Conclusion

Sleep quality, insomnia and stress are interlinked phenomena which affect university students and have negative consequences for their academic performance and mental health. The pooled associations in this review show moderate and comparable effect sizes for both sleep quality and stress as well as insomnia and stress in undergraduate university students. However, due to the high heterogeneity among studies and a preponderance of cross-sectional studies, the findings from the meta-analysis should be interpreted with care. Our findings also highlight methodological challenges including the high variability between the studies and the lack of longitudinal approaches to capture the interplay between sleep disturbances and the variation in stress across the academic year. Such studies would permit the role of stress in the development and maintenance of insomnia to be more fully elucidated, as well as facilitating the identification of personality traits and risk factors that characterise vulnerable individuals. Given the importance of sleep to wellbeing, it is important for university policy-makers to promote good sleep health amongst students.

Practice points

1. Both poor sleep quality and insomnia symptoms are moderately associated with stress.
2. The presence of sleep disturbance and insomnia symptoms should be assessed routinely by College and University counselling and mental health services, and may present a risk factor for ongoing and subsequent difficulties.
3. In a preventative effort, students may benefit from sleep psychoeducation, especially during transition phases.
4. Treating sleep offers potential to improve student health and wellbeing, and potentially benefit assessment performance and experiences.

Research agenda

1. More studies should provide a prospective and/or longitudinal design approach to understand symptom progression and the possible exaggeration of these at various points of the academic curriculum such as exams, including via ESM.
2. How, and to what extent, stress contributes to the development and maintenance of insomnia, and other mental health conditions, should be considered longitudinally in this population.
3. Future studies should measure and report pertinent characteristics such as field of studies and ethnic background, in addition to known risk factors, to aid the understanding of who may benefit from psychoeducation on sleep.
4. Single-item and bespoke measures which are not reported to be validated should be avoided.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2021.101565.

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