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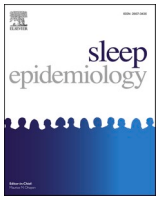

Sleep health association with asthma, allergic rhinitis, and atopic dermatitis: Systematic review of population-based studies

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ABSTRACT

Introduction: Poor sleep health is frequent among people with three common diseases that may co-occur: asthma, allergic rhinitis (AR), and atopic dermatitis (AD). However, few studies have assessed sleep health in people with coexisting diseases. The aims of this review were to systematically summarise: the proportion of people with asthma, or AR or AD, who have sleep disorders; and the evidence on the association of sleep health with these diseases in general populations.

Methods: We searched three databases (Medline, Web of Science and Google Scholar) for population-based studies regarding the association between sleep health, asthma, AR, or AD published by May 2023. After a systematic review of the studies, we summarised the evidence including the most prevalent sleep outcomes according to four groups of exposure: 1) asthma; 2) AR; 3) AD and 4) coexisting diseases.

Results: A total of 20 studies were identified of which one used coexisting diseases as main exposure. The majority of the selected studies were of fair quality. The most frequently assessed outcomes were nocturnal sleep-related dysfunctions (e.g. insomnia) and daytime sleep-related dysfunctions (e.g. daytime sleepiness). High proportions of sleep disorders were found among people with asthma, AR or AD. We found significant evidence that people with asthma, allergic rhinitis, or atopic dermatitis had impaired sleep health.

Conclusion: This systematic review highlights the need for methodologically robust population-based studies focused on the assessment of sleep outcomes among people with three diseases that may co-occur.

1. Introduction

Asthma, allergic rhinitis (AR) and atopic dermatitis (AD) are common diseases that may co-occur [1–3]. Approximately 20.0 % of the worldwide population have atopy [4]. However, the burden of asthma, AR and AD vary widely within and between countries [5–7]. The prevalence of AD ranged from 2.0 % to 33.7 % [7–9] and AR from 1 % to 63.0 % [7,10] in both children and adults, across the world. In 2019, there were >260 million existing cases of asthma, and >450 thousand reported deaths [11,12]. The co-existence of asthma, AD and AR increases mortality risk [13–15].

Since the 1980s, several studies have suggested that sleep disturbances and poor sleep health are frequent among people with asthma, AR and AD [16–22]. However, the impact of these conditions on sleep health has been studied mainly in people with a single disease [23]. For example, Jensen and collaborators [24], who analysed polysomnographic recordings of 217 children, found that male children with asthma slept an average of 16 min less than male children without asthma [24]. In addition, the length of time it takes to fall asleep was significantly longer in children with asthma than in children without

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asthma [24]. Other studies also suggest that even when well-controlled, asthma can be associated with shorter sleep duration [25,26] and excessive daytime sleepiness [27,28]. Similarly, wheezing children may have a higher prevalence of sleep disturbances compared to non-wheezing children [27].

AR and AD can also affect sleep health. Common symptoms in people with AR, such as nasal congestion, runny nose and itching are main risk factors for decreased sleep quality, increased restless sleep and daytime sleepiness [19,29–32]. Nocturnal pruritus and itching are attributed to frequent nocturnal awakenings among people with AD [18,22,33,34]. The few studies that have assessed sleep health in people with two or more diseases [17,18,31] have suggested that people with more than one comorbidity have more likely to report poor-quality sleep. Nonetheless, some findings remain controversial due to inconsistent replication caused by variations in sample size, protocols, and definitions of exposure and/or outcome [27,31,35,36].

Good sleep is essential to good health [37]. The negative effects of asthma, AR and AD on sleep health can lead to detrimental social and economic impact [37–39]. Poor sleep quality is associated with poor cognitive outcomes, decreased productivity, higher prevalence of metabolic syndromes and mortality rates [38–40]. These associations have important clinical and therapeutic implications [17–19].

To the best of our knowledge current systematic reviews [17,18,30] regarding the association between coexisting diseases (asthma, AR or AD) and sleep health focus on a single disease. In addition, they are limited to small studies with volunteers or clinical samples, not allowing a comprehensive and generalisable overview of this association. The aims of this review were to systematically summarise: (1) the proportion of people with asthma, or AR or AD, who have sleep disorders; and (2) the evidence on the association of sleep health with asthma, AR and AD in general populations.

2. Methods

2.1. Search strategy

The protocol of this systematic review was registered at PROSPERO (CRD42023418383) and followed the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [41]. The PRISMA Checklist is reported as Supplementary Material (Table S1). We searched Medline (PubMed) and Web of Science, for original research published in peer reviewed journals from database inception to 10 May 2023. Google Scholar was used to identify grey literature. The search terms were selected according to medical subject headings (MeSH) and text words related to sleep parameters or sleep disorders (Supplementary Table S2).

2.2. Inclusion and exclusion criteria

Studies were included if: 1) they were population-based (cross-sectional, case-control, cohort); and 2) with data comparing differences in sleep (any individual sleep measure) between individuals with and without diseases (asthma, AR or AD or multiple diseases). Studies were excluded if: 1) they were based on convenience/opportunity/availability sampling; 2) they investigated multimorbidity (asthma or AR or AD in combination with other diseases); 3) they focused on treatments or interventions; or 4) they focused on the effects of sleep disturbances on asthma or AR or AD. The selection was not restricted to age of participants or language of publication.

All results returned by the search were imported into Covidence [42], a screening and data extraction tool for conducting systematic reviews. After removing duplicates, the title and abstract and then full texts were independently reviewed by two researchers (GAM and VQS). In occasions where the information in the title and abstract was not enough to make a decision, the study was included in the full-text screening. Disagreements were resolved by a third reviewer (AFSA).

2.3. Quality assessment

Study quality was assessed using the Newcastle-Ottawa scale for observational studies, with an adapted version for cross-sectional studies [43]. Each study was scored according to three items: 1) Selection of study population; 2) Comparability; and 3) Ascertainment of exposure/outcome (depending on study design). A maximum of one star could be given for Selection and Outcome categories and a maximum of two stars for Comparability. Therefore, cross-sectional studies were assigned a score from zero to eight and cohort studies from zero to nine. Then, they received a rating of good, fair, or poor quality, based on total number of stars received (Supplementary Tables S3 and S4).

2.4. Data extraction

The Covidence software was also used for creating and completing data extraction forms by two independent reviewers (GAM and VQS). Inconsistencies were highlighted by the software and, after re-reviewing the full texts and discussing with the third reviewer (AFSA), discrepancies were resolved. Several attempts to contact study authors were made to obtain relevant information or resolve data extraction uncertainties.

Data extraction included measurement and prevalence of both exposure and outcome. It also included measure of association of any sleep disorder. The outcomes were reported as summary (mean, median) and dispersion measures (SE, 95 % CI, SD, IQ). For studies with data on evaluating the effect of asthma or AR or AD or coexisting diseases on sleep-related outcomes, the effect measure with 95 % confidence interval (CI) was provided. The following characteristics from the selected studies were also extracted: author, year, country, study design, sample age, sample size, and main results.

2.5. Data synthesis

Results were presented in four groups of exposure 1) asthma; 2) allergic rhinitis; 3) atopic dermatitis and 4) coexisting diseases. Additionally, when there were enough number of studies, the results were split into the most prevalent sleep outcomes from the selected studies (A) insomnia; (B) sleep duration and (C) daytime sleepiness and (D) other sleep outcomes, according to the main exposure.

3. Results

From a total of 5631 titles and abstracts, 119 studies were selected for full-text screening and 20 studies were selected for final review (Fig. 1). The most common reason for exclusion was failure to meet the criteria for a population-based study.

Characteristics of the selected articles are summarised in Table 1. Publication dates ranged from 1993 [35,44] to 2022 [31] and sample size ranged from 278 [45] to 59,442 individuals [26]. Regarding the design, the majority (90.0 %) of the selected studies was cross-sectional [25–29,31,34–36,44–52], with five of these studies of them embedded in longitudinal studies [44,46,49–51]. Across the 20 studies, 11 (55.0 %) included samples of infants, children and adolescents [23,25–27,31,36,44,48–50,53]. According to the World Bank Classification [54], most studies (75.0 %) were from high-income countries [23,27–29,31,34,35,44–49,51,53], especially the United States of America ($n = 7$) [23,29,34,45,47,48,51]. No studies from low-income countries were found (Supplementary Tables).

Twelve studies [25–28,35,36,44–46,48,49,53] used asthma as the main exposure, four used AD [23,34,47,50] and three AR [29,51,52]. Only one [31] investigated sleep problems in people with asthma and allergic diseases. Regarding outcomes, all studies used self-reported data, and most (75.0 %) used non-validated instruments to assess the outcomes. Five studies (25.0 %) used validated instruments [25,31,48,51,52], such as the Epworth Sleepiness Scale (ESS) [25,52], the

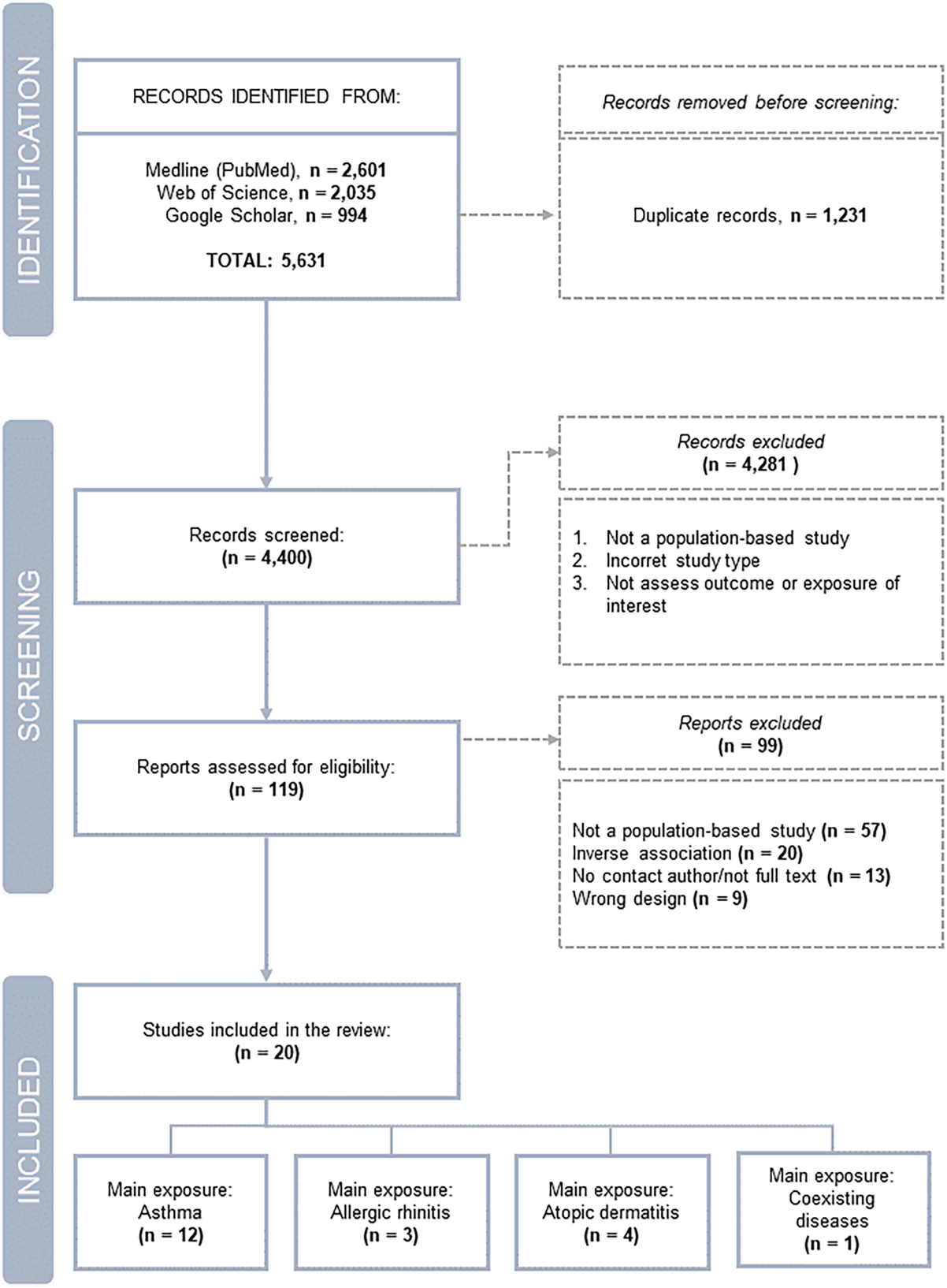

Fig. 1. PRISMA flow diagram describing the study selection.

Paediatric Sleep Survey Instrument (PSSI) [31], the Munich Chronotype Questionnaire, the Pittsburgh Sleep Quality Index (PSQI) [25], the Medical Outcomes Study Sleep Scale (MOS-SS) [51], the Insomnia Severity Index (ISI) [48], and the Children's Report of Sleep Patterns (CRSP) [48].

Different sleep parameters were identified among the selected articles (Fig. 2A). The most common outcomes were sleep duration ($n = 14$) and insomnia ($n = 14$), followed by daytime sleepiness ($n = 13$).

Table 1
Description of selected studies ($n = 20$).

Variables	Number of studies (%)	Authors and reference
Exposure		
Asthma	12 (60 %)	Desager et al. 2005 [27]; Estanislau et al. 2021 [26]; Ferreira et al. 2022 [25]; Fitzpatrick et al. 1993 [35]; Garden et al. 2016 [53]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Meltzer et al. 2014 [48]; Sundberg et al. 2010 [46]; Tirosh et al. 1993 [44]; van Maanen et al. 2013 [49]; Verhulst et al. 2007 [36]
Allergic rhinitis	3 (15 %)	Al-Digheari et al. 2018 [52]; Meltzer et al. 2009 [51]; Roxbury et al. 2018 [29]
Atopic dermatitis	4 (20 %)	Anuntaseree et al. 2012 [50]; Ramirez et al. 2019 [23]; Silverberg et al. 2015 [34]; Yu et al. 2016 [47]
Asthma, allergic rhinitis and atopic dermatitis	1 (5 %)	Sherrey et al. 2022 [31]
Instrument to access the outcome(s)		
At least one vaidated instrument	5 (25 %)	Al-Digheari et al. 2018 [52]; Ferreira et al. 2022 [25]; Meltzer et al. 2009 [51]; Meltzer et al. 2014 [48]; Sherrey et al. 2022 [31]
Non-validated or some questions derived from validated instrument	15 (75 %)	Anuntaseree et al. 2012 [50]; Desager et al. 2005 [27]; Estanislau et al. 2021 [26]; Fitzpatrick et al. 1993 [35]; Garden et al. 2016 [53]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Ramirez et al. 2019 [23]; Roxbury et al. 2018 [29]; Silverberg et al. 2015 [34]; Sundberg et al. 2010 [46]; Tirosh et al. 1993 [44]; van Maanen et al. 2013 [49]; Verhulst et al. 2007 [36]; Yu et al. 2016 [47]
Sample		
Infants, children and adolescents	11 (55 %)	Anuntaseree et al. 2012 [50]; Desager et al. 2005 [27]; Estanislau et al. 2021 [26]; Ferreira et al. 2022 [25]; Garden et al. 2016 [53]; Meltzer et al. 2014 [48]; Ramirez et al. 2019 [23]; Sherrey et al. 2022 [31]; Tirosh et al.1993 [44]; van Maanen et al. 2013 [49]; Verhulst et al. 2007 [36]
Adults and the elderly	9 (45 %)	Al-Digheari et al. 2018 [52]; Fitzpatrick et al. 1993 [35]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Meltzer et al. 2009 [48]; Roxbury et al. 2018 [29]; Silverberg et al. 2015 [34]; Sundberg et al. 2010 [46]; Yu et al. 2016 [47]
Study design		
Cross-sectional	18 (90 %)	Al-Digheari et al. 2018 [52]; Anuntaseree et al. 2012 [50]; Desager et al. 2005 [27]; Estanislau et al. 2021 [26]; Ferreira et al. 2022 [25]; Fitzpatrick et al. 1993 [35]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Meltzer et al. 2009 [51]; Meltzer et al. 2014 [48]; Roxbury et al. 2018 [29]; Sherrey et al. 2022 [31]; Silverberg et al. 2015 [34]; Sundberg et al. 2010 [46]; Tirosh et al. 1993 [44]; van Maanen et al. 2013 [49]; Verhulst et al. 2007 [36]; Yu et al. 2016 [47]
Cohort	2 (10 %)	Garden et al. 2016 [53]; Ramirez et al. 2019 [23]
Sample size		
Up to 500	3 (15 %)	Luyster et al. 2020 [45]; Meltzer et al. 2014 [48]; Sundberg et al. 2010 [46]
501 to 1000	4 (20 %)	Al-Digheari et al. 2018 [52]; Desager et al. 2005 [27]; Tirosh et al. 1993 [44]; Verhulst et al. 2007 [36]
1001 to 2000	2 (10 %)	Ferreira et al. 2022 [25]; Fitzpatrick et al. 1993 [35]
2001 to 3000	2 10 %)	Sherrey et al. 2022 [31]; van Maanen et al. 2013 [49]
3001+	9 (45 %)	Anuntaseree et al. 2012 [50]; Estanislau et al. 2021 [26]; Garden et al. 2016 [53]; Kallin et al. 2018 [28]; Meltzer et al. 2009 [51]; Ramirez et al. 2019 [23]; Roxbury et al. 2018 [29]; Silverberg et al. 2015 [34]; Yu et al. 2016 [47]
Region		
East Asia & Pacific	3 (15 %)	Anuntaseree et al. 2012 [50]; Garden et al. 2016 [53]; Sherrey et al. 2022 [31]
Europe & Central Asia	5 (25 %)	Desager et al. 2005 [27]; Fitzpatrick et al.1993 [35]; Kallin et al. 2018 [28]; Sundberg et al. 2010 [46]; van Maanen et al. 2013 [49]
Latin America & Caribbean	2 (10 %)	Estanislau et al. 2021 [26]; Ferreira et al. 2022 [25]
Middle East & North Africa	7 (35 %)	Luyster et al. 2020 [45]; Meltzer et al. 2009 [51]; Meltzer et al. 2014 [48]; Ramirez et al. 2019 [23]; Roxbury et al. 2018 [29]; Silverberg et al. 2015 [34]; Yu et al. 2016 [47]
North America	2 (10 %)	Al-Digheari et al. 2018 [52]; Tirosh et al. 1993 [44]
South Asia	1 (5 %)	Verhulst et al. 2007 [36]
World Bank Classification		
Lower middle-income	1 (5 %)	Verhulst et al. 2007 [36]
Upper middle-income	3 (15 %)	Anuntaseree et al. 2012 [50]; Estanislau et al. 2021 [26]; Ferreira et al. 2022 [25]
High-income countries	15 (75 %)	Desager et al. 2005 [27]; Fitzpatrick et al. 1993 [35]; Garden et al. 2016 [53]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Meltzer et al. 2009 [51]; Meltzer et al. 2014 [48]; Ramirez et al. 2019 [23]; Roxbury et al. 2018 [29]; Sherrey et al. 2022 [31]; Silverberg et al. 2015 [34]; Sundberg et al. 2010 [46]; Tirosh et al. 1993 [44]; van Maanen et al. 2013 [49]; Yu et al. 2016 [47]
Lower middle-income / upper middle-income / high-income	1 (5 %)	Al-Digheari et al. 2018 [52]
Adjusted/stratified to		
Sex, age and socioeconomic variables	16 (80 %)	Anuntaseree et al. 2012 [50]; Desager et al. 2005 [27]; Estanislau et al. 2021 [26]; Fitzpatrick et al. 1993 [35]; Garden et al. 2016 [53]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Meltzer et al. 2014 [48]; Ramirez et al. 2019 [23];

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Table 1 (*continued*)

Variables	Number of studies (%)	Authors and reference
		Roxbury et al. 2018 [29]; Silverberg et al. 2015 [34]; Sundberg et al. 2010 [46]; Tirosh et al. 1993 [44]; van Maanen et al. 2013 [49]; Verhulst et al. 2007 [36]; Yu et al. 2016 [47]
Other variables	1 (5 %)	Sherrey et al. 2022 [31]
No	3 (15 %)	Al-Digheari et al. 2018 [52]; Ferreira et al. 2022 [25]; Meltzer et al. 2009 [51]
Year of publication		
Up to 2000	2 (10 %)	Fitzpatrick et al.1993 [35]; Tirosh et al.1993 [44]
2001 to 2010	4 (20 %)	Desager et al. 2005 [27]; Meltzer et al. 2009 [51]; Sundberg et al. 2010 [46]; Verhulst et al. 2007 [36]
2011 to 2017	6 (30 %)	Anuntaseree et al. 2012 [50]; Garden et al. 2016 [53]; Meltzer et al. 2014 [48]; Silverberg et al. 2015 [34]; van Maanen et al. 2013 [49]; Yu et al. 2016 [47]
2018 to 2023	8 (40 %)	Al-Digheari et al. 2018 [52]; Estanislau et al. 2021 [26]. Ferreira et al. 2022 [25]; Kallin et al. 2018 [28]; Luyster et al. 2020 [45]; Ramirez et al. 2019 [23]; Roxbury et al. 2018 [29]; Sherrey et al. 2022 [31]

Frequencies varied across the exposure groups (Fig. 2B-D).

3.1. Asthma and sleep health

Twelve studies used asthma as the main exposure [25–28,35,36,44–46,48,49,53], with the prevalence varying from 4.0 % [49] to 48.0 % [48]. Five studies used the International Study of Asthma and Allergies in Childhood (ISAAC) to assess asthma or wheezing [25–27,36,48]. The remaining used questionnaires on asthma symptoms or self-reported medical diagnosis. Only one study used spirometry parameters to evaluate lung function [27]. Eight assessed samples which were comprised of infants, children and adolescents [25–27,36,44,48,49,53]. The majority (n = 11) used cross-sectional design [25–28,35,36,44–46,48,49] and one was a cohort study [53]. The main findings are summarised in Table 2. All studies used questionnaires to measure sleep health, however, only two [25,48] used validated instruments, including PSQI, ESS, CRSP and ISI. All studies assessed multiple sleep outcomes, the most utilised parameters were insomnia (n = 9), sleep duration (n = 8) and daytime sleepiness (n = 8). Other parameters assessed include snoring (n = 5), sleep quality (n = 4), daytime tiredness (n = 4) and restless sleep (n = 4) and sleep latency (n = 3). Assessed sleep characteristics are summarised in Fig. 2B. All these studies were of fair quality (Supplementary Tables S5 and S6).

3.1.1. Asthma and insomnia

Nine out of 12 studies investigated insomnia as the outcome [27,28,36,44–46,48,49,53]. Only one used a validated instrument [48], while the others relied on self-reported physician diagnosis or subjective symptoms [27,28,36,44–46,49,53]. The symptoms assessed were nocturnal awakenings [27,36,44,49], problems in falling asleep or inducing and maintaining sleep [27,28,36,45,46,48]. Two studies presented the results using a consolidated score of sleep problems and

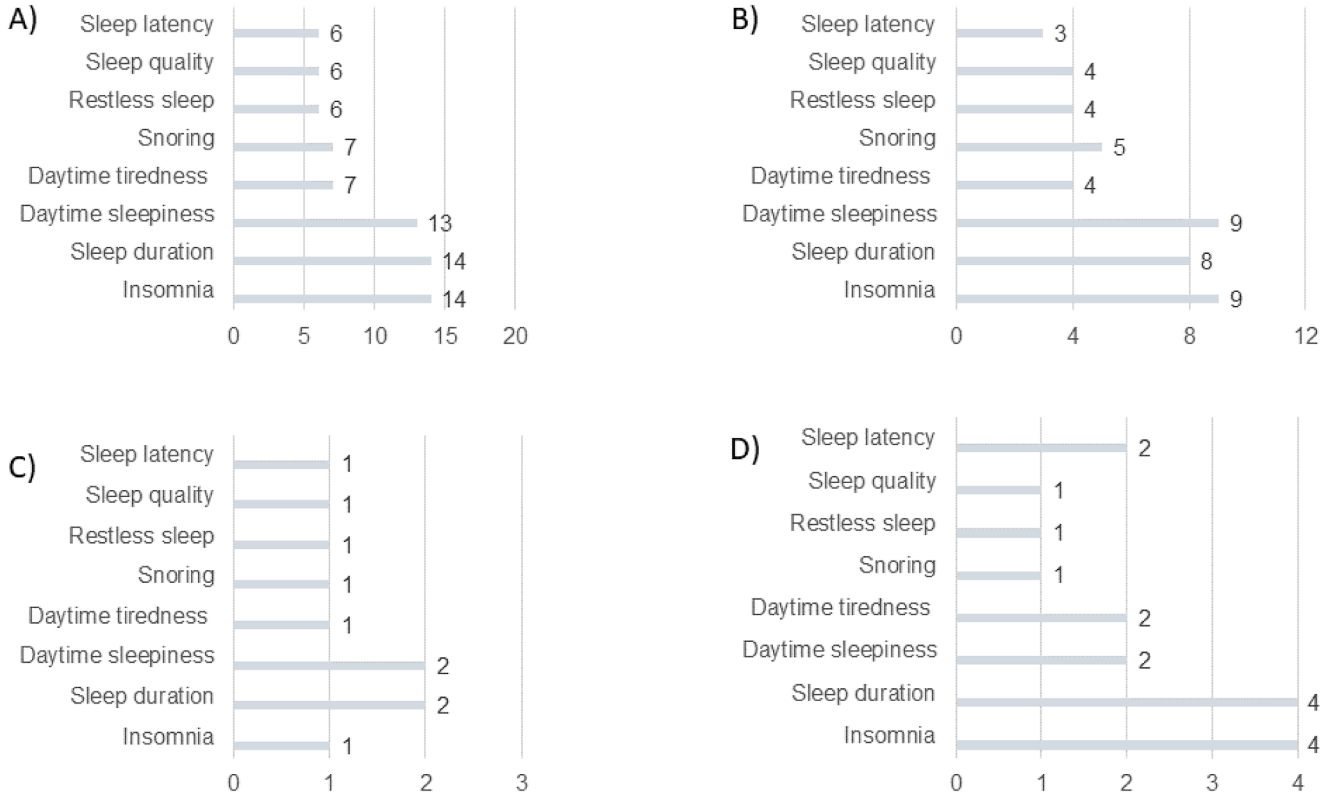

Fig. 2. Parameters used to measure sleep health in population-based studies.
Different sleep parameters identified among A) all studies (n = 20); B) studies that used asthma as main exposure (n = 12); C) studies that used allergic rhinitis as main exposure (n = 3); D) studies that used atopic dermatitis as main exposure (n = 4).<AuQuery: Please check,Part designations in figure legends should be in normal typeface (not bold face).>

Table 2
Detailed information of selected studies using asthma as main exposure ($n = 12$).

Author, year, Country	Country	Study design	Sample age and sample size	Exposure	Outcome		Study Quality
				Instrument or measurement	Instrument or measurement	Parameter	
Desager et al. 2005 [27]	Belgium	Cross-sectional	6–14 years; n = 943	A: Wheezing by ISAAC; Pulmonary function test by spirometry (FEV_1)	Self-report based on PSQ and an adult sleep questionnaire	TST, snoring, restless sleep, difficulties falling asleep, nocturnal awakenings, daytime sleepiness, daytime tiredness	Fair
Estanislau et al. 2021 [26]	Brazil	Cross-sectional	12–17 years, n = 59,442	A: ISAAC questionnaire	Self-report	Sleep duration (short sleep duration)	Fair
Ferreira et al. 2022 [25]	Brazil	Cross-sectional	14–19 years, n = 1457	A: ISAAC and ACT questionnaires	(1) PSQI, (2) ESS	Sleep duration, sleep quality, sleep latency, sleep efficiency, sleep disorders, use of sleep medications, excessive daytime sleepiness	Fair
Fitzpatrick et al. 1993 [35]	United Kingdom	Cross-sectional	$\geq$ 18 years, n = 1478	A: Self-report	Self-report	Nocturnal sleep quality: sleep duration, refreshing sleep, snoring, accidental sleep, sleep while driving	Fair
Garden et al. 2016 [53]	Australia	Cohort	Baseline: birth Follow up 1: 14 years Follow up 2: 21 years, n = = 3237	A: maternal report at 14 years; self-reported symptoms and self-reported medical diagnoses at 21 years	Self-report	Sleep disturbance score: sleep duration, sleep qualtity, daytime sleepiness, snoring, having trouble sleeping, feeling overtired, restless sleep, daytime drowsiness, trouble staying awake	Fair
Kallin et al. 2018 [28]	Sweden	Cross-sectional	16–75 years, n = 25,160	A: self-report	Self-report	EDS, insomnia, snoring	Fair
Luyster et al. 2020 [45]	United States	Cross-sectional	$\geq$ 60 years, n = 278	A: self-reported medical diagnoses	Self-report	Insomnia	Fair
Meltzer et al. 2014 [48]	United States	Cross-sectional	12 - 17 years, n = 298	A: ISAAC	(1) Children's Report of Sleep Patterns; (2) Insomnia Severity Index	TST, sleep hygiene, daytime sleepiness, insomnia	Fair
Sundberg et al. 2010 [46]	Sweden	Cross-sectional	20–44 years, n = 470	A: self-reported medical diagnoses	Self-report based on BNSQ	Insomnia and EDS	Fair
Tirosh et al. 1993 [44]	Israel	Cross-sectional	4 months - 4 years; n = 752	A: self-reported symptoms; self-reported medical diagnoses	Maternal-report	Sleep duration, interrupted nights, number of interruptions each night, time required to fall asleep, sleep latency	Fair
van Maanen et al. 2013 [49]	Netherlands	Cross-sectional	11 years, n = 2529	A: Maternal-report	Self-report	Bedtimes and rise times (time spent in bed), sleep latency, nocturnal awakenings, feeling fit at rise time, sleep quality, daytime sleepiness/ tiredness.	Fair
Verhulst et al. 2007 [36]	Sri Lanka	Cross-sectional	6–12 years, n = 652	A: ISAAC focused on wheezing	Self-report based on PSQ	Snoring, restless sleep, difficulties falling asleep, nocturnal awakenings, daytime sleepiness, daytime tiredness	Fair

A: Asthma; ACT: Asthma Control Test; BNSQ: Basic Nordic Sleep Questionnaire; CRSP: Children's Report of Sleep Pattern; EDS: Excessive daytime sleepiness; ESS: Epworth Sleepiness Scale; FEV1: forced expiratory volume in 1 s; ISAAC: International Study of Asthma and Allergies in Childhood; PSQ: Pediatric Sleep Questionnaire; PSQI: Pittsburgh Sleep Quality Index; PSSI: Pediatric Sleep Survey Instrument; SSD: Short sleep duration; TST: Total sleep time.

insomnia but specific data regarding this parameter were not shown [45,53]. Efforts were made to obtain the relevant data from the authors of those studies, but without success. Among the four studies that assessed nocturnal awakenings [27,36,44,49], two suggested that the frequency of nocturnal awakenings did not differ in people with or without asthma [44,49]. The other two studies found a higher prevalence of nocturnal awakenings in wheezing children [27,36].

Problems in falling asleep or inducing and maintaining sleep as symptoms of insomnia were assessed in five studies [27,28,36,46,48] and 20.0 % of those studies found no association between wheezing and this outcome [36]. The other studies suggested that wheezing children were at a higher risk of having difficulties falling asleep [27] and that insomnia was more common in the asthma group [28,48]. People with severe disease reported more severe insomnia than people without asthma [48]. Finally, the prevalence of this outcome ranged from 39.0 % [48] to 46.9 % [49] in both children and adults with asthma.

3.1.2. Asthma and sleep duration

Among the eight studies that evaluated sleep duration [25–27,35,44,48,49,53], five calculated the total sleep time (TST) from questions regarding the time people usually go to bed and get up during the week or weekend [25–27,44,48]. In three studies questions were asked about the time spent in bed and hours of sleep per night [35,49,53]. Half of the studies did not find differences between groups [27,44,48,49]. Two studies [25,26] showed that current asthma, even when well-controlled, was significantly associated with short sleep duration (<7 h) in adolescents. Another study also found a reduction in TST and showed that it can be more evident in people with increased disease severity [53].

The frequency of short sleep duration ranged from 44.0 % [48] to 47.8 % [25] in people with asthma. Also, the average sleep duration in this population ranged from 5.7 h ($\pm$ 1.8 h) [25] to 10.4 h ($\pm$ 0.4 h) [27].

3.1.3. Asthma and daytime sleepiness

Eight studies investigated asthma and daytime sleepiness [25,27,28,36,46,48,49,53]. Of these, two (25.0 %) used different validated instruments, the ESS [25] and the CRSP [48]. The others used questionnaires based on validated instruments [27,28,36,46,49,53]. One study did not present specific results about daytime sleepiness because it was consolidated in the sleep problem score [53].

Five studies (62.5 %) suggested that wheezing children [27], uncontrolled and controlled asthma groups [25], adults with asthma [28], adolescents with severe asthma [48] and children with frequent asthma

symptoms [49] have significantly higher prevalence or worse symptoms of daytime sleepiness than healthy controls. One study found no association between wheezing and this outcome [36]. Three studies found significant and positive associations between wheeze [27] or asthma [28] or asthma severity [48] and daytime sleepiness. The prevalence of this outcome ranged from 25 % [27] to 56.5 % [25] in both children and adults with asthma.

3.1.4. Asthma and other sleep outcomes

Other parameters were measured (Fig. 2B), but with a lower frequency. Five studies (41.7 %) investigated snoring as an outcome. Wheezing children [27] and people with asthma [28,35,53] had a significantly higher prevalence of this outcome. Four studies assessed restless sleep [27,35,36,53]. Higher prevalence of this outcome was found in wheezing children [27,36], people with asthma under 40 years and young wheezers [35]. One study suggested that asthma and wheezing increased the risk of unrefreshing nocturnal sleep [36]. Morning and daytime tiredness were also investigated [27,36,49,53]. These outcomes were more often reported by wheezing children [27,36] or children with frequent asthma symptoms [49] than the healthy control groups. One study [36] did not find associations between wheezing and daytime tiredness.

Subjective sleep quality was measured by four studies [25,35,49,53], of which three found that people with asthma had worse sleep quality [25,35,53], with adolescents with asthma being almost three-fold more likely to have poor sleep quality [25] than people without asthma. Another study suggested that in women, poor sleep quality at 14 years can predict asthma at 21 years [53]. One study did not find association between asthma and sleep quality [49]. Three studies [25,44,49] used sleep latency (time to get to sleep) as an indicator of sleep quality. Only one study showed that sleep latency was one of the most affected domains of PSQI [25].

Table 3
Detailed information of selected studies using allergic rhinitis ($n = 3$), atopic dermatitis ($n = 4$) and multiple atopic diseases ($n = 1$) as main exposure.

Allergic rhinitis as main exposure							
Author, year, Country	Country	Study design	Sample age and sample size	Exposure	Outcome		Study Quality
				Instrument or measurement	Instrument or measurement	Parameter	
Al-Digheari et al. 2018 [52]	Egypt, Kuwait, Saudi Arabia, Republic of Türkiye, and the United Arab Emirates	Cross-sectional	≥ 18 years, n = 857	AR: SFAR	ESS	Daytime sleepiness	Fair
Meltzer et al. 2009 [51]	United States	Cross-sectional	mean age 46.7, n = 7024	AR: self-reported symptoms in the past 12 months	MOS-SS 6-item	Sleep problems and sleep adequacy (amount of sleep)	Fair
Roxbury et al. 2018 [29]	United States	Cross-sectional	≥ 16 years, n = 5563	AR: self-reported symptoms in the past 12 months	Self-report	Sleep duration, sleep latency, sleep quality, sleep disturbances, trouble falling asleep, waking up during the night, waking up too early in the morning, feeling unrested during the day, feeling overly sleeping, not getting enough sleep, use of sleep medication, daytime dysfunction, snoring	Fair
Atopic dermatitis as main exposure							
Author, year, Country	**Country**	**Study design**	**Sample age and sample size**	**Expusure Instrument or measurement**	**Sleep outcomes Instrument or measurements**	**Parameters**	**Study Quality**
Anuntaseree et al. 2012 [50]	Thailand	Cross-sectional	1 year, n = 4085	AD: Modified ISAAC questionnaire and 3 pictures of a typical manifestation of AD on the face, trunk and legs.	Self-report	Sleep duration, night wakings, difficulty falling asleep, night waking requiring the parents to calm down the baby, sleep onset/latency	Fair
Ramirez et al. 2019 [23]	United States	Cohort	Baseline: birth; Follow up 1: six months; Follow up 2: 16 years, n = 13,988	AD: Self-reported symptoms	Maternal or self-report	Sleep duration, sleep quality: nighttime awakinings, difficulty falling asleep, early morning awakenings	Good
Silverberg et al. 2015 [34]	United States	Cross-sectional	≥ 18 years, n = 34,613	AD: Self-reported symptoms	Self-report	Sleep duration, daytime sleepiness, insomnia, fatigue	Fair
Yu et al. 2016 [47]	United States	Cross-sectional	≥ 18 years, n = 5563	AD: Self-reported symptoms	Self-report	Hours of sleep, trouble falling asleep, nighttime awakenings, early morning awakening, feeling unrested, feeling overly sleepy, not enough sleep, snoring, sleep latency, fatigue, use of sleeping pills, leg cramps during sleep	Fair
Multiple atopic diseases as main exposure							
Author, year, Country	**Country**	**Study design**	**Sample age and sample size**	**Expusure Instrument or measurement**	**Sleep outcomes Instrument or measurements**	**Parameters**	**Study Quality**
Sherrey et al. 2022 [31]	Australia	Cross-sectional	5–10 years; n = 1449	A + AR + AD: Adapted item from the ISAAC	26-item PSSI	Sleep routine, morning tiredness, night arousals, restless sleep,	Fair

AD: Atopic dermatitis; AR: Allergic rhinitis; ESS: Epworth Sleepiness Scale (ESS); ISAAC: International Study of Asthma and Allergies in Childhood (ISAAC); MOS-SS: Medical Outcomes Study Sleep Scale; PSSI; A: Asthma; Pediatric Sleep Survey Instrument; SFAR: Score For Allergic Rhinitis.

3.2. Allergic rhinitis and sleep health

Among the three [29,51,52] studies that documented a link between AR and sleep health, one (33.3 %) used a validated screening tool for AR [52]. The AR prevalence ranged from 5.6 % [52] to 54.5 % [51]. All three studies investigated adults only. The majority (66.5 %) was carried out in high-income countries [29,51]. The sample size ranged between 857 and 7024 people. Two studies used validated instruments, (ESS) [52] and MOS-SS [51], to assess sleep outcomes. The other study used a non-validated questionnaire [29]. The major sleep outcomes assessed were sleep duration [29,51] and daytime sleepiness [29,52]. The other outcomes, such as insomnia, restless sleep, daytime tiredness and sleep quality were reported just by one study [29] (Fig. 2C). All these studies using AR as exposure were of fair quality. Only one [29] study adjusted the models for potential confounders such as sex, age, and socioeconomic status to determine whether AR was an independent predictor for each of the sleep outcomes (Supplementary Tables S5 and S7). More detailed information about each included study can be found in Table 3.

3.2.1. AR and insomnia, sleep duration, daytime sleepiness and other sleep outcomes

Only one reference assessed insomnia as an outcome. People with AR were more likely to report insomnia, with an 85 % higher odds of having this outcome [29]. From the two studies that assessed sleep duration [29,51], only one found lower sleep adequacy in people with more severe symptoms [51]. Daytime sleepiness was measured by two studies [29,52]. Both studies found significant differences between groups, with people with AR [29] and uncontrolled symptoms [52] being more likely to suffer from severe daytime sleepiness. The prevalence of this outcome ranged from 22.9 % [29] to 59.3 % [52] in people with AR. One study assessed other parameters [29]. Results showed that people with AR were more likely to report daytime dysfunctions, feeling unrested and had higher sleep latency (>30 min). Restless leg syndrome was not related to AR [29].

3.3. Atopic dermatitis and sleep health

Four (20.0 %) studies examined AD and sleep outcomes [23,34,47,50] (Table 3) of which three had data from high-income countries [23,34,47]. The majority used modified ISAAC questionnaire, pictures of typical manifestations of AD [50] or self-reported symptoms [34,47]. The prevalence of this disease ranged from 3.0 % [47] to 35.3 % [23]. Half of the studies investigated the adults ($n = 2$) [34,47] and the other two, infants and adolescents [23,50]. Across the four studies, all measured insomnia and sleep duration [23,34,47,50] and half investigated daytime sleepiness [34,47], sleep latency [47,50], and daytime tiredness [34,47]. Other sleep outcomes, such as sleep quality [23], snoring [47], and restless sleep [47] were evaluated by one study (Fig. 2D). The majority ($n = 3$) was of fair quality [34,47,50] and only one was of good quality [23]. All studies received the maximum score for comparability (Supplementary Tables S5 and S7).

3.3.1. AD and insomnia, sleep duration, daytime sleepiness, other sleep outcomes

Insomnia was investigated as difficulty falling asleep, night waking or early morning awakenings in all studies ($n = 4$) [23,34,47,50]. Of these, one [50] did not find significant differences between groups. However, the authors observed a higher proportion of infants with AD who often required their parents to calm them down after waking during the night [50]. Children with active AD were more likely to report early morning awakenings and had high frequency of difficulty falling asleep and nighttime awakenings between ages 2 and 9 years [23]. In adults, AD was associated with higher odds of insomnia [34,47]. The frequency of this outcome ranged from 13.0 % [50] to 34.4 % [34] in people with AD.

All studies ($n = 4$) measured sleep duration [23,34,47,50]. Among these, one observed similar sleep duration between children with active AD and healthy control children [23]. The others found significantly higher odds of short sleep duration in people with AD [34,47,50]. After adjustment for total caffeine intake, the association did not remain significant in one of these studies [47]. Two studies (50.0 %) evaluated self-reported daytime sleepiness in adults [34,47]. In both studies, AD was associated with higher odds of regular daytime sleepiness [34] or being overly sleepy during the day [47]. The associations remained significant in multivariable models [34,47]. AD was considered an important predictor of daytime sleepiness [34]. The prevalence this outcome ranged from 26 % [34] to 27.2 % [47] in people with AD.

Other sleep outcomes were evaluated by different studies. AD appears to be associated with impaired sleep quality throughout childhood [23]. Higher odds of sleep quality disturbances were observed in this population [23]. In addition, adults with AD had significantly higher odds of both restless sleepiness [47] and fatigue (or lack of energy) [34]. No significant associations regarding snoring and sleep latency were found in one study [47]. In contrast, another study observed that sleep onset latency was significantly shorter in infants with mild AD [50].

3.4. Coexisting diseases and sleep health

Only one study investigated sleep health outcomes using more than one disease (asthma, AR and AD) as main exposure [31] (Table 3). The PSSI was used to measure six different sleep disorders [31]. This was of fair quality and received one of the lowest scores (Supplementary Tables S5 and S7). The main reasons for that were: unjustified sample size, and unsatisfactory model adjustment [31]. In this study [31], the total score of PSSI was markedly higher among children with two or more diseases [31]. These children had markedly elevated total sleep problems, especially restless sleep and morning tiredness [31].

From the 20 selected studies, few explored other diseases in secondary analyses. One study [23], which investigated AD as the main exposure, assessed asthma or AR as additional covariables. The authors found an important interaction between multiple diseases for the occurrence of poor sleep quality [23]. Children with both AD and asthma or AR had higher odds (nearly 80.0 %) of reporting poor sleep quality throughout childhood [23]. Other studies that assessed asthma related risk factors for sleep disturbance [27,36] found that, as well as wheezing, AR was strongly related to impaired quality of sleep [27,36]. In both studies, AR was an important risk factor for snoring [27,36]. This disease was also associated with higher odds of daytime tiredness [27], nocturnal awakenings [27], and restless sleep [36]. Another study identified higher odds of restless sleep among people with AD [27]. Only one study [36] did not find statistically significant associations between AD and sleep.

4. Discussion

This systematic review examined population-based studies which assessed the association between asthma, AR, AD and sleep health across all age groups. A total of 20 studies were identified of which one used coexisting diseases as main exposure. The majority used cross-sectional design and were conducted in high-income countries. Respiratory symptoms, such as wheeze and cough were reported to be more predictive of sleep disorders than specific diagnoses of diseases [27]. Most of the studies that used asthma as main exposure assessed wheezing [25–27,36,44,48,49,53].

The most frequently assessed outcomes were nocturnal sleep-related dysfunctions (insomnia, short sleep duration and restless sleep) and daytime sleep-related dysfunctions (daytime sleepiness, difficulty waking up, and daytime tiredness). Several studies suggest that poor sleep quality is related to poor disease control and it is extremely relevant for daytime functioning and quality of life [17,25,55]. Babcock and collaborators [56] used wrist actigraphy to measure sleep patterns of people with asthma in three scenarios. The results suggested that people

with poorly controlled asthma had less total sleep duration compared to people with well-controlled disease [56].

On the other hand, a meta-analysis examined the association between AR and sleep duration and found no significant difference in sleep duration between groups [19]. However, the study showed that AR was associated with higher risk of insomnia, restless sleep, and daytime sleepiness [19]. Regarding AD, a study showed that severe and increased scratching can lead to decreased sleep efficiency [57]. Those variables were measured by self-report, and objectively by polysomnography and actigraphy over two nights [57].

The main underlying mechanisms that explain the effects of asthma, AR and AD on sleep health are divided into four factors: pathophysiologic (inflammatory mediators), environmental (poor disease control), individual (nonadherence to treatment), and family/cultural (cultural beliefs) [17,19]. Using wrist actigraphy to study sleep in ten people with mild to moderate persistent asthma, researchers [58] concluded that those with asthma who frequently used rescue medications had higher sleep latency and shorter sleep duration compared to individuals with better disease control. Additionally, medication use, such as antihistamines or corticosteroids, which are commonly prescribed for allergy symptoms, can disrupt sleep-wake regulation [34]. Psychiatric disorders, like anxiety and depression, along with their pharmacological treatments, may also affect sleep patterns, making them important confounders in studies of sleep health [59,60].

Overall, the quality of the included studies was fair, and some aspects may increase risk of information and selection bias, as well as confounding, making it difficult to reach a conclusion. Firstly, the doubtful representativeness given that most studies presented unsatisfactory response/follow-up rate and there was no description of the characteristics of responders and non-responders. Secondly, the poor adjustment. Studies with poor or no adjustment for potential confounding can lead to misinterpretation of the data and wrong conclusions [25,51,52]. For those that conducted adjustment for confounders, the majority controlled for sex, age, gender, and income. Only two [26,45] adjusted the models for mental disorders. None of the studies considered the effects of medication for asthma, AR, or AD in their analyses, using medication only as a diagnostic tool. Silverberg and colleagues [34] argued that medication use deserves exploration in larger-scale studies. Ferreira and collaborators [25] also emphasised that the use of medication should be investigated in future studies.

Thirdly, the outcome in all of the 20 studies was based on self-reported data. Self-reporting is frequently used in epidemiologic research [61], but can lead to social desirability bias and recall bias [61,62]. Only 25 % of the studies used at least one validated instrument. Corroborating with Thorarinsdottir and collaborators [63], the ESS was the most reported. Non-validated instruments may lead to low accuracy and may result in information bias which affects the validity of the study [61,64]. Polysomnography is considered the gold standard to measure sleep parameters objectively [65], but its high cost makes it less applicable for large for population-based studies.

Health and disease follow a social gradient in which lower socioeconomic position are more likely to show worse health. Inequalities in health may result from inequities in power, money and resources [66]. There is evidence that morbidity and mortality related to asthma, AR and AD are disproportionately higher in low- and middle-income countries [67,68]. Sleep impairment caused by those diseases may be a key indicator of illness-related morbidity [17,69,70]. This outcome has been recognised as an important factor contributing to socioeconomic disparities in health outcomes [17,70]. In this review, however, it was not possible to infer socioeconomic disparities on sleep health data regarding the sleep outcomes as the majority ($n = 15$) of the studies were from high-income countries.

This review identified several gaps in the literature regarding the association of asthma, allergic diseases, and sleep health. There is a lack of studies investigating the impact of having more than one disease on sleep health. Nearly all studies used a single disease as the main exposure. Few studies included other diseases in their analyses [23,27,28,34,36] and, as they were not of direct interest, those diseases were analysed as covariates. The impact of a single disease on sleep health cannot be fully assessed without also acknowledging the contribution of others [18]. Differences in sleep quality in individuals with more than one condition have been observed by few studies [17,18,30], however they were not population-based studies. Although not representative of the general population, the authors agree that individuals with several diseases may represent a group at higher risk of experiencing disrupted sleep, which leads to important clinical and therapeutic implications [17–19,30].

One of the aims of this study was to assess the effects of co-occurrence of asthma, AR and AD on sleep outcomes in population-based studies. However, as the majority of the selected studies investigated a single disease, results were presented according to the main exposure. Thus, the real contribution of the co-occurrence of asthma, AR and AF on sleep health remains unknown. Another gap is related to data heterogeneity across studies. Different instruments, operationalising definitions and a variety of definitions were used to assess sleep outcomes, making it difficult to combine and summarise findings. In addition, most studies used cross-sectional design, not allowing for temporality of the associations to be established.

This review also has some limitations. Studies focused on sleep-related breathing disorders, such as obstructive sleep apnoea (OSA) were avoided. Additional relevant data were requested, but only one author provided them [23]. Finally, given the limited number of studies and the heterogeneity across them, meta-analyses were not conducted. On the other hand, this is the first systematic review evaluating the association between multiple diseases (asthma, AR or AD) and sleep health in population-based (i.e. non-clinical) settings, which may provide results generalisable to the general population of similar characteristics [71].

5. Conclusion

This systematic review highlights important methodological issues in the assessment of sleep outcomes using three diseases that may co-occur as main exposures in population-based studies. We found significant evidence that people with asthma, AR or AD have impaired sleep health, which is characterised by shorter sleep duration, difficulty falling asleep, restless sleep and excessive daytime sleepiness. This review emphasises the need for studies focused on the effects of coexisting diseases on sleep health outcomes, using objective measures. Also, clinicians caring for people with a single or coexisting conditions should always consider sleep health during routine clinic visits.

CRediT authorship contribution statement

Gabriela Avila Marques: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Valentina Quintero Santofimio:** Writing – review & editing, Visualization, Investigation, Data curation. **Andre F.S. Amaral:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Bryndis Benediktsdóttir:** Writing – review & editing, Validation, Methodology, Conceptualization. **Thorarinn Gislason:** Writing – review & editing, Validation, Methodology, Conceptualization. **Priscila Weber:** Writing – review & editing, Conceptualization. **Paula Duarte de Oliveira:** Writing – review & editing, Conceptualization. **Fernando Wehrmeister:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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