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CLINICAL REVIEW

Restless sleep in children: A systematic review

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SUMMARY

This systematic review assessed the prevalence of restless sleep in children, documented the association of restless sleep with other conditions, and summarized the existing evidence regarding whether restless sleep should be considered a distinct sleep disorder. A comprehensive search of electronic databases was performed using the broad search term "restless sleep" in all fields. Of the 266 articles retrieved, 107 were retained for inclusion in this review. The majority (n = 93) were observational studies. The studies were grouped under several pathologic/condition categories: sleep-disordered breathing (n = 19); adenotonsillectomy (n = 7); respiratory disorders, otitis media, and smoke exposure (n = 12); sleep-related movement disorders and restless sleep disorder (n = 11); neurologic or psychiatric disorders (n = 7); Down syndrome/other neurodevelopmental disorders (n = 10); sleep-related bruxism and other sleep disorders (n = 7); and restless sleep in the general population/mixed clinical samples (n = 18). A high prevalence of restless sleep was found in children with many of these underlying conditions, likely related to associated inherent sleep disruption and frequent awakenings (e.g., apnea and periodic limb movements), pain, sleep instability, and caregiver perception. The majority of studies identified restless sleep as reported by the caregiver, only 34 studies attempted to define restless sleep further. Four studies provided supportive evidence for designating restless sleep as an independent sleep disorder, restless sleep disorder (RSD). This review highlights the fact that the prevalence, etiology and sequelae (including daytime impairments) of restless sleep in children are important topics deserving of further research and that clinical definitions based on empirical evidence need to be developed. The designation of "primary" versus "secondary" restless sleep may be a useful construct, especially with regard to developing clinical trials and treatment algorithms.

Abbreviations: ADHD, attention-deficit/hyperactivity disorder; ICSD, International Classification of Sleep Disorders; IRLSSG, International Restless Legs Syndrome Study Group; NIH, National Institutes of Health; OSA, obstructive sleep apnea; PLMD, periodic limb movement disorder; PLMS, periodic leg movements during sleep; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RLS, restless legs syndrome; RSD, restless sleep disorder; SDB, sleep-disordered breathing.

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Introduction

Our understanding of sleep disorders and their consequences has grown exponentially over the last decades. Technological advances enable the objective monitoring of patients and can determine the quantity and quality of sleep, the presence or absence of a sleep disorder, and the physiologic effects produced by sleep conditions.

Historically, the modern identification and classification of sleep disorders date back to the 1970s. In 1979, the Association of Sleep Disorders Centers and the Association for the Psychophysiological Study of Sleep published the *Diagnostic Classification of Sleep and Arousal Disorders* [1]. The term "*restlessness*" during sleep was introduced in this publication and was defined as "*persistent or recurrent body movements, arousals, and brief awakenings (that occur) in the course of sleep*". It was described as a symptom of a variety of sleep disorders, including sleep apnea syndrome, psychophysiological insomnia, and abnormal swallowing syndrome. The description of sleep-related myoclonus included "*restless sleep, disruption of bedclothes, and falling out of bed*".

The symptom of restless sleep is a common pediatric sleep complaint. It is frequently mentioned in the pediatric sleep literature and there are questions about restless sleep in many validated pediatric sleep questionnaires including the Child's Sleep Habits Questionnaire, Pediatric Sleep Questionnaire, and the Sleep Disturbance Scale for Children. In 2018, restless sleep disorder (RSD) was proposed as a new pediatric sleep diagnosis based on clinical and video-polysomnographic findings [2]. However, we are unaware of any comprehensive reviews of restless sleep in children or how restless sleep might relate to various pediatric sleep disorders.

In 2019, the International Restless Legs Syndrome Study Group (IRLSSG) formed a task force to establish consensus diagnostic criteria for RSD consistent with the International Classification of Sleep Disorders (ICSD) guidelines (in progress). In addition, the task force agreed to conduct this literature review of pediatric restless sleep with the aims to: 1) comprehensively assess the presence of restless sleep in the pediatric medical literature, 2) evaluate the association of restless sleep with other medical or sleep conditions, and 3) investigate if restless sleep had been proposed as an independent sleep disorder prior to 2018.

Methods

Study design

This systematic review was not preregistered but was conducted and reported in accordance with the quality standards recommended in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement protocol [3] (Fig. 1).

Study eligibility was defined according to the PICOS criteria [4] (population, intervention, comparison, outcomes, and study design): Population (children aged ≤18 years with or without sleep complaints); Intervention (this element was not applicable as this was a systematic review of observational studies, and while some interventional studies were included they were not directly intended to treat restless sleep); Comparison (comparisons to healthy controls, other clinical groups, or within the same group, and descriptive studies not comparing data vs. any control group); Outcomes (the primary outcome was to assess the presence of "restless sleep" in the pediatric medical literature, secondary outcomes were to evaluate the association of "restless sleep" with other medical or sleep conditions, and to investigate if "restless sleep" had previously been proposed as an independent sleep disorder); and Studies (all studies reporting ≥5 cases).

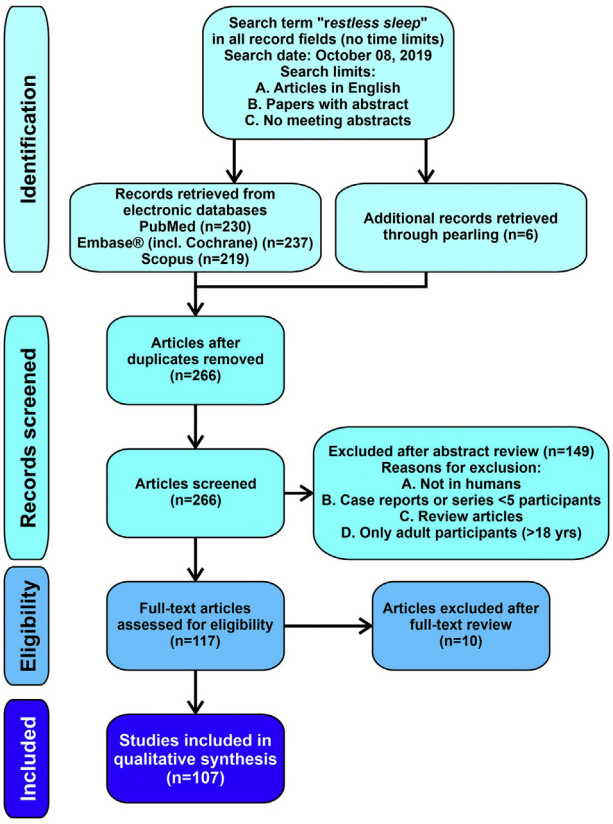

Fig. 1. Flowchart of the article search and selection strategy.

Search strategy and selection criteria

A comprehensive literature search was performed using PubMed, EMBASE (including the Cochrane library), and Scopus electronic databases up until October 9th, 2019 (Fig. 1). The broad search term "restless sleep" was used and all fields were searched ensuring that any article mentioning restless sleep in the title or abstract was retrieved. Reference lists were examined and citation searching was performed.

Exclusion criteria were: studies in adults and animals, in languages other than English, and with less than five participants. Review papers, congress proceedings, guidelines, editorials, abstracts, comments, and statements were also excluded. If the same participants were included in more than one publication, then only the dataset with the most relevant information for our systematic review was used to avoid data duplication.

Data extraction and analysis

A data extraction form was created and tailored to the review questions and included the National Institutes for Health (NIH) *Guidance for Assessing the Quality of Observational Cohort and Cross-Sectional Studies* [5]. Full-text versions of eligible studies were retrieved and each article was randomly assigned to two reviewers who worked independently to extract the data into the extraction form. Reviewers did not review any articles they had authored. Any discrepancies were resolved by a third reviewer. The NIH quality assessment has slightly different sets of items per study design [5].

After scoring, we regrouped these items into: "Study population, definition and selection" e.g., reporting subject selection method, inclusion/exclusion criteria etc.; "Soundness of information" e.g., reporting of (in)dependent variables, interventions, etc.; "Analysis, comparability and outcomes" e.g. reporting of statistical analyses, confounding variables, blinding etc.; and "Interpretation and reporting" e.g., results being well-described and in line with the hypothesis, design, etc. Subsequently, given that the presence of an item is scored as "yes" a grading of "*poor*" is obtained when, in accordance with the appropriate study design, none of the items had an affirmative answer, a "*fair*" grading when less than half of the items received a "yes" score, and "*good*" when more than half the items obtained a "yes" score.

Data extracted from the papers were tabulated as mean ± standard deviation, range, interquartile range, median and percentages. Descriptive analyses reporting the summary of papers reviewed are presented as mean ± standard deviation and frequencies.

After approval of the written report by all coauthors, it was submitted to the Executive Committee of the IRLSSG for approval.

Results

A total of 117 articles were retrieved for full review (Fig. 1), 10 were excluded as they did not meet the pre-specified inclusion criteria. The majority (n = 93) of the remaining 107 were observational studies, three were controlled randomized studies, six were uncontrolled clinical studies, and five studies were mixed. Finally, studies were grouped together under several pathology/condition categories and are described in Tables 1–9. Restless sleep was defined in 34 papers. Four studies identified restless sleep as an independent disorder.

Restless sleep in patients with sleep-disordered breathing (SDB)

Nineteen studies assessed restless sleep in patients with different types of SDB (Table 1). Seven studies referred to children with obstructive sleep apnea (OSA) [6–12], five of which reported restless sleep to be highly prevalent ranging from 65.5% to 81%. One study (without controls) reported restless sleep in 24.7% of children and another study, while not reporting prevalence, stated that sleep in children with OSA was much more restless and with an increased number of movements. None of these studies had a normal control group. However, when comparing to OSA, restless sleep was less prevalent in "non-OSA" (81% vs. 52.4%) [7] or in snoring children (65.5% vs. 44.9%) [11] and less prevalent in patients from a general pediatric clinic (78% vs. 23%) [12]. All studies evaluated restless sleep by questionnaire or interview except one study that defined it as an enhanced number of movements and EEG arousals on polysomnography [10].

Three additional studies did not clarify SDB type but reported a prevalence of restless sleep similar to that of OSA (71% vs. 29% of children in a non-snoring community sample [13] and in 84.4% of children with adenotonsillar hypertrophy [14]). In the remaining paper [15], restless sleep was one of the elements of a clinical score but its prevalence was not reported.

Restless sleep was also reported in 50% of children with central sleep apnea but in none of the controls [16] and in 46.8% of children sleeping at high altitude [17].

Finally, another seven papers reported restless sleep in snoring children [18–24]. A general increase in the prevalence of restless sleep with increasing severity and frequency of snoring is reported in these studies, with prevalence ranging from 34.1% to 70% in habitual/frequent snorers and in 9.4%–30% of never snored/non-snorers. A history of restless sleep was reported to be significantly associated with snoring in one of these papers [22], but its prevalence was not reported.

Of the 19 studies on restless sleep in children with SDB, 18 (94.7%) were observational, 18 had a cross-sectional design. Seventeen studies were prospective. The quality analysis of these studies, performed in agreement with the *NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies* [5] and reported in Table 2, indicated that the great majority of studies in this group had a "*good*" rating for "Study population, definition and selection" but "*poor*" for "Analysis, comparability and outcomes" while the ratings for "Interpretation and reporting" were "*fair*" in almost three-quarters of them; the ratings for "Soundness of information" were similarly distributed among the three possible grades.

Restless sleep in children undergoing adenotonsillectomy

Seven studies assessed restless sleep in children undergoing adenotonsillectomy for SDB and/or on restless sleep as a consequence of the surgical intervention (Table 3) [25–31]. The prevalence of restless sleep was comparable to that reported for SDB, ranging from 37.7% to 91% (reported in four out of seven studies [27,29–31]). The three remaining studies focused on other aspects and reported that anti-inflammatory treatment in patients with SDB was effective for restless sleep but not in severe OSA [25]. In addition, adenotonsillectomy improved restless sleep (implicitly establishing a secondary nature of restless sleep in these patients) [26], and restless sleep can occur in up to 56% of children post-surgery and correlated with subjective pain intensity (again indicating a clear secondary nature) [28].

Three of the seven studies were observational, two were before-after studies, one was a randomized-controlled trial, and the remaining study was not classifiable. Three studies had a cross-sectional design, while the remaining four were a clinical trial, a non-controlled clinical trial, a before-after study, and a before-after study without control. All studies were prospective. The majority of these studies were rated as "*good*" for the items "Study population, definition and selection", "Soundness of information", "Analysis, comparability and outcomes", while the "*fair*" and "*good*" ratings were approximately similar for "Interpretation and reporting" (Table 2).

Respiratory disorders, otitis media, and smoking

Four studies assessed restless sleep in children with respiratory disorders (Table 4) [32–35], three in patients with asthma [36–38], and two in smoke exposed patients [39,40]. Pneumonia, upper respiratory tract infections with or without otitis media, tonsillitis, hypertrophy of tonsils, and coughing at night were all found to be associated with restless sleep, with variable prevalence ranging from 16.8% to 48.5%. One study on acute otitis media [41] indicated the presence of restless sleep in 85.2% of patients and emphasized the role of moderate to severe pain in this association. Restless sleep was also found to affect up to 83.5% of children with poorly-controlled asthma, but also in approximately half the children with well-controlled asthma, compared to less than one-third of children without asthma [36]. Interestingly, restless sleep was reported in 8.2% of a large group of adolescents, among whom 23% were exposed to second-hand smoking every day vs. 9.4% of those without exposure [39]; another study reported restless sleep in 9.8% of adolescent males who smoked vs. 17.6% of adolescent females who smoked [40].

Eleven studies were observational and one was a randomized controlled trial. Ten studies were cross-sectional, one was a cohort study, and another was a clinical trial. Ten studies were prospective and two were retrospective. The majority of studies in this group were rated as "*good*" for "Study population, definition and

Table 1
Papers reporting restless sleep in patients with sleep-disordered breathing.

Paper	Patients	Other group(s)	Method(s)	Definition of restless sleep (RS)	Results/Conclusions
	(sample size), age mean ± standard deviation, range, median, and interquartile range (IQR)				
Obstructive sleep apnea					
Chang et al., 2013 [6]	obstructive sleep apnea (OSA) (78), median 3.85 y, IQR 3.08−5.45 y	non-OSA (63), median 4.7 y, IQR 3.20−7.20 y	questionnaire, polysomnography (PSG)	None	RS in 69.2% of OSA vs. 52.4% of non-OSA
Sakellaropoulou et al., 2012 [7]	OSA (42), 7.63 ± 2.90 y, 3.5−14.5 y		questionnaire, PSG	None	RS in 81% of OSA (almost every night in 41.5%)
Mohamad et al., 2011 [8]	OSA (16), 7.75 ± 3.38 y, 3−14 y		questionnaire, PSG	moves frequently or falls out of the bed	RS in 68.8% of OSA
Ramos et al., 2006 [9]	OSA (93), 5.2 ± 2.1 y		PSG	None	RS in 24.7% of OSA
Scholle and Zwacka, 2001 [10]	OSA (20), 3.1−14.3 y	non-OSA (20), 3.3−13.9 y	PSG	enhanced number of movement and EEG arousals	Sleep in OSA much more restless and marked by increased frequency of movements
Nieminen et al., 1997 [11]	OSA (29), snoring (49), 5.6, 2.4−10.5 y (pooled together)		questionnaire, cardiovascular monitoring	None	RS in 65.5% of OSA vs. 44.9% of snoring; RS is a risk factor for OSA in children
Brouilette et al., 1984 [12]	OSA (23), 3.8 ± 2.4, possible OSA (23), 5.3 ± 3.6 y	general pediatric clinic (46), 4.0 ± 2.3 y	Questionnaire	None	RS in 78% of OSA vs. 23% of controls
Sleep-disordered breathing not otherwise specified					
Biggs et al., 2014 [13]	sleep-disrodered breathing (SDB) (87), 7.5 ± 1.7 y, 5−11 y	non-snoring community sample (55), 7.4 ± 1.5 y, 5−11 y	questionnaire, PSG	four questionnaire items	RS in 71% of SDB and 29% of controls
Martha et al., 2013 [14]	SDB (33), 1−16 y	normal (10), 1−16 y	Questionnaire	None	RS in 84.4% of children with adenotonsillar hypertrophy
Bitar et al., 2006 [15]	SDB (86), 4.3, 1.1−15.1 y		Questionnaire (self-composed clinical score)	None	Clinical score, in which RS is one of the elements.
Central sleep apnea					
Gurbani et al., 2017 [16]	central sleep apnea (CSA) (14), 9.6 ± 4.5 y	normal (9), 8.5 ± 3.2 y	cardiovascular monitoring, PSG	None	RS in 50% of CSA vs. none of the controls
Accinelli et al., 2015 [17]	high-altitude sleep (77), 11.8 ± 1.4 y, 9−14 y		Questionnaire	repetitive movements	RS in 46.8% (repetitive movements)
Snoring					
Piteo et al., 2011 [18]	snoring frequently (55), infrequently (82), 1−12 w	not at all snoring (320), 1−12 w	questionnaire	None	RS ≥ 3 nights in 48% of frequent snorers, 23% of infrequent snorers, and 15% of not at all snorers
Sogut et al., 2009 [19]	habitual snorers (41), occasional snorers (291), 12−17 y	never snored (698), 12−17 y	questionnaire	None	RS in 41% of habitual snorers, 22.4% of occasional snorers, and 14.7% of never snorers
Sahin et al., 2009 [20]	habitual snorers (41), occasional snorers (412), 7−13 y	non-snorers (711), 7−13 y	questionnaire	None	RS/irritability in 34.1% of habitual snorers, 16.7% of occasional snorers, and 9.4% of non-snorers
Ersu et al., 2004 [21]	habitual snoring (151), occasional snoring (743)	never snored (1,253), 8.5 ± 1.3, 5−13 y (all groups pooled together)	questionnaire	None	RS in 59.6% of habitual snoring vs. 39.1% of occasional snoring vs. 24.3% of never snored
Owen et al., 1996 [22]	snorers (66), ≤11 y	non-snorers (179), ≤11 y	questionnaire	None	Snoring significantly associated with history of RS
Ali et al., 1994 [23]	snored rarely (170), snored sometimes (144), snored most nights (60), 6.5−7.5 y	never snored (133), 6.5−7.5 y	questionnaire	None	RS in 28% of never snored, 32% of rarely, 49% of sometimes, and 70% of most nights snoring. RS overall prevalence 39%, unchanged vs. 2 years earlier.
Ali et al., 1993 [24]	snored rarely (239), snored sometimes (201), snored most nights (95), 4.5−5.5 y	never snored (247), 4.5−5.5 y	questionnaire, pulse-oximetry, home video	None	RS in 30% of never snored, 36% of rarely, 50% of sometimes, and 64% of most nights snoring

Abbreviations: CSA = central sleep apnea; OSA = obstructive sleep apnea; PSG = polysomnography; RS = restless sleep; SDB = sleep-disordered breathing (non specified); w = weeks; y = years.

Table 2
Study quality analysis in the groups of papers included in this review.

	Study population, definition and selection	Soundness of information	Analysis, comparability and outcomes	Interpretation and reporting
Sleep-disordered breathing (n = 19)				
Poor	0.0	26.3	84.2	0.0
Fair	10.5	42.1	10.5	73.7
Good	89.5	31.6	5.3	26.3
Adenotonsillectomy (n = 7)				
Poor	14.3	0.0	28.6	0.0
Fair	14.3	14.3	0.0	57.1
Good	71.4	85.7	71.4	42.9
Respiratory tract disorders, otitis and smoking (n = 12)				
poor	0.0	0.0	83.3	8.3
Fair	16.7	50.0	8.3	33.3
good	83.3	50.0	8.3	58.3
Sleep-related movement disorders and restless sleep disorder (n = 11)				
poor	0.0	0.0	81.8	0.0
Fair	0.0	18.2	18.2	63.6
good	100.0	81.8	0.0	36.4
Neurologic or psychiatric disorders (n = 7)				
poor	0.0	42.9	85.7	0.0
Fair	28.6	14.3	14.3	71.4
good	71.4	42.9	0.0	28.6
Down's syndrome and other neurodevelopmental disorders (n = 10)				
poor	0.0	20.0	70.0	10.0
Fair	30.0	40.0	30.0	60.0
good	70.0	40.0	0.0	30.0
Sleep-related bruxism and other sleep disorders (n = 7)				
poor	0.0	71.4	85.7	0.0
Fair	0.0	0.0	14.3	42.9
good	100.0	28.6	0.0	57.1
Children from the general population and from mixed clinical samples (n = 18)				
poor	0.0	11.1	66.7	0.0
Fair	0.0	27.8	11.1	33.3
good	100.0	61.1	22.2	66.7

Table 3
Papers reporting restless sleep in children undergoing adenotonsillectomy and on its effect on restless sleep.

Paper	Patients (sample size), age mean ± standard deviation, range, median, and interquartile range (IQR)	Other group(s)	Method(s)	Definition of restless sleep (RS)	Results/ Conclusions	Treatment effect on RS
Yang al., 2017 [25]	obstructive sleep apnea (OSA) (193), three treatment groups: A 4.2 ± 1.3 y, B 4.0 ± 1.7 y, C 3.9 ± 1.6 y		questionnaire, cardiovascular monitoring, PSG	none		Anti-inflammatory treatment effective on RS in sleep-disordered breathing (SBD), but not in severe OSA
Choi et al., 2015 [26]	OSA (17), 6.65 ± 3.02 y		questionnaire, polysomnography (PSG)	none		Adenotonsillectomy improved RS scores
Arrarte et al., 2007 [27]	SDB (27), 5.2 ± 1.8 y		cardiovascular monitoring	none	RS in 81.5%	Post operatively, RS in 7.4%.
Sutters and Miaskowski, 1997 [28]	tonsillectomy (84), 7 ± 2.31 y		questionnaire, semi-structured phone interview	none		RS in 56% of post-surgery children, correlated with subjective pain intensity
Ali et al., 1996 [29]	OSA (12), median 7.5 y, range 5.8–12.3 y snoring (11), median 7.4 y, range 6.1–12.1 y	unrelated surgical procedure (10), median 7.6 y, range 6.2–12.5 y	questionnaire, cardiovascular monitoring	none	RS in 84% of OSA vs. 91% of snoring vs. 30% of controls; in OSA and snoring groups higher time spent moving than controls.	Post operatively RS improved only in OSA (68%) and snoring (55%). Post operatively the three groups were no longer different for time spent moving.
Gerber et al., 1996 [30]	scheduled adenotonsillectomy (292), 1.4 ± 19 y		questionnaire	none	RS in 37.7% of patients. The risk of respiratory compromise >2 times with RS.	
Stradling et al., 1990 [31]	Recurrent tonsillitis (61), 4.70 ± 1.70 y	healthy children (31), 4.71 ± 1.66 y	questionnaire, cardiovascular monitoring, home video	none	RS “often” in 75% of patients, before surgery	RS no significantly different from controls post-operatively.

Abbreviations: CSA = central sleep apnea; OSA = obstructive sleep apnea; PSG = polysomnography; RS = restless sleep; SDB = sleep-disordered breathing; y = years.

Table 4
Papers reporting restless sleep in patients with different respiratory tract disorders, otitis and smoking.

Paper	Patients (sample size), age mean ± standard deviation, range, median, and interquartile range (IQR)	Other group(s)	Method(s)	Definition of restless sleep (RS)	Results/Conclusions
Respiratory tract disorders					
McCormick et al., 2016 [32]	upper respiratory tract infection (193), 3.9 ± 2.5 m		questionnaire	None	RS (moderate/severe) in 19.1% of upper respiratory tract infection with acute otitis media and 16.9% of without
Goldbart et al., 2012 [33]	community-acquired alveolar pneumonia (1,546), 22.2 ± 15.6 m	controls (441), 11.1 ± 16.4 m	questionnaire, polysomnography (PSG)	None	RS in 16.8% of pneumonia and 5.3% of controls.
Capper and Canter, 2001 [34]	waiting list for adenotonsillectomy (139), 3–11 y normal with tonsillitis (65), 3–11 y	normal (631), 3–11 y	questionnaire	None	RS in 48.5% of subjects waiting for adenotonsillectomy, 14.8% of normal with tonsillitis, and 33.8% of normal
Fuller et al., 1998 [35]	cough at night (96), 1–10 y		questionnaire	eyes closed, with bodily movement, with <5 min between movements (movement due to breathing not included)	40% of the night, not reduced after reducing cough
Otitis media					
Uitti et al., 2018 [41]	acute otitis media (201), median 15 m, range 6–35 m	non-acute otitis media (225), median 13 m, range 6–35 m	questionnaire	None	RS in 85.2% of total sample associated with moderate/severe pain
Tahtinen et al., 2012 [100]	otitis media: immediate treatment (53), delayed treatment (161), 6–35 m		questionnaire	None	resolution of restless sleep was not significantly delayed in children with delayed treatment
Laine et al., 2010 [101]	acute otitis media (237), median 16 m, range 6–35 m	upper respiratory tract infection (232), median 16 m, range 6–35 m	questionnaire	None	RS in 28% of acute otitis media and in 29% of upper respiratory tract infection
Asthma					
Meltzer and Pugliese, 2017 [36]	poorly controlled asthma (79), 12–59 m well controlled asthma (121), 12–59 m	no asthma (164), 12–59 m	questionnaire	None	RS in 83.5% of poorly controlled asthma, 50.4% of well controlled asthma, and 30.5% of no asthma
Verhulst et al., 2007 [37]	wheezing (89), 6–12 y	non-wheezing (563), 5–12 y	questionnaire	None	RS in 22.6% of wheezing and 7.8% of non-wheezing
Desager et al., 2005 [38]	wheeze (83), 7–13 y	no wheeze (860), 7–14 y	questionnaire	None	RS in 26% of wheezing children and 10% of non-wheezers
Smoking					
Schwartz et al., 2014 [39]	students (1,592), 13–18 y		questionnaire	None	RS 5–7 times/week in 8.2%. RS in 23% of exposed to second hand smoking every day vs. 9.4% of those without exposure
Seltzer and Oechsli, 1985 [40]	smokers (154), 15–17 y	non-smokers (973), 15–17 y	questionnaire	8 items of questionnaire	RS in 9.8% of male smokers vs. 17.6% of female smokers

Abbreviations: m = months; PSG = polysomnography; RS = restless sleep; y = years.

selection" but a "*poor*" rating for "Analysis, comparability and outcomes" while the ratings for "Soundness of information" were half "*fair*" and half "*good*"; "Interpretation and reporting" was rated with decreasing scores from "*good*" to "*poor*" (Table 2).

Sleep-related movement disorders and restless sleep disorder (RSD)

Eleven papers were classified in this category (Table 5). Four identified restless sleep as a new disorder, RSD, where restless sleep was not associated with other known conditions and was considered a primary disorder [2,42–44]. RSD prevalence was reported to be 7.7% among participants referred to a single sleep disorders center [42]. Preliminary evidence of a possible beneficial effect of iron supplementation in RSD was also suggested [43]. It is of note that the RSD studies included a full set of criteria for the definition of the condition and, ultimately, for the definition of restless sleep, including a quantitative measure of movements on video recordings [2,42–44]. The remaining seven papers in this group [45–51] focused on restless legs syndrome (RLS) and/or periodic limb movement disorder (PLMD). The prevalence of restless sleep in RLS/PLMD is almost unanimously reported to be very high in these papers (>80%), with the exception of one study in which a prevalence of 28.6% was found in RLS patients, but the definition of restless sleep was somewhat ambiguous ("periodic limb movement symptoms").

Nine studies were observational with a cross-sectional design. Three were prospective and eight were retrospective. All studies received a "*good*" score for "Study population, definition and selection", nine of them were rated as "*good*" for "Soundness of information", but nine of them were rated as "*poor*" for "Analysis, comparability and outcomes"; "Interpretation and reporting" were rated "*fair*" in seven papers and "*good*" in the remaining four (Table 2).

Neurologic or psychiatric disorders

Seven studies assessed restless sleep in neurologic (n = 3) [52–54] or psychiatric disorders (n = 4) [55–58] (Table 6). Restless

Table 5
Papers reporting restless sleep in patients with sleep-related movement disorders and papers on restless sleep disorder.

Paper	Patients	Other group(s)	Method(s)	Definition of restless sleep (RS)	Results/Conclusions
	(sample size), age mean ± standrad deviation, range, median, and interquartile range (IQR)				
DelRosso and Ferri, 2019 [42]	Different sleep disorders (300), 7.9 y, 0.33–19 y		polysomnography (PSG)	restless sleep disorder (RSD) criteria (DelRosso et al., 2018)	RSD in 7.7% of children evaluated in a single sleep disorders center
DelRosso et al., 2020 [43]	iron supplementation responders (42), median 10 y, range 2–17 y, IQR 5–14 y	iron supplementation non-responders (35), median six y, range 2–17 y, IQR 4–12 y	PSG	RSD criteria (DelRosso et al., 2018)	RSD in 14.3% of responders and 8.6% of non-responders
DelRosso et al., 2019a [44]	RSD (15), 9.5 ± 3.18 y restless legs syndrome (RLS) (15), 11.9 ± 3.52 y	controls (15), 10 ± 3.16 y	video-PSG	RSD criteria (DelRosso et al., 2018)	Five movements per hour 100% accuracy for RSD vs. controls and 90% vs. RLS
Rosen et al., 2019 [45]	RS (31), median 10 y, IQR 8.0–14 (RS and RLS pooled together)	RLS (16), median 12 y, IQR 8.0–15.5	RLS severity scale	None	iron supplementation followed by a modest and nonsignificant improvement in RS and RLS, despite significant improvement in ferritin
DelRosso et al., 2018 [2]	RLS (15), 11.9 ± 3.52 y RSD (15), 9.5 ± 3.18 y	controls (30), 10.6 ± 3.8 y	PSG	RSD criteria (DelRosso et al., 2018)	clinical and PSG characterization of RSD proposed as a new diagnostic
Gingras et al., 2011 [46]	periodic limb movement disorder (PLMD) (66), 8.05 ± 3.93 y, 1–17 y	obstructive sleep apnea (OSA) (90), 7.47 ± 4.07 y, 1–15 y	questionnaire, cardiovascular monitoring, PSG	None	RS in 89% of PLMD and 97% of OSA
Turkdogan et al., 2011 [47]	RLS (119), 10–19 y		questionnaire	periodic limb movement symptoms	RS (periodic limb movement symptoms) 28.6%
Yilmaz et al., 2011 [48]	RLS (119), 16.3 ± 0.95 y	no-RLS (3185), 16.2 ± 0.95 y	questionnaire	None	RS in 28% of RLS and 16% of no-RLS
Picchietti et al., 2009 [49]	RLS (10), 11.9 y PLMD (27), nine y		questionnaire	None	RS in 80% of RLS and 89% of PLMD
Picchietti and Stevens, 2008 [50]	RLS (18), 10.3 y, 0.2–17.1 y		questionnaire	None	RS in 88.9% of children
Picchietti and Walters, 1999 [51]	moderate/severe PLMD (16), 11.1 y, 6–17 years		questionnaire	None	RS in 93.8% of children

Abbreviations: IQR = interquartile range; PLMD = periodic limb movement disorder; PSG = polysomnography; RLS = restless legs syndrome; RS = restless sleep; RSD = restless sleep disorder; y = years.

sleep was reported to be associated with tension-type headache and improved with treatment in one paper [52], but its prevalence was not reported; also, it was found in 64.3% of children with epilepsy [53] and in 34.04% of individuals with migraine [54]. Restless sleep was reported to be present in 31.7% of psychiatric patients [55], and in 67.8% of children evaluated in psychiatric clinics [56]. Restless sleep was also found to be significantly associated with bipolar mood disturbance [57], and with an anxiety-affective disorder or conduct disorder [58].

Six studies were observational with a cross-sectional design and one was a before-after study. Five studies were prospective and two were retrospective. “Study population, definition and selection” were rated “*good*” in 71.4% of reports, “Soundness of information” was rated either “*good*” or “*poor*” in 42.9% of papers, “Analysis, comparability and outcomes” were rated “*poor*” in 85.7% of cases, and “Interpretation and reporting” were rated “*fair*” in 71.4% of studies and “*good*” in the remaining ones (Table 2).

Down syndrome and other neurodevelopmental disorders

Five papers evaluating sleep in Down syndrome [59–63] reported restless sleep prevalence ranging from one-thirds to two-thirds of cases (Table 7). One paper [61] concluded that the parental report of restless sleep in this population was suboptimal to decide the need for a sleep study. Three additional papers assessed the presence of restless sleep in children with attention-deficit/hyperactivity disorder (ADHD) [64,65] (reporting a prevalence of restless sleep in 50% and 57% of children, respectively) or their symptoms (inattention/hyperactivity) [66]. In this latter study, restless sleep score was found to be associated with the periodic leg movements during sleep (PLMS) score. Finally, two papers reported restless sleep in patients with autism; one found restless sleep (≥once or twice/week) in 77% of patients at baseline, which improved significantly with iron therapy [67] and the other [68] reported a prevalence of restless sleep of 40% among these patients.

Nine studies were observational and had a cross-sectional design and one was a before-after study. All studies were prospective. “Study population, definition and selection” were rated “*good*” in seven reports and “*fair*” in the remaining three, “Soundness of information” was rated either “*good*” or “*fair*” in 40% of papers, “Analysis, comparability and outcomes” were rated “*poor*” in seven reports and “*fair*” in the other three, and “Interpretation and reporting” were rated “*fair*” in 60% of studies and “*good*” in 30% (Table 2).

Sleep-related bruxism and other sleep disorders

Bruxism was the focus of four papers selected for this review (Table 8) [69–72], which reported a prevalence of restless sleep

Table 6
Papers reporting restless sleep in patients with neurologic or psychiatric disorders.

Paper	Patients (sample size), age mean ± SD, range, median, and interquartile range (IQR)	Other group(s)	Method(s)	Definition of restless sleep (RS)	Results/Conclusions
Neurologic conditions					
Esin, 2018 [52]	tension-type headaches (64), 14–15 y		questionnaire	None	RS associated with headaches and improved after treatment
Becker et al., 2003 [53]	epilepsy (14), 10.7 ± 2.2 y	obstructive sleep apnea (OSA) (14), 10.3 ± 2.2 y	questionnaire, polysomnography (PSG)	None	RS in 64.3% of both epilepsy and OSA
Bruni et al., 1999 [54]	migraine (70): A sample (35) 9.3 ± 1.3 y, B sample (35), 10.1 ± 1.6 y	healthy children (893), 10.6 ± 1.3 y, 5.5–14.7 y	questionnaire	None	RS in 34.04% of migraine and 17.41% of healthy children
Psychiatric conditions					
Huhdanpaa et al., 2018 [55]	psychiatric outpatients (139), 69.3 ± 9.1 m	normal controls (139), "sex and age-matched"	questionnaire	None	RS in 31.7% of psychiatric outpatients, significantly higher than in controls
Ivanenko et al., 2006 [56]	psychiatric disorders (174), 10.5 ± 3.6 y, 5–18 y	normal controls (174), 7.2 ± 2.2 y, 5.0–16.1 y	questionnaire	None	RS in 67.8% of psychiatric patients (69.0% of ADHD alone, 78.0% of ADHD with other psychiatric comorbidities, 59.6% of mood and anxiety disorders, 66.6% of other psychiatric disorders) and 23.9% of controls
Mehl et al., 2006 [57]	bipolar mood disturbance (13), 6.7 ± 0.67 y	controls (13), 6.6 ± 0.62 y	questionnaire, cardiovascular monitoring, PSG	None	RS significantly associated with bipolar mood disturbance
Simonds and Parraga, 1984 [58]	psychiatric outpatients (150), 4–18 y	non-clinic sample (309), 4–18 y	questionnaire	moving around in bed a lot	RS more frequent in the clinic sample and more likely to occur in patients having anxiety-affective disorder or conduct disorder

Abbreviations: ADHD = attention-deficit/hyperactivity disorder; IQR = interquartile range; m = months; PSG = polysomnography; RS = restless sleep; y = years.

Table 7
Papers reporting restless sleep in patients with Down syndrome and other neurodevelopmental disorders.

Paper	Patients (sample size), age mean ± SD, range, median, and interquartile range (IQR)	Other group(s)	Method(s)	Definition of restless sleep (RS)	Results/Conclusions
Down's syndrome					
Esbensen and Hoffman, 2018 [59] Esbensen et al., 2018 [60]	Down syndrome (DS) (30), 11.68 ± 2.73 y, 6–17 y		questionnaire, actigraphy	Children's Sleep Habits Questionnaire (CSHQ) item	RS 5–7/week in one third; RS predictive of parent-reports of concerns with inhibitory control, shifting and working memory, and of teacher-reports of inhibitory control
Friedman et al., 2018 [61]	DS (113), age not reported		questionnaire, polysomnography (PSG)	None	parental report of no snoring, apnea, or RS suboptimal to decide execution of a sleep study
Stores and Stores, 2014	DS (31), 8.7 ± 3.3 y, 2.3–16.3 y		questionnaire, actigraphy, cardiovascular monitoring	None	RS in 61% of DS
Dahlqvist et al., 2003 [63]	DS (17), 5.9 ± 2.3 y	siblings (21), 7.0 ± 2.1 y	questionnaire, cardiovascular monitoring, PSG	frequent changes of body position	RS in 64.7% of DS
Attention-deficit/hyperactivity disorder					
Galland et al., 2010 [64]	ADHD (27), mean 10.5 y, 6.6–12.3	controls (27), mean 10.3 y, 6.5–12.2 y	questionnaire, PSG	None	RS in 50% of ADHD and 4% of controls
Chervin et al., 2002 [66]	hyperactive (98), 7.8 ± 3.3 y	not hyperactive (768), 6.6 ± 3.2 y	questionnaire, cardiovascular monitoring, PSG	None	periodic limb movement of sleep (PLMS) score associated with RS score
Greenhill et al., 1983 [65]	ADHD (7), 8.6 ± 1.4 y, 6.7–10.7 y	normal controls (11), 9.3 ± 1.1 y, 8.3–11.8 y	questionnaire	None	RS in 57% of ADHD
Autism					
Dosman et al., 2007 [67]	autism (33), mean 6.5 y, 2.7–10.7 y		questionnaire	Sleep Disturbance Scale for Children item	RS (≥once or twice/week) in 77% of patients, improved significantly with iron therapy
Gail Williams et al., 2004 [68]	autism (201), mean 8.4 y, 2–16 y		questionnaire	None	RS in 40% of autism

Abbreviations: ADHD = attention-deficit/hyperactivity disorder; CSHQ = Childrens Sleep Habits Questionnaire; DS = Down syndrome; IQR = interquartile range; PLMS = periodic limb movements of sleep; PSG = polysomnography; RS = restless sleep; y = years.

Table 8
Papers reporting restless sleep in patients with sleep-related bruxism and other sleep disorders.

Paper	Patients	Other group(s)	Method	Definition of restless sleep (RS)	Conclusions
	(sample size), age mean ± standard deviation, range, median, and interquartile range (IQR)				
Bruxism					
Clementino et al., 2017 [69]	bruxism (48), 2−12 y	no-bruxism (100), 2−12 y	questionnaire	none	RS in 77.1% of bruxism and 53% of no-bruxism
Nahas-Scocate et al., 2014 [70]	bruxism (251), 2.1 −6.9 y	no-bruxism (622), 2.1−6.9 y	Questionnaire	none	RS in 49.8% of bruxism and 30.5% of no-bruxism
Junqueira et al., 2013 [71]	teeth grinding (275), 2.1−6.9 y	no-teeth grinding (662), 2.1−6.9 y	Questionnaire	none	RS in 50.9% of teeth grinding and 28.2% of no-teeth grinding
Serra-Negra et al., 2013 [72]	bruxism (106), 7.6 y, 5 −11 y	no-bruxism (115), 7.6 y, 5−11 y	Questionnaire	none	RS in 73.6% of bruxism and 17.4% of no-bruxism
Other sleep disorders					
Ferrara et al., 2019 [73]	nocturnal enuresis (401), 8.8 ± 2.44 y, 5 −16 y		Questionnaire	none	RS in 5.7% of nocturnal enuresis
Foerster et al., 2019 [74]	mobile phone-related awakenings (843), 10.4 −17.0 y		Questionnaire	none	RS in 37.9% of exposed and 13.2% of non-exposed
Stallman et al., 2017 [75]	sleepwalkers (187), 5 −10 y	non-sleepwalkers (1590), 5−10 y	Questionnaire	none	RS occurring at least once during the previous week in94.5% of sleepwalkers and in 79.7% of non-sleepwalkers

Abbreviations: RS = restless sleep; y = years.

ranging from 49.8% to 77.1%. Other sleep disorders include nocturnal enuresis [73] (restless sleep was found in 5.7% of children), children with mobile phone-related awakenings [74] (restless sleep in 37.9% of subjects), and sleepwalking [75] (restless sleep ≥ once during the previous week in 94.5%).

All seven studies were observational, with a cross-sectional design and prospective. "Study population, definition and selection" for all was rated as good, while "Soundness of information" was rated "*poor*" in 71.4%, "Analysis, comparability and outcomes" were rated "*poor*" in 85.7%, and "Interpretation and reporting" were rated "*fair*" in 42.9% and "*good*" in 57.1% (Table 2).

General population and mixed clinical samples

Fourteen studies assessed restless sleep in the general pediatric population (Table 9) [76−89]. These studies reported a highly variable prevalence of restless sleep, ranging from 6% to 49.6%, probably depending on the variable and often undisclosed/uncertain definition of restless sleep and the study sample recruitment. There was an association of restless sleep with the presence of different types of pain (orofacial pain, temporomandibular dysfunction, headache, and morning headache) [79], night arousal and SDB [82], "a sleep problem" [83], and snoring [84,88]. An early study from 1974 [89] reported restless sleep in 14% of children, caused by "meteorological circumstances". The last four studies of this group [90−93] involved mixed clinical samples of children and reported restless sleep in 9.9%−12.7%.

All studies were observational, 14 had a cross-sectional design and four were cohort studies, 13 were prospective and five were retrospective. "Study population, definition and selection" were rated as "*good*" in all studies, "Soundness of information" was rated "*good*" in 61.1%, "Analysis, comparability and outcomes" were rated "*poor*" in 66.7%, and "Interpretation and reporting" were rated "*fair*" in 33.3% and "*good*" in 66.7% (Table 2).

Miscellaneous conditions/disorders

Finally, 16 additional studies were not included in the above groups and classified as miscellaneous conditions/disorders (see online Supplement).

Quality analysis

The results of the quality analysis of all 107 articles selected for this review are reported in Fig. 2, in the form of a radar graph that shows that the item "Study population, definition and selection" was rated "*good*" in approximately 85% of papers and "*poor*" in a negligible percentage, "Analysis, comparability and outcomes" was graded "*poor*" in 76% of reports and "*good*" in only 7%. "Soundness of information" was rated "*good*" in 53% of cases, "*fair*" in 30% and "*poor*" in 17% of articles. Finally, "Interpretation and reporting" were considered to be "*good*" in 44% of reports, "*fair*" in 53%, and "*poor*" in only 3%. Overall, this analysis shows that the papers retrieved, in general, reported an acceptable ("*good*" of "*fair*") definition of the study population with sufficiently clear subject selection criteria, the soundness of the information provided was sufficiently reliable, and their interpretation and reporting were adequate. The analysis of data carried out in at least three-quarters of these studies appears to be insufficiently accurate.

Discussion

This systematic review comprehensively assessed restless sleep in the pediatric literature and identified a high prevalence in children with SDB, acute otitis media, asthma, pain, bruxism, ADHD, RLS, and periodic leg movements, among other disorders. This finding demonstrates that restless sleep in children is commonly seen in association with other medical or sleep disorders. We also identified publications in which restless sleep improved significantly after an intervention [26] (i.e., adenotonsillectomy).

We can speculate multiple reasons for restless sleep in association with other conditions. One possible explanation is that some conditions, such as obstructive sleep apnea or periodic limb movements of sleep, present with sleep disruption, which manifests as an increased number of arousals or awakenings. Naturally, during arousals or awakenings, one would expect body movements or repositioning that might be interpreted by an observer as restless sleep. For instance, studies have demonstrated sleep architecture changes, decreased sleep efficiency, and increased arousal index in children with RLS, SDB, and asthma [94−96]. Adenotonsillectomy, as a treatment option for SDB, has been shown to

Table 9
Papers reporting restless sleep in children from the general population and from mixed clinical samples.

Paper	Study population (sample size), age mean ± standard deviation or range	Method	Definition of restless sleep (RS)	Conclusions
General population				
Meltzer et al., 2019 [76]	healthy community-dwelling children and adolescents (671), 13.5 ± 2.4 y	actigraphy	activity index, the percent of sleep or wake epochs in the sleep period with >0 activity value	reference values provided, by age group and sex, for "restlessness". Boys with more activity in sleep.
Milanesi et al., 2019 [77]	elementary school children (123), 8.5 ± 1.6 y	questionnaire		RS in 49.6% of children, associated with lower values of peak nasal inspiratory flow
Quach et al., 2018 [78]	kindergarten cohort (4,983), 4.7 ± 0.2 y	questionnaire	none	No data on RS, bidirectional associations were detected between sleep problems and externalizing difficulties
Vierola et al., 2017 [79]	primary-school children (439), 7.6 ± 0.4 y	questionnaire, actigraphy	none	RS in 15.5% of children, associated with orofacial pain, the painful signs of temporomandibular dysfunction, headache, and morning headache
Shanahan et al., 2014 [80]	representative population sample, (1420), 9–16 y	questionnaire	none	weighted prevalence of RS 10.8%
Galbally et al., 2013 [81]	representative population sample, (4507), 6 m	questionnaire	none	RS in 12.1% of children; breastfeeding at 6 mo of age not associated with RS
Biggs et al., 2012 [82]	elementary school children (1,904), 7.7 ± 1.7 y, 5–10 y	questionnaire	none	RS associated to night arousal and sleep disordered breathing
Byars et al., 2012 [83]	mother/child pairs (359), 6–36 m	questionnaire	none	RS emerged as association with report of a sleep problem at 24–36 months
Montgomery–Downs and Gozal, 2006 [84]	community sample (944), two w to two y	questionnaire	none	RS exclusively related to snoring 2 d/wk and ethnicity
Liu et al., 2005a [85]	elementary school children: Chinese (517), 11.0 ± 1.9 y, 7–13 y Untied States (494), 7.56 ± 1.51 y, 4.83–11.00 y	questionnaire	none	RS in 36.3% of Chinese and 35.1% of US children
Liu et al., 2005b [86]	kindergarten and primary school children (5,979), 2–12 y	questionnaire	none	RS in 5% of children
Valery et al., 2004 [87]	community sample (1650), 0–17 y	questionnaire	"Does your child lose sleep?"	RS (≥2/night, past 6 mo) in 6% of children
Smedje et al., 2001 [88]	children at healthcare centre visits (614), 69 ± 4 m, 60–84 m	questionnaire	none	Snoring at baseline associated with a trend towards RS at follow-up
Faust et al., 1974 [89]	pupils and apprentices (1,575), 13–20 y	questionnaire	none	RS in 14% of children, caused by "meteorological circumstances"
Mixed groups				
Heubi et al., 2017 [90]	otolaryngology referrals (1,258), 80.2 ± 62.7 y	questionnaire, polysomnography (PSG)	none	RS as reason of referral in 12.7%.
Veeravigrom and Desudchit, 2016 [91]	clinical sample (136), mode 5 y, 1–17 y	PSG	none	RS in 11.0% of subjects
Lamprecht et al., 2015 [92]	clinical sample (33), median 9 y, 5–16 y	multisite actigraphy, PSG	heuristic approach to actigraphic raw data to detect body shift, hand position change or "random" movement	sleep and wake discrimination improved by RS detection
Reddy et al., 2014 [93]	clinical sample (425), median 10 y, 2 m to 18 y	PSG	none	RS in 9.9% of subjects

Abbreviations: m = months; PSG = polysomnography; RS = restless sleep; y = years.

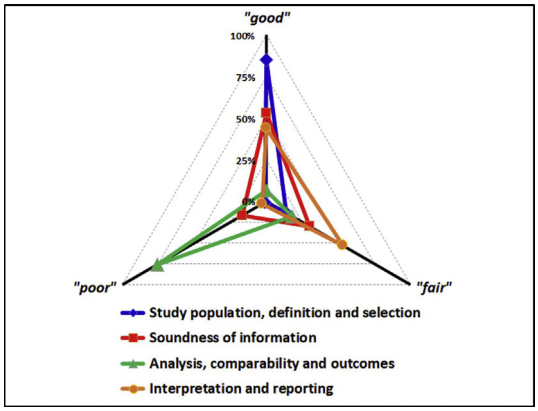

Fig. 2. Results of the article study quality analysis.

increase both sleep efficiency and slow-wave sleep in children, which can be the mechanism that explains why perceived restless sleep improves after surgery [97]. Another possible explanation for restless sleep in medical conditions is sleep instability, although studies on cyclic alternating pattern in children are scarce. Finally, another reason could be a misperception by the caregiver, as the majority of studies questioned if restless sleep was present but did not attempt to provide an objective measure. In fact, the majority of studies did not define restless sleep but instead relied on the parent's or caregiver's interpretation. Furthermore, in many studies, the words "restless sleep" were part of a questionnaire without explanation or definition. Only 34 studies defined restless sleep further.

Four studies [2,42–44] proposed restless sleep as an independent sleep disorder, providing a definition, as well as polysomnographic data and diagnostic criteria [2,44]. This primary form of restless sleep was called "restless sleep disorder" and the diagnostic criteria proposed included video-polysomnographic evidence of five or more movements per hour of sleep, evidence for significant impairment, and lack of another medical problem, sleep disorder, or substance that can be established as a potential cause for restless sleep [102].

Although treatment options for secondary restless sleep were based on the treatment of the underlying condition, publications highlighting treatment options for primary RSD are scarce except for two studies suggesting oral iron supplementation [43,98]. A recently published study has shown clinical improvement of RSD in children after oral (ferrous sulfate) and intravenous (ferric carboxymaltose) iron supplementation [98]. Iron is a cofactor in the synthesis of various neurotransmitters, particularly dopamine, and iron deficiency is associated with some sleep-related movement disorders such as RLS and PLMD [99].

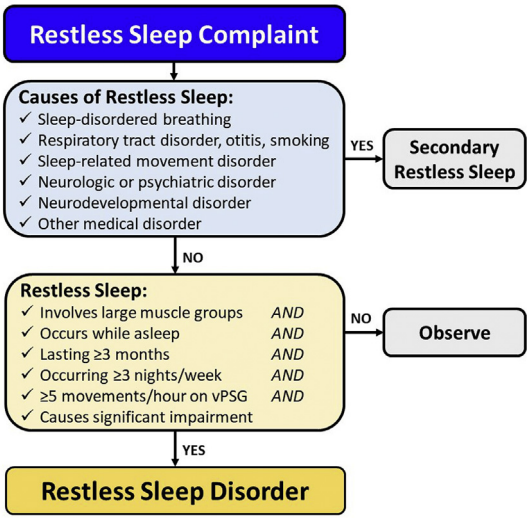

Fig. 3. Algorithm for the evaluation of restless sleep. vPSG = video-polysomnography.

Few studies assessed restless sleep in children from community- or school-based populations (Table 9). In one study, actigraphy was used to identify activity during sleep in community-dwelling children [76]. The range of the activity index was wide (14–74%) but sleep disorders were not excluded in about two-thirds of cases. Furthermore, studies using questionnaires showed a wide prevalence of restless sleep (5–35%), but even in these "normal" children, restless sleep was still associated with pain [79], nasal airway resistance [77], or "meteorological circumstances" [89]. The challenges to develop normative data for restless sleep in a large population include undiagnosed conditions and diverse environments.

Although the quality of the studies was heterogeneous, the majority of studies were considered to be of good quality, particularly concerning the study populations (Fig. 2). Analysis and outcomes were considered the weakest points of the majority of studies, while interpretation and soundness of information were considered good to fair.

In summary, restless sleep can present in association with many conditions. The clinician should rule out potential medical or environmental causes of restless sleep and address the primary cause. If secondary causes are not identified, a primary restless sleep disorder can be confirmed demonstrating five or more large body movements per hour by video-polysomnography (Fig. 3). Treatment options for RSD remain to be determined.

Conclusion

Restless sleep is common in children and adolescents. It can be perceived by the parent or caregiver in association with other conditions and can be improved after treating the underlying medical or sleep disorders. Primary restless sleep disorder has been described as a new diagnostic category with specific criteria for its identification.

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Practice points

- Children with restless sleep and a suspected sleep disorder need a polysomnogram to rule out a comorbid sleep condition.
- If a sleep disorder is not suspected but a medical condition is present, such as asthma, otitis media or migraine, treat the underlying condition and reassess restless sleep after improvement of the medical condition.
- Primary restless sleep disorder is diagnosed in the presence of frequent movements during sleep on video-polysomnography associated with significant daytime symptoms in the absence of other causes of restless sleep.
- More research is needed regarding the treatment of children with primary restless sleep disorder.

Research agenda

- To develop objective methods further, which assess restless sleep, including actigraphy, video-polysomnography, and home video.
- To establish better normative data for restless sleep at various ages.
- To determine the contribution of restless sleep to daytime symptomatology with neurocognitive studies and other methods.
- To study the natural history of restless sleep across the lifespan, including in adult and elderly populations.
- To understand the pathophysiology of and develop treatment options for restless sleep disorder (RSD).

Conflicts of interest

The authors do not have any conflicts of interest to disclose.

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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.2020.101406.

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