

# **Association of allergic rhinitis with obstructive sleep apnea** A meta-analysis

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### Abstract

**Background:** The co-existence of allergic rhinitis (AR) and obstructive sleep apnea (OSA) is a common phenomenon in clinical practice. AR has long been considered a risk factor for OSA. However, the relationship is not completely clear. Therefore, we conducted a meta-analysis to evaluate the prevalence of AR in sleep-disordered breathing (SDB) /OSA and their relationship.

**Methods:** A comprehensive literature search was performed in PubMed/Medline, Google Scholar, Wiley Online Library, EMBASE, and Web of Science. Data were analyzed and pooled to estimate effect size (ES) /odds ratio (OR) with 95% confidence intervals (95% CI). Heterogeneity was quantified and evaluated by chi-squared-based Q-test and I2 test, with P < .05 and  $I^2 > 50\%$  indicating evidence of heterogeneity.

**Results:** 44 studies contained 6086 participants were included in this meta-analysis. For adults, the prevalence of AR was 22.8 (95% Cl, 15.0–30.6) % in SDB and 35.2 (95% Cl, 25.6–44.7) % in OSA. In children with SDB and OSA, the prevalence of AR was 40.8 (95% Cl, 24.3–57.2) %, and 45.2 (95% Cl, 25.4–65.0) % respectively. The odds ratios of prevalence of the SDB pediatric patients with AR was 2.12 (95% Cl, 1.75, 2.57; *P* < .0001) times higher than that of non-SDB pediatric patients. There were no significant differences between OSA adults with or without AR in BMI (Body Mass Index), neck circumference, apnea hypopnea index (AHI) and epworth sleep scale score (ESS).

**Conclusion:** The prevalence of AR in OSA/SDB is considerably high and children with SDB suffering from a higher incidence of AR than non-SDB. OSA adults accompanied with AR do not have any influences on sleep parameters.

**Abbreviations:** AH = adenotonsillar hypertrophy, AHI = apnea hypopnea index, AR= allergic rhinitis, BMI = body mass index, CI = confidence intervals, CPAP = continuous positive airway pressure, cysLTs = cysteinyl leukotriene, ES= estimate effect size, ESS = Epworth Sleep Scale Score, IgE = immunoglobulin E, IL-1 $\beta$ = interleukin-1 $\beta$ , IL-4 = interleukin-1, INCS = intranasal corticosteroids, OR = odds ratio, OSA= obstructive sleep apnea, PRISRM = Preferred Reporting Items for Systematic Reviews and Meta-analysis, PSG = polysomnography, SDB= sleep-disordered breathing, Th2 = T helper 2 lymphocyte.

Keywords: allergic rhinitis, apnea hypopnea index, body mass index, Epworth Sleep Scale score, meta-analysis, obstructive sleep apnea

### 1. Introduction

Obstructive sleep apnea (OSA) is the most common sleepdisordered breathing (SDB). The prevalence of OSA in healthy children and adults was as high as 1% to 5% and 3.5% to 20.4%, respectively, and it was even higher for SDB.<sup>[1–4]</sup> OSA is characterized by prolonged partial upper airway obstruction and/ or intermittent complete obstruction. It disrupts normal ventilation and patterns during sleep.<sup>[1]</sup> Moreover, these breathing

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For this type of study formal consent is not required.

Ethical approval and informed consent were not suitable for this study.

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disorders may increase the risks of complications of cardiovascular, neurocognitive, and metabolic morbidities.<sup>[5]</sup> Allergic diseases, allergic rhinitis (AR), asthma, and eczema are common among individuals. AR is a very common disease that affects 10% to 40% of the global population.<sup>[6]</sup> With the increasing exposure to allergens and pollutants, the prevalence of AR has increased over the past few decades.<sup>[7]</sup> Since it usually leads to nasal obstruction and increased upper airway resistance, AR has long been recognized as a risk factor of OSA in previous studies.<sup>[8–10]</sup> Some articles have reviewed the association between AR and SDB in children. However, no meta-analysis was obtained from databases. Therefore, in view of this scenario, we conducted a meta-analysis to explore and summarize the prevalence and association between OSA and AR in order to gain a deeper insight of these 2 diseases.

## 2. Materials and methods

We performed this meta-analysis in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.<sup>[11]</sup>

#### 2.1. Literature search

In accordance with the PRISMA guidelines, we identified relevant research articles through a systematic review of scientific databases (PubMed /Medline, Google Scholar, Wiley Online Library, Embase, and Web of Science). The MeSH and keywords used in different logical combinations and phrases were: allergic rhinitis, allergic rhino conjunctivitis, hay fever, nasal allergy, OSA, apnea, hypopnea, Epworth Sleepiness Scale (ESS), apneahypopnea index (AHI), SDB, sleep-associated breathing disorder, sleep-related disordered breathing, snoring. The search encompassed original research papers published by July 1, 2017 in online journals in English language.

#### 2.2. Inclusion and exclusion criteria

Inclusion criterion was clinical or epidemiological studies which examined the relationship between AR and sleep disorders and reported the prevalence of AR in OSA or SDB patients. Studies were excluded from the meta-analysis if reported only the sleep quality measures other than OSA or SDB, or provided qualitative information only. Other studies that were excluded include review article, conference abstract, article not published in English, animal study, case report, article with no abstract/full text available.

#### 2.3. Data extraction

The following data were extracted from each eligible study: participants' demographic and clinical characteristics, the prevalence of AR in OSA (diagnosed with sleep studies according to guidelines),<sup>[1,12]</sup> and SDB (one or more abnormal/difficulty breathing during sleep and/or gas exchange patterns during sleep including habitual snoring 3 or more times per week) patients, body mass index (BMI), neck circumference, AHI and ESS score, and other relevant information were obtained from the selected research articles of the respective studies and organized on data sheets. To ensure the quality of the meta-analysis, all eligible publications were reviewed by 2 researchers independently according to the standardized approach and later cross checked the work of each other. The final selection of a study for inclusion in the meta-analysis was reached in consensus.

#### 2.4. Statistical analyses

Random effects meta-analyses were performed with STATA 12.0 (Stata Inc. Texas) to achieve overall effect sizes of the prevalence of AR in OSA and SDB patients and to achieve a summary estimate of the odds ratio of the prevalence of AR between OSA/SDB and non-OSA/SDB patients observed in the individual



Figure 1. Flowchart of study screening and selection process.

#### Table 1

Characteristics of the included studies.

		Study	n	Diagnosis tool	Design	Age, years	BMI	Male (%)	Country
2         Auntescree 2001         85         Questionnaire/PSG         Epidemiological study         7.36-2.065         —         65.5         Tmailand           3         Bengtsson 2014         88         Questionnaire/PSG         Clinical study         50.1 ± 11.3         26.7 ± 5.0         0.0         Sweden           4         Bhattachapte 2010         537         PSG         Clinical study         44.2 ± 11.4         29.9 ± 5.0         66.7         Turkey           6         Broulistite 2001         25         PSG         Clinical study         10.1         10         0         2.6         79.4         Swetzerand           7         Carova 2004         72         PSG         Clinical study         47.2 ± 10.6         78.5         Tmailand           10         Chrag 2014         50         PSG         Clinical study         47.2 ± 10.8         7.3 ± 2.4 ± 6.6         60.3         Turkey           11         Ersu 2004         151         Questionnaire         Epidemiological survey         Range, 6-13         60.3         Survey         8.3 ± 4.2 ± 5.6         60.3         Turkey           12         Fabra 2014         54         PSG         Clinical study         6.4 ± 2.5.6         60.4 ± 2.5.6         60.2         <	1	Abdullah 2012	82	Questionnaire	Epidemiological study	8.7±1.1	$16.6 \pm 7.6$	68.3	Malaysia
3         Bergtson 2014         88         Ouestionnaire/PSG         Olincal study         50.1 $\pm$ 1.1.3         26.7 $\pm$ 5.0         0.0         Sweden           4         Bhattachagie 2010         537         PSG         Retrospective study         6.9 $\pm$ 3.8         61.4         United States,           5         Boxurt 2017         To         PSG         Clinical study         11.0         56.0         Carada           7         Carova 2004         72         PSG         Case control study         60.7         frange, 61.0         82.4 $\pm$ 6.6         79.4         Switzerland           9         Chiaral 214         50         PSG         Retrospective study         47.2 $\pm$ 10.6         78.5         Trainago           9         Chiaral 214         50         PSG         Clinical study         47.4 $\pm$ 5.9         28.4 $\pm$ 3.6         82.8         Brazil           12         Fabro 2016         135         PSG         Clinical study         6.4 $\pm$ 2.55 (Range, 3-14)         15.2 $\pm$ 2.4         61.5         Brazil           12         Fabro 2016         97         PSG         Cross-sectional study         43.4 $\pm$ 1.7.4         30.4         United States,           12         Fabro 2016         97         PSG	2	Anuntaseree 2001	85	Questionnaire/PSG	Epidemiological study	$7.36 \pm 0.65$		56.5	Thailand
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14       Gadi 2014       54       PSG       Cross-sectional study $49.3 \pm 13.42$ $38.5 \pm 12.63$ $58.6$ Saudi Arabia         16       Gadi 2016       97       PSG       Cross-sectional study $45.3 \pm 13.5$ $37.4 \pm 15.6$ $61.2$ Saudi Arabia         16       Gupta 2009       20       Questionmaire       Clinical study $55 \pm 16$ $34 \pm 6$ $72.5$ Australia         17       Helgren 2009       20       PSG       Clinical study $7.8 \pm 0.56$ $11.99 \pm 0.47$ $63.8$ China         19       Husen 2014       45       PSG       Retrospective cross-sectional study $7.9 \pm 2.6$ $70.0$ Korea         20       Kim 2011       19       PSG       Clinical study $7.7$ (range, $3-16$ ) $17.5 \pm 3.0$ $86.6$ Korea         22       Kranz 2001       00       Questionmaire       Epidemiological study $53 \pm 11.9$ $31.9 \pm 6.4$ Finland         24       Larsson 2001       1064       Questionmaire/PSG       Epidemiological study $12.05 \pm 0.76$ $24.88 \pm 2.68$ $57.1$ Hong Kong, China         25       Li 2007       14       PSG       Clinical study	13	Francesco 2016	135	PSG	Clinical study	6.44±2.55 (Range, 3–14)	15.2±2.4	61.5	Brazil
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16Gupta 200923QuestionnaireClinical study $8.3 \pm 4.7$ $30.4$ United States17Helgren 200920PSGClinical study $55 \pm 16$ $34 \pm 6$ $72.5$ Australia18Huang 201647PSGClinical study $7.84 \pm 0.56$ $11.95 \pm 0.47$ $63.8$ China19Huseni 2014145PSGRetrospective cross-sectional study $6.26 \pm 3.1$ $20.4 \pm 6.3$ $62.0$ United States20Kim 201119PSGClinical study $7.9 \pm 2.6$ $7.0$ Korea21Kim 201570QuestionnaireObservational cohort study $7.7$ (range, $3-16$ ) $17.5 \pm 3.0$ $68.6$ Korea22krame 200190PSGCohort studyAverage 58.3Average 28.9 $85.9$ Germany24karson 20011064QuestionnaireEpidemiological study20 to 69 $50.5$ Sweden25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chin28ki 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chin29Ma 201186PSGRetrospective study $8\pm 3.1$ $80.2$ Hong Kong, Chin29Ma 201186PSGRetrospective study $5.2 \pm 2.1$ $61$	15	Gadi 2016	97	PSG	Cross-sectional study	$45.3 \pm 13.5$	37.4±15.6	61.2	Saudi Arabia
17Heligren 200920PSGClinical study $55\pm16$ $34\pm6$ $72.5$ Australia18Huang 201647PSGClinical study $7.84\pm0.56$ $11.95\pm0.47$ $63.8$ China19Huseni 2014145PSGRetrospective cross-sectional study $7.9\pm2.6$ 70.0Korea21Kim 201570QuestionnaireObservational cohort study $7.7$ (range, $3-16$ ) $17.5\pm3.0$ $68.6$ Korea23Kraiv 201190PSGCohort studyAverage 58.3Average 28.9 $85.9$ Germany23Kreiv 201290QuestionnaireEpidemiological study $20 to 69$ $50.5$ Sweden24Larsson 20011064QuestionnaireEpidemiological study $12.05\pm0.76$ $24.88\pm2.68$ $57.1$ Hong Kong, Chin24Larsson 2001164Questionnaire/PSGEpidemiological study $11\pm1.1$ $23.4\pm3.4$ $68.3$ Hong Kong, Chin25Li 2013161Questionnaire/PSGEpidemiological study $11\pm1.7$ $18.0\pm3.1$ $67.6$ Hong Kong, Chin29Ma 201186PSGRetrospective study $8\pm3.1$ $80.2$ Hong Kong, Chin20Nigro 201190PSGClinical study $49.6\pm15.1$ $29.1\pm2.1$ $77.0$ Argentina31Nigro 201190PSGRetrospective study $45.2\pm2.1$ $63.6$ Hong Kong, Chin26sha 2015415PSGRetrospective study $5$	16	Gupta 2009	23	Questionnaire	Clinical study	$8.3 \pm 4.7$		30.4	United States
18       Huag 2016       47       PSG       Clinical study $7.84\pm0.56$ $11.95\pm0.47$ $63.8$ China         19       Huseni 2014       145       PSG       Retrospective cross-sectional study $7.9\pm2.6$ 70.0       Korea         21       Kim 2015       70       Questionnaire       Observational cohort study $7.7$ (range, 3-16) $17.5\pm3.0$ $68.6$ Korea         21       Kramer 2001       90       PSG       Cohort study       Average 58.3       Average 28.9 $85.9$ Germany         23       Kreivi 2012       290       Questionnaire/PSG       Epidemiological study $20 to 69$ $50.5$ Sweden         24       Larsson 2001       104       Questionnaire       Epidemiological study $11\pm1.1$ $23.4\pm3.4$ $68.3$ Hong Kong, Chin         25       Lavigne 2013       55       PSG       Clinical study $11\pm1.1$ $23.4\pm3.4$ $68.3$ Hong Kong, Chin         28       Li 2013       161       Questionnaire/PSG       Epidemiological study $10.1\pm1.7$ $18.0\pm3.1$ $67.6$ Hong Kong, Chin         29       Na 2011       86       PSG       Retrospective study $84\pm3.$	17	Hellgren 2009	20	PSG	Clinical study	$55 \pm 16$	$34 \pm 6$	72.5	Australia
19Husen2014145PSGRetrospective cross-sectional study $6.26 \pm 3.1$ $20.4 \pm 6.3$ $62.0$ United States20Kim 201119PSGClinical study $7.9 \pm 2.6$ 70.0Korea21Kim 201570QuestionnaireObservational cohort study $7.7$ (range, 3-16) $17.5 \pm 3.0$ $68.6$ Korea22Krawr 200190PSGCohort studyAverage 58.3Average 28.9 $85.9$ Germany23Kreivi 2012290QuestionnaireEpidemiological study $53 \pm 11.9$ $31.9 \pm 6.4$ Finland24Larsson 20011064QuestionnaireEpidemiological study $20 \text{ to } 69$ $50.5$ Sweden25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Conada26Li 200714PSGClinical study $11.\pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, Chin:27Li 200847PSGClinical study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chin:29Ma 201186PSGRetrospective study $8\pm 3.1$ $80.2$ Hong Kong, Chin:20Ni 2015127PSGClinical studyRange, $3-6$ China21Nigor 201190PSGClinical study $43.4 \pm 13.4$ $29.1 \pm 2.1$ $70.0$ Argentia28kao 2015415PSGRetrospective study $5.2 \pm 2.1$ $63.3$ Portugal	18	Huang 2016	47	PSG	Clinical study	$7.84 \pm 0.56$	$11.95 \pm 0.47$	63.8	China
20Kim 201119PSGClinical study $7.9\pm 2.6$ $70.0$ Korea21Kim 201570QuestionnaireObservational cohort study $7.7$ (range, $3-16$ ) $17.5\pm 3.0$ $68.6$ Korea22Kramer 200190PSGCohort studyAverage 58.3Average 28.9 $85.9$ Germany23Kreivi 2012290Questionnaire/PSGEpidemiological study $53\pm 11.9$ $31.9\pm 6.4$ Finland24Larsson 20011064QuestionnaireEpidemiological study $20$ to $69$ $50.5$ Sweden25Laiyine 201355PSGProspective study $46\pm 9.2$ $28.9\pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $10.1\pm 1.7$ $18.0\pm 3.1$ $67.6$ Hong Kong, Chin28Li 2013161Questionnaire/PSGEpidemiological study $10.1\pm 1.7$ $18.0\pm 3.1$ $67.6$ Hong Kong, Chin29Ma 201186PSGRetrospective study $8\pm 3.1$ $80.2$ Hong Kong, Chin20Ni 2015127PSGClinical studyRange, $3-6$ China21Nigro 201190PSGClinical study $45.2\pm 2.1$ $61.3$ 21Nigro 201190PSGRetrospective study $5.2\pm 2.1$ $61.3$ 23Rance 200693PSGRetrospective study $5.2\pm 2.1$ $61.3$ 34Shao 2015415PSGRetrospective study $5.2\pm 2.6$ $80.2\pm$	19	Huseni 2014	145	PSG	Retrospective cross-sectional study	$6.26 \pm 3.1$	$20.4 \pm 6.3$	62.0	United States
21Kim 201570QuestionnaireObservational cohort study7.7 (range, 3-16) $1.7.5 \pm 3.0$ $68.6$ Korea22Kramer 200190PSGCohort studyAverage 58.3Average 28.9 $85.9$ Germany23Kreivi 2012290Questionnaire/PSGEpidemiological study $20$ to 69 $50.5$ Sweden24Larsson 2011106QuestionnaireEpidemiological study $20$ to 69 $50.5$ Sweden25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $63.3$ Hong Kong, Chin.28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chin.28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $80.2$ Hong Kong, Chin.29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, Chin.21Nigro 201190PSGClinical study $49.6 \pm 15.1$ $29.1 \pm 2.1$ $7.0$ Agentina20Park 2012112PSGObservational cohort study $5.2 \pm 2.1$ $61.3$ Portugal21Nigro 201190PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal23Ramos 200693PSGRetrospective study $5.2 \pm 2.$	20	Kim 2011	19	PSG	Clinical study	$7.9 \pm 2.6$		70.0	Korea
22Kramer 200190PSGCohort studyAverage 58.3Average 28.985.9Germany23Kreivi 2012290Questionnaire/PSGEpidemiological study $53 \pm 11.9$ $31.9 \pm 6.4$ Finland24Larsson 20011064QuestionnaireEpidemiological study $20$ to 69 $50.5$ Sweden25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, Chinz28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chinz29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, Chinz29Ma 201190PSGClinical studyRange, 3-6Clinical study $49.6 \pm 15.1$ $29.1 \pm 2.1$ $77.0$ Argentina20Park 2012112PSGObservational cohort study $45.7 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China31Nigro 2015415PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal34Shao 2015415PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal35Sin 201430PSGRetrospective study $5.2 \pm 2.1$ $63.6$ Turkey35Sin 201430PSGRetrospective study $5.2 \pm 3$ $63.6$ <	21	Kim 2015	70	Questionnaire	Observational cohort study	7.7 (range, 3–16)	$17.5 \pm 3.0$	68.6	Korea
23Kreivi 2012290Questionnaire/PSGEpidemiological study $53 \pm 11.9$ $31.9 \pm 6.4$ Finland24Larsson 20011064QuestionnaireEpidemiological study20 to 69 $50.5$ Sweden25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $12.05 \pm 0.76$ $24.88 \pm 2.68$ $57.1$ Hong Kong, China27Li 200847PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, China29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, China29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, China20Ni 2015127PSGClinical studyRange, 3-6China21Nigro 201190PSGClinical study $44.1 \pm 13.4$ (range, 20-68) $26.0 \pm 4.0$ $8.9$ 24Shao 2015415PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal34Shao 2015415PSGRetrospective study $5.2 \pm 3$ $63.6$ Turkey37Sogut 200539Questionnaire/PSGCross-sectional study $5.3 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China38Su 201742PSGRetrospective study $45.1 \pm 1.52$ (average, 12-17) $48.7$ Turkey38Su 201742PSG <td>22</td> <td>Kramer 2001</td> <td>90</td> <td>PSG</td> <td>Cohort study</td> <td>Average 58.3</td> <td>Average 28.9</td> <td>85.9</td> <td>Germany</td>	22	Kramer 2001	90	PSG	Cohort study	Average 58.3	Average 28.9	85.9	Germany
24Larsson 20011064QuestionnaireEpidemiological study20 to 6950.5Sweden25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $12.05 \pm 0.76$ $24.88 \pm 2.68$ $57.1$ Hong Kong, Chin.27Li 200847PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, Chin.28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chin.29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, Chin.30Ni 2015127PSGClinical studyRange, 3-6China31Nigro 201190PSGObservational cohort study $44.1 \pm 13.4$ (range, 20-68) $26.0 \pm 4.0$ $83.9$ 32Park 2012112PSGObservational cohort study $45.7 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China33Ramos 200693PSGRetrospective study $5.2 \pm 2.1$ $63.6$ Turkey34Shao 2015415PSGRetrospective study $5.2 \pm 2.1$ $63.6$ Turkey35Sin 201430PSGRetrospective study $5.2 \pm 2.1$ $63.6$ Turkey36Sogut 200539QuestionnaireCross-sectional study $5.4$ $81.2 \pm 3.5$ (range, $22.37$ )Finland37Sog	23	Kreivi 2012	290	Questionnaire/PSG	Epidemiological study	53 + 11.9	31.9+6.4		Finland
25Lavigne 201355PSGProspective study $46 \pm 9.2$ $28.9 \pm 5.2$ $61.9$ Canada26Li 200714PSGClinical study $12.05 \pm 0.76$ $24.88 \pm 2.68$ $57.1$ Hong Kong, Chinz27Li 200847PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, Chinz28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, Chinz29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, Chinz30Ni 2015127PSGClinical studyRange, 3-6China31Nigro 201190PSGClinical study $49.6 \pm 15.1$ $29.1 \pm 2.1$ $77.0$ Argentina32Park 2012112PSGObservational cohort study $44.1 \pm 13.4$ (range, 20-68) $26.0 \pm 4.0$ $83.9$ Korea33Ramos 200693PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal34Shao 2015415PSGRetrospective study $45.7 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China36Sogut 200539Questionnaire/PSGCross-sectional study $5\pm 3$ $63.6$ Turkey38Su 201742PSGEpidemiological study $53.8 \pm 11.8$ $27.6 \pm 5.1$ $65.5$ Finland41Vuorjoki 2013142QuestionnaireClinical study $53.8 \pm 11.4$ $27.6 \pm 6.82$ <td>24</td> <td>Larsson 2001</td> <td>1064</td> <td>Questionnaire</td> <td>Epidemiological study</td> <td>20 to 69</td> <td></td> <td>50.5</td> <td>Sweden</td>	24	Larsson 2001	1064	Questionnaire	Epidemiological study	20 to 69		50.5	Sweden
26Li 200714PSGClinical study $12.05 \pm 0.76$ $24.88 \pm 2.68$ $57.1$ Hong Kong, China27Li 200847PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, China28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, China29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, China30Ni 2015127PSGClinical studyRange, $3-6$ China31Nigro 201190PSGClinical study $49.6 \pm 15.1$ $29.1 \pm 2.1$ $77.0$ 32Park 2012112PSGObservational cohort study $44.1 \pm 13.4$ (range, $20-68$ ) $26.0 \pm 4.0$ $83.9$ Korea33Ramos 200693PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal34Shao 2015415PSGRetrospective study $45.7 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China35Sin 201430PSGRetrospective study $5.3$ $63.6$ Turkey36Sogut 200539Questionnaire/PSGCross-sectional study $5.43$ $63.6$ Turkey37Sogut 200941QuestionnaireCross-sectional study $3.8 \pm 11.8$ $27.6 \pm 5.1$ $65.5$ Finland41Vuorjoki 2013142QuestionnaireClinical study $44 \pm 8.9$ (range, $26-62$ ) $28.1 \pm 3.5$ (range, $22-37$ ) <td>25</td> <td>Lavigne 2013</td> <td>55</td> <td>PSG</td> <td>Prospective study</td> <td>46 + 9.2</td> <td>28.9 + 5.2</td> <td>61.9</td> <td>Canada</td>	25	Lavigne 2013	55	PSG	Prospective study	46 + 9.2	28.9 + 5.2	61.9	Canada
27Li 200847PSGClinical study $11 \pm 1.1$ $23.4 \pm 3.4$ $68.3$ Hong Kong, China28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, China29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, China30Ni 2015127PSGClinical studyRange, $3-6$ China31Nigro 201190PSGClinical study $49.6 \pm 15.1$ $29.1 \pm 2.1$ $77.0$ Argentina32Park 2012112PSGObservational cohort study $44.1 \pm 13.4$ (range, $20-68$ ) $26.0 \pm 4.0$ $83.9$ Korea33Ramos 200693PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal34Shao 2015415PSGRetrospective study $45.7 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China35Sin 201430PSGRetrospective study $13.8 \pm 2.6$ (range, $8-17$ ) $38.9 \pm 10.5$ $70.0$ United States36Sogut 200539QuestionnaireCross-sectional study $5\pm 3$ $63.6$ Turkey37Sogut 200941QuestionnaireCross-sectional study $33.8 \pm 1.6$ $(range, 26-62)$ $28.1 \pm 3.5$ (range, 22-37)Finland39Virkkula 200941PSGClinical study $44 \pm 8.9$ (range, 26-62) $28.1 \pm 3.5$ (range, 22-37)Finland41Vuorjoki 2013142Questionnaire <td>26</td> <td>Li 2007</td> <td>14</td> <td>PSG</td> <td>Clinical study</td> <td><math>12.05 \pm 0.76</math></td> <td><math>24.88 \pm 2.68</math></td> <td>57.1</td> <td>Hong Kong, China</td>	26	Li 2007	14	PSG	Clinical study	$12.05 \pm 0.76$	$24.88 \pm 2.68$	57.1	Hong Kong, China
28Li 2013161Questionnaire/PSGEpidemiological study $10.1 \pm 1.7$ $18.0 \pm 3.1$ $67.6$ Hong Kong, China29Ma 201186PSGRetrospective study $8 \pm 3.1$ $80.2$ Hong Kong, China30Ni 2015127PSGClinical studyRange, $3-6$ China31Nigro 201190PSGClinical study $49.6 \pm 15.1$ $29.1 \pm 2.1$ $77.0$ Argentina32Park 2012112PSGObservational cohort study $44.1 \pm 13.4$ (range, $20-68$ ) $26.0 \pm 4.0$ $83.9$ Korea33Ramos 200693PSGRetrospective study $5.2 \pm 2.1$ $61.3$ Portugal34Shao 2015415PSGRetrospective study $45.7 \pm 11.4$ $27.4 \pm 3.4$ $87.2$ China35Sin 201430PSGRetrospective study $13.8 \pm 2.6$ (range, $8-17$ ) $38.9 \pm 10.5$ $70.0$ United States35Sogut 200539QuestionnaireCross-sectional study $5\pm 3$ $63.6$ Turkey37Sogut 200941QuestionnaireCross-sectional study $3.8 \pm 11.8$ $27.6 \pm 5.1$ $65.5$ Finland40Vuorjoki 2013142QuestionnaireClinical study $44 \pm 8.9$ (range, $26-62$ ) $28.1 \pm 3.5$ (range, $22-37$ )Finland41Vuorjoki 2013142QuestionnaireRetrospective studyAdults $67.0$ Finland42Weinstock 2013223QuestionnaireClinical study </td <td>27</td> <td>Li 2008</td> <td>47</td> <td>PSG</td> <td>Clinical study</td> <td>11 + 1.1</td> <td>23.4 + 3.4</td> <td>68.3</td> <td>Hong Kong, China</td>	27	Li 2008	47	PSG	Clinical study	11 + 1.1	23.4 + 3.4	68.3	Hong Kong, China
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43 Wirasinghe 201045QuestionnaireClinical study $44 \pm 13$ $27.62 \pm 8.82$ $66.7$ Sri Lanka44 Zhang 201693PSGClinical study $5.2 \pm 1.9$ $82.8$ China	42	Weinstock 2013	223	Questionnaire/PSG	Cross-sectional study	7.08+1.42		49.6	United States
44 Zhang 2016 93 PSG Clinical study 5.2±1.9 82.8 China	43	Wirasinghe 2010	45	Questionnaire	Clinical study	$44 \pm 13$	$27.62 \pm 8.82$	66.7	Sri Lanka
	44	Zhang 2016	93	PSG	Clinical study	$5.2 \pm 1.9$	—	82.8	China

PSG = polysomnography.

studies. The significance of differences in BMI, neck circumference, AHI, and ESS between OSA/SDB patients with and without AR were carried out by STATA 12.0 with under random effects model. Heterogeneity was quantified and evaluated by the chi-squared-based Q-test and  $I^2$  test, with P < .05 and  $I^2 > 50\%$ indicating evidence of heterogeneity.

#### 3. Results

Data were acquired from 44 studies  $[^{[8,13-56]}$  (6086 patients) which fulfilled the eligibility criteria (Fig. 1). Important characteristics of the included studies are presented in Table 1. Average age of adult SDB patients was  $47.97 \pm 4.00$  years and  $7.73 \pm 3.34$  years for SDB children. Proportion of males in this sample population was  $68.55 \pm 20.85\%$  in adults and  $62.09 \pm$ 

12.17% in children. In adult SDB and OSA patients, the prevalence of AR was 22.8 (95%CI, 15.0–30.6)%, and 35.2 (95%CI, 25.6–44.7)%, respectively (Fig. 2A). In children SDB and OSA patients, the prevalence of AR was 40.8 (95%CI, 24.3–57.2)% and 45.2 (95%CI, 25.4–65.0)%, respectively (Fig. 2B). The overall prevalence of AR (in SDB and OSA) was 41.6 (95% CI, 23.1–60.1)% in Asia, and 33.5 (95%CI, 25.3–41.6)% in other continents (Europe, Oceania, and America, Fig. S1, http:// links.lww.com/MD/C714). Pooling analysis of odds ratios observed in the children's studies showed that the prevalence of the AR was 2.12 (95%CI, 1.75, 2.57; P<.0001) times higher in SDB patients than in non-SDB patients (Fig. 3A). However, in adult studies, the prevalence of AR showed no significant difference between SDB/OSA patients and non-SDB/non-OSA patients (P=.082; P=.078, Fig. 3B). In adults, there was no

Study Adults ID	ES (95% CI)	% Weight
1 SDB		
Virkkula 2009	0.15 (0.04, 0.25)	14.68
Larsson 2001		20.18
Bengtsson 2014	0.22 (0.18, 0.26)	19.36
Vuorjoki 2014	0.28 (0.19, 0.37)	16.31
Wirasinghe 2010	0.42 (0.28, 0.57)	12.04
Vuorjoki 2013	0.25 (0.18, 0.33)	17.44
Subtotal (I-squared = 91.2%, p = 0.000)	0.23 (0.15, 0.31)	100.00
2 OSA		
Bozkurt 2016	0.37 (0.29, 0.44)	8.00
Canova 2004	0.11 (0.04, 0.18)	8.04
Fabbro 2014	0.31 (0.14, 0.48)	6.69
Gadi 2014	0.48 (0.35, 0.61)	7.25
Gadi 2016	<u> </u>	7.73
Hellgren 2009	0.20 (0.02, 0.38)	6.58
Kramer 2001	0.13 (0.06, 0.20)	8.07
Lavigne 2013	0.62 (0.49, 0.75)	7.33
Nigro 2011,2012	0.24 (0.16, 0.33)	7.86
Park 2012	0.33 (0.24, 0.42)	7.88
Shao 2015	0.38 (0.34, 0.43)	8.27
Kreivi 2012	0.61 (0.56, 0.67)	8.20
Chierakul 2007	0.25 (0.19, 0.32)	8.09
Subtotal (I-squared = 94.4%, p = 0.000)	0.35 (0.26, 0.45)	100.00
NOTE: Weights are from random effects analysis		

Figure 2. (A) Forest graph showing the percent prevalence of AR in SDB and OSA children. (B) Forest graph showing the percent prevalence of AR in SDB and OSA adults. AR= allergic rhinitis, OSA= obstructive sleep apnea, SDB= sleep-disordered breathing.

significant difference between OSA with AR and OSA without AR in BMI (mean difference: -0.19 [95%CI, -0.45-0.07]; P=.149), neck circumference (mean difference: 0.16 [95%CI, -0.11-0.42]; P=.245), AHI (mean difference: -0.52 [95%CI, -1.79-0.74]; P=.416), or ESS (mean difference: 0.21 [95%CI, -0.15-0.58]; P=.246, Fig. S2, http://links.lww.com/MD/C714).

#### 4. Discussion

Nasal obstruction had long been considered as one of the leading risk facts for the upper airway obstruction during the sleep. Further, some clinical studies had found that patients with nasal congestion caused by AR were more susceptible to disturbed sleep.<sup>[57–59]</sup> Rhinorrhea, nasal blockage, or congestion always led to stuffy nose, which were the most complained symptoms of AR patients.<sup>[60]</sup> The nasal obstruction may gradually increase, resulting in daytime fatigue, sleepiness, and performance decrements. In addition, symptoms brought by AR such as

apnea and snoring were also considered to be risk factors for sleep-disordered breathing events and contributed to the development of OSA.<sup>[61]</sup> In addition, some studies had demonstrated that several chemical mediators and inflammatory cytokines play interaction roles between AR and OSA, including histamine, cysteinyl leukotrienes (cysLTs), interleukin-1β(IL-1β), and interleukin-1 (IL-4) and so on.<sup>[58,62]</sup> Given the impact of AR to OSA, it seemed logical to investigate their relationship which may help understand overlapped subjects.<sup>[62]</sup>

In this meta-analysis, we reported that the prevalence of children diagnosed with AR is 2.12 times higher in SDB patients than that of non-SDB patients. However, we did not find this tendency in adults, due to immaturity of immune system in children and the studies' bias. AR was one of the most common chronic diseases in children. Children's immune system developed around the age of 2-year old. During this time, they were more likely to acquire Type I hypersensitivity which reflecting more T helper 2 lymphocyte (Th2) and consequently immuno-

Study Children		ES (95% CI)	% Weight
1 SDB			
Abdullah 2012	-	0.07 (0.02, 0.13)	9.29
Anuntaseree 2001	-	0.11 (0.04, 0.17)	9.26
Chan 2014		0.80 (0.69, 0.91)	9.01
Chng2004		0.14 (0.11, 0.17)	9.37
Ersu 2004	-	0.11 (0.06, 0.16)	9.31
Gupta 2009		0.70 (0.51, 0.88)	8.37
Kim 2015		0.66 (0.55, 0.77)	9.01
Li 2013	-	► 0.80 (0.74, 0.86)	9.27
Liukkonen 2008		0.07 (-0.01, 0.15)	9.19
Sogut 2009		0.67 (0.52, 0.81)	8.73
Francesco 2016		0.42 (0.34, 0.51)	9.17
Subtotal (I-squared = 98.5%, p = 0.000)	$\diamond$	0.41 (0.24, 0.57)	100.00
2 OSA			
Bhattachariee 2010	+	0.39 (0.35, 0.44)	6.83
Brouillette 2001		0.16 (0.02, 0.30)	6.61
Huang 2016		0.49 (0.35, 0.63)	6.61
Huseni 2014		0.43 (0.35, 0.52)	6.77
Kim 2011		0.47 (0.25, 0.70)	6.30
Li 2007		- 0.64 (0.39, 0.89)	6.17
Li 2008		0.23 (0.11, 0.36)	6.68
Ma 2011		0.38 (0.28, 0.49)	6.73
Ni 2015		0.24 (0.17, 0.32)	6.78
Ramos 2006		• 0.99 (0.97, 1.01)	6.84
Sin 2014		0.20 (0.06, 0.34)	6.61
Sogut 2005		0.21 (0.09, 0.34)	6.67
Su 2017	+	0.22 (0.16, 0.27)	6.81
Weinstock 2013		0.85 (0.78, 0.92)	6.79
Zhang 2016		• 0.85 (0.78, 0.92)	6.79
Subtotal (I-squared = 99.2%, p = 0.000)	$\sim$	0.45 (0.25, 0.65)	100.00
NOTE: Weights are from random effects ana	alysis		
B			
-1.01	<b>U</b> Figure 2. (Continued)	1.01	

globulin E (IgE) driven response to allergen exposure.<sup>[63]</sup> Adenotonsillar hypertrophy (AH) was a common comorbidity of pediatric AR, it was reported that 92.6% of AR children also suffered AH .[61] Furthermore, AH is the main cause of OSAS for children aged 3 to 6, yet adults patients were often caused by obesity.<sup>[64]</sup> This meta-analysis showed no significant difference in the prevalence of AR in OSA and non-OSA patients (children and adults). This would lead to widely underdiagnosis of OSA in group of patients in clinical practice.<sup>[65,66]</sup> Although weight and neck circumference had been shown to be good predictors for OSA in epidemiologic studies, our study suggested that there was not enough evidence that OSA adults patients coexist AR were related to individuals' BMI, neck circumference, ESS, and AHI. Additionally, Francesco and Alvarez<sup>[24]</sup> reported that AR is not an aggravating factor regarding the severity of AHI in children. The relationship between the OSA and AR is remaining a longstanding controversy. In traditional view, AR was considered as a potential risk factor for OSA. However, Kramer et al<sup>[33]</sup> revealed that AR did not influence sleeping parameters of OSA. They found no statistically significant difference in sleeping behavior or polysomnography (PSG) parameters between AR and non-AR patients. Recent studies had also revealed AR only had effect on symptoms, but did not affect PSG results for OSA patients nor belong to risk factors for OSA.<sup>[15,17]</sup> Similarly, a demographic study conducted in OSA children reported that allergic rhinitis did not contribute to sleep disordered breathing in Australian.<sup>[67]</sup> Intranasal corticosteroids (INCS) were generally considered as the most effective agent in relieving nasal symptoms of allergic rhinitis. Therefore, it was believed that the effectiveness of INCS in relieving nasal congestion may have a positive effect on SDB. A randomized, controlled trial of OSA children aged 6 to 18 years old demonstrated that intranasal mometasone furoate effectively



Figure 3. Forest graph showing the meta-analysis of odds ratios reported in individual studies with regard to the odds of prevalence of AR in SDB/OSA and non-SDB/OSA [(A) Children, (B) Adults]. AR= allergic rhinitis, OSA= obstructive sleep apnea, SDB= sleep-disordered breathing.

improved obstructive apnea hypopnea index and oxygen desaturation index.<sup>[20]</sup> Beyond that, Lavigne et al<sup>[36]</sup> found that INCS not only reduced upper airway inflammation but also improved OSA morbidity in patients with concomitant AR. A meta-analysis showed that patients receiving INCS had a better effect on decreasing the AHI; however, with limited evidences.<sup>[68]</sup> In general, continuous positive airway pressure (CPAP) was the preferred therapy for OSA, whereas, INCS did not alleviate nasal symptoms during CPAP treatment in OSA patients.<sup>[69]</sup> Hence, further research should be performed on INCS in these 2 entities.

In conclusion, patients with AR were more likely to become habitual snorers, and had increasing risk of SDB and the SDB children suffered from a higher incidence of AR. Physicians may need a comprehensive understanding of the overlapping disorders before making a reasonable therapeutic strategy.

## 5. Conclusion

This meta-analysis revealed that the prevalence of AR in adult SDB/OSA patients was 23%, and 35%, and in children SDB/OSA patients 41%, and 45%, respectively. The odds of having AR were 2.12 times higher in SDB than that of non-SDB children

patients (significantly). However, there was no significant difference between OSA patients and those who suffered AR and OSA in neck circumference simultaneously BMI, AHI, or ESS. Whether AR is a risk event of OSA need further consideration, meanwhile, patients with SDB should be cautiously focused especially accompanied with nasal symptoms.

## Author contributions

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## References

Marcus CL, Brooks LJ, Draper KA, et al. Diagnosis and management of childhood obstructive sleep apnea syndrome. Pediatrics 2012; 130:576–84.

- [2] Sharma SK, Ahluwalia G. Epidemiology of adult obstructive sleep apnoea syndrome in India. Indian J Med Res 2010;131:171–5.
- [3] Heinzer R, Vat S, Marques-Vidal P, et al. Prevalence of sleep-disordered breathing in the general population: the HypnoLaus study. Lancet Respir Med 2015;3:310–8.
- [4] Moreira GA, Pradella-Hallinan M. Sleepiness in children: an update. Sleep Med Clin 2017;12:407–13.
- [5] Carberry JC, Amatoury J, Eckert DJ. Personalized management approach for OSA. Chest 2018;153:744–55.
- [6] Brozek JL, Bousquet J, Agache I, et al. Allergic rhinitis and its impact on asthma (ARIA) guidelines—2016 revision. J Allergy Clin Immunol 2017;140:950–8.
- [7] Stewart MG. Identification and management of undiagnosed and undertreated allergic rhinitis in adults and children. Clin Exp Allergy 2008;38:751–60.
- [8] Ersu R, Arman AR, Save D, et al. Prevalence of snoring and symptoms of sleep-disordered breathing in primary school children in Istanbul. Chest 2004;126:19–24.
- [9] Lin SY, Melvin TA, Boss EF, et al. The association between allergic rhinitis and sleep-disordered breathing in children: a systematic review. Int Forum Allergy Rhinol 2013;3:504–9.
- [10] Muliol J, Maurer M, Bousquet J. Sleep and allergic rhinitis. J Investig Allergol Clin Immunol 2008;18:415–9.
- [11] Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. J Clin Epidemiol 2009;62:e1–34.
- [12] Chesson ALJr, Berry RB, Pack A. Practice parameters for the use of portable monitoring devices in the investigation of suspected obstructive sleep apnea in adults. Sleep 2003;26:907–13.
- [13] Fadzil Abdullah AA, Jamalludin AR, Norrashidah AW, et al. Prevalence of sleep disordered breathing symptoms among Malay school children in a primary school in Malaysia. Med J Malaysia 2012;67:181–5.
- [14] Anuntaseree W, Rookkapan K, Kuasirikul S, et al. Snoring and obstructive sleep apnea in Thai school-age children: prevalence and predisposing factors. Pediatr Pulmonol 2001;32:222–7.
- [15] Bengtsson C, Jonsson L, Holmstrom M, et al. Impact of nasal obstruction on sleep quality: a community-based study of women. Eur Arch Otorhinolaryngol 2015;272:97–103.
- [16] Bhattacharjee R, Kheirandish-Gozal L, Spruyt K, et al. Adenotonsillectomy outcomes in treatment of obstructive sleep apnea in children: a multicenter retrospective study. Am J Respir Crit Care Med 2010; 182:676–83.
- [17] Bozkurt B, Serife Ugur K, Karamanli H, et al. Polysomnographic findings in persistent allergic rhinitis. Sleep Breath 2017;21:255–61.
- [18] Brouillette RT, Manoukian JJ, Ducharme FM, et al. Efficacy of fluticasone nasal spray for pediatric obstructive sleep apnea. J Pediatr 2001;138:838–44.
- [19] Canova CR, Downs SH, Knoblauch A, et al. Increased prevalence of perennial allergic rhinitis in patients with obstructive sleep apnea. Respiration 2004;71:138–43.
- [20] Chan CC, Au CT, Lam HS, et al. Intranasal corticosteroids for mild childhood obstructive sleep apnea—a randomized, placebo-controlled study. Sleep Med 2015;16:358–63.
- [21] Chierakul N, Chaipattarapol C, Ruttanaumpawan P, et al. Comparison of clinical and polysomnographic characteristics of non-obese and obese patients with obstructive sleep apnea. J Med Assoc Thai 2007;90(suppl 2):48–53.
- [22] Chng SY, Goh DY, Wang XS, et al. Snoring and atopic disease: a strong association. Pediatr Pulmonol 2004;38:210–6.
- [23] Dal-Fabbro C, Garbuio S, D'Almeida V, et al. Mandibular advancement device and CPAP upon cardiovascular parameters in OSA. Sleep Breath 2014;18:749–59.
- [24] Di Francesco RC, Alvarez J. Allergic rhinitis affects the duration of rapid eye movement sleep in children with sleep-disordered breathing without sleep apnea. Int Forum Allergy Rhinol 2016;6:465–71.
- [25] Gadi GU, Albar MH, Fida R, et al. The frequency of allergic rhinitis among obstructive sleep apnea patients: a hospital-based, cross-sectional study. J King Abdulaziz Univ 2014;21:21–59.
- [26] Gadi G, Wali S, Koshak E, et al. The prevalence of allergic rhinitis and atopic markers in obstructive sleep apnea. J Epidemiol Glob Health 2017;7:37–44.
- [27] Gupta N, Emre U, Kearney S, et al. Allergic rhinitis and inner-city children—is there a relationship to sleep-disordered breathing? J Allergy Clin Immunol 2007;119:S154.

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- [28] Hellgren J, Yee BJ, Dungan G, et al. Altered positional regulation of nasal patency in patients with obstructive sleep apnoea syndrome. Eur Arch Otorhinolaryngol 2009;266:83–7.
- [29] Huang YS, Guilleminault C, Hwang FM, et al. Inflammatory cytokines in pediatric obstructive sleep apnea. Medicine (Baltimore) 2016;95: e4944.
- [30] Huseni S, Gutierrez MJ, Rodriguez-Martinez CE, et al. The link between rhinitis and rapid-eye-movement sleep breathing disturbances in children with obstructive sleep apnea. Am J Rhinol Allergy 2014;28:e56–61.
- [31] Kim HY, Dhong HJ, Lee JK, et al. Sleep quality and effects of position on sleep apnea in East Asian children. Auris Nasus Larynx 2011;38:228–32.
- [32] Kim DK, Han DH. Impact of allergic rhinitis on quality of life after adenotonsillectomy for pediatric sleep-disordered breathing. Int Forum Allergy Rhinol 2015;5:741–6.
- [33] Kramer MF, De La Chaux R, Dreher A, et al. Allergic rhinitis does not constitute a risk factor for obstructive sleep apnea syndrome. Acta Otolaryngol 2001;121:494–9.
- [34] Kreivi HR, Virkkula P, Lehto JT, et al. Upper airway symptoms in primary snoring and in sleep apnea. Acta Otolaryngol 2012;132:510–8.
- [35] Larsson LG, Lindberg A, Franklin KA, et al. Symptoms related to obstructive sleep apnoea are common in subjects with asthma, chronic bronchitis and rhinitis in a general population. Respir Med 2001; 95:423–9.
- [36] Lavigne F, Petrof BJ, Johnson JR, et al. Effect of topical corticosteroids on allergic airway inflammation and disease severity in obstructive sleep apnoea. Clin Exp Allergy 2013;43:1124–33.
- [37] Li AM, Hung E, Tsang T, et al. Induced sputum inflammatory measures correlate with disease severity in children with obstructive sleep apnoea. Thorax 2007;62:75–9.
- [38] Li AM, Lam HS, Chan MH, et al. Inflammatory cytokines and childhood obstructive sleep apnoea. Ann Acad Med Singapore 2008; 37:649–54.
- [39] Li AM, Zhu Y, Au CT, et al. Natural history of primary snoring in school-aged children: a 4-year follow-up study. Chest 2013;143:729–35.
- [40] Liukkonen K, Virkkula P, Aronen ET, et al. All snoring is not adenoids in young children. Int J Pediatr Otorhinolaryngol 2008;72:879–84.
- [41] Ma AL, Lam YY, Wong SF, et al. Risk factors for post-operative complications in Chinese children with tonsillectomy and adenoidectomy for obstructive sleep apnea syndrome. Sleep Breath 2012;16:909–11.
- [42] Ni K, Zhao L, Wu J, et al. Th17/Treg balance in children with obstructive sleep apnea syndrome and the relationship with allergic rhinitis. Int J Pediatr Otorhinolaryngol 2015;79:1448–54.
- [43] Nigro CA, Dibur E, Aimaretti S, et al. Comparison of the automatic analysis versus the manual scoring from ApneaLink device for the diagnosis of obstructive sleep apnoea syndrome. Sleep Breath 2011; 15:679–86.
- [44] Park CE, Shin SY, Lee KH, et al. The effect of allergic rhinitis on the degree of stress, fatigue and quality of life in OSA patients. Eur Arch Otorhinolaryngol 2012;269:2061–4.
- [45] Ramos RT, da Cunha Daltro CH, Gregorio PB, et al. OSAS in children: clinical and polysomnographic respiratory profile. Braz J Otorhinolaryngol 2006;72:355–61.
- [46] Shao C, Jiang JB, Wu HC, et al. Clinical assessment and polysomnographic study of sleep apnea in a Chinese population of snorers. J Zhejiang Univ Sci B 2015;16:215–23.
- [47] Sin S, Wootton DM, McDonough JM, et al. Anterior nasal resistance in obese children with obstructive sleep apnea syndrome. Laryngoscope 2014;124:2640–4.
- [48] Sogut A, Altin R, Uzun L, et al. Prevalence of obstructive sleep apnea syndrome and associated symptoms in 3–11-year-old Turkish children. Pediatr Pulmonol 2005;39:251–6.
- [49] Sogut A, Yilmaz O, Dinc G, et al. Prevalence of habitual snoring and symptoms of sleep-disordered breathing in adolescents. Int J Pediatr Otorhinolaryngol 2009;73:1769–73.
- [50] Su MS, Xu L, Xu K, et al. Association of T lymphocyte immune imbalance and IL-10 gene polymorphism with the risk of obstructive sleep apnea in children with obesity. Sleep Breath 2017;21:929–37.
- [51] Virkkula P, Maasilta P, Hytonen M, et al. Nasal obstruction and sleepdisordered breathing: the effect of supine body position on nasal measurements in snorers. Acta Otolaryngol 2003;123:648–54.
- [52] Vuorjoki-Ranta T-R, Lobbezoo F, Tuomilehto H, et al. Mandibular advancement devices in the treatment of obstructive sleep apnea and snoring in community dental care: A pilot study on self-reported sleep quality. Health 2013;5:1–5.
- [53] Vuorjoki-Ranta T-R, Lobbezoo F, Tuomilehto H, et al. Mandibular advancement device therapy in obstructive sleep apnea and snoring in

community dental care: two-year follow-up study on self-reported sleep quality, side effects, and compliance. J Sleep Disorders Ther 2014;3:180.

- [54] Weinstock TG, Rosen CL, Marcus CL, et al. Predictors of obstructive sleep apnea severity in adenotonsillectomy candidates. Sleep 2014;37: 261–9.
- [55] Wirasinghe C, Godevithanage S, Nakandala SC, et al. The use of overnight pulse oximetry for obstructive sleep apnoea in a resource poor setting in Sri Lanka. J Ceylon Coll Physicians 2011;41:61–6.
- [56] Zhang J, Zhao J, Chen M, et al. Airway resistance and allergic sensitization in children with obstructive sleep apnea hypopnea syndrome. Pediatr Pulmonol 2016;51:426–30.
- [57] McColley SA, Carroll JL, Curtis S, et al. High prevalence of allergic sensitization in children with habitual snoring and obstructive sleep apnea. Chest 1997;111:170–3.
- [58] Young T, Finn L, Kim H. Nasal obstruction as a risk factor for sleepdisordered breathing. The University of Wisconsin Sleep and Respiratory Research Group. J Allergy Clin Immunol 1997;99:S757–62.
- [59] Young T, Finn L, Palta M. Chronic nasal congestion at night is a risk factor for snoring in a population-based cohort study. Arch Intern Med 2001;161:1514–9.
- [60] Craig TJ, McCann JL, Gurevich F, et al. The correlation between allergic rhinitis and sleep disturbance. J Allergy Clin Immunol 2004;114: S139–45.
- [61] Said SA, McHembe MD, Chalya PL, et al. Allergic rhinitis and its associated co-morbidities at Bugando Medical Centre in Northwestern

Tanzania; a prospective review of 190 cases. BMC Ear Nose Throat Disord 2012;12:13.

- [62] Chirakalwasan N, Ruxrungtham K. The linkage of allergic rhinitis and obstructive sleep apnea. Asian Pac J Allergy Immunol 2014;32: 276–86.
- [63] Sih T, Mion O. Allergic rhinitis in the child and associated comorbidities. Pediatr Allergy Immunol 2010;21:e107–13.
- [64] Greenfeld M, Tauman R, DeRowe A, et al. Obstructive sleep apnea syndrome due to adenotonsillar hypertrophy in infants. Int J Pediatr Otorhinolaryngol 2003;67:1055–60.
- [65] Jennum P, Ibsen R, Kjellberg J. Morbidity and mortality in children with obstructive sleep apnoea: a controlled national study. Thorax 2013;68:949–54.
- [66] Kapur V, Strohl KP, Redline S, et al. Underdiagnosis of sleep apnea syndrome in U.S. communities. Sleep Breath 2002;6:49–54.
- [67] Tamanyan K, Walter LM, Davey MJ, et al. Risk factors for obstructive sleep apnoea in Australian children. J Paediatr Child Health 2016; 52:512–7.
- [68] Liu HT, Lin YC, Kuan YC, et al. Intranasal corticosteroid therapy in the treatment of obstructive sleep apnea: A meta-analysis of randomized controlled trials. Am J Rhinol Allergy 2016;30:215–21.
- [69] Charakorn N, Hirunwiwatkul P, Chirakalwasan N, et al. The effects of topical nasal steroids on continuous positive airway pressure compliance in patients with obstructive sleep apnea: a systematic review and metaanalysis. Sleep Breath 2017;21:3–8.