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SCIENTIFIC INVESTIGATIONS

Effect of Three Hypopnea Scoring Criteria on OSA Prevalence and Associated Comorbidities in the General Population

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Study Objectives: Apnea-hypopnea index (AHI) is the main polysomnographic measure to diagnose obstructive sleep apnea (OSA). We aimed to evaluate the effect of three standard hypopnea definitions on the prevalence of OSA and its association with cardiometabolic outcomes in the general population.
Methods: We analyzed data from the HypnoLaus study (Lausanne, Switzerland), in which 2,162 participants (51% women, 57 ± 19 years) underwent in-home full polysomnography. AHI was calculated using three hypopnea definitions: $AASM_{1999}$ (≥ 50% decrease in airflow or lower airflow reduction associated with oxygen desaturation ≥ 3% or an arousal), $AASM_{2007}$ (≥ 30% airflow reduction associated with ≥ 4% oxygen desaturation), and $AASM_{2012}$ (≥ 30% airflow reduction associated with ≥ 3% oxygen desaturation or an arousal). Participants underwent clinical assessment for hypertension, diabetes, and metabolic syndrome.
Results: Median AHI of $AASM_{1999}$, $AASM_{2007}$ and $AASM_{2012}$ criteria were 10.9, 4.4, and 10.1 events/h, respectively. OSA prevalence defined as AHI ≥ 5, ≥ 15, and ≥ 30 events/h was 74.5%, 39.3%, and 16.3% using $AASM_{1999}$; 46.9%, 18.8%, and 6.8% using $AASM_{2007}$; and 72.2%, 36.6%, and 14.9% using $AASM_{2012}$. Different AHI thresholds derived from $AASM_{1999}$, $AASM_{2007}$, and $AASM_{2012}$ criteria, respectively, were associated with hypertension (11.5, 4.8, 10.7 events/h), diabetes (15.7, 7.1, 14.4 events/h), and metabolic syndrome (12.8, 5.5, 11.8 events/h).
Conclusions: Hypopnea definition has a major effect on AHI and on OSA prevalence in the general population and, hence, important implications for public health policies. There is a twofold difference in the threshold above which an association with diabetes, hypertension, and metabolic syndrome is observed using $AASM_{2007}$ compared to $AASM_{1999}$ or $AASM_{2012}$ criteria.
Keywords: general population, hypopnea, methodology, obstructive sleep apnea, polysomnography
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BRIEF SUMMARY
Current Knowledge/Study Rationale: The American Academy of Sleep Medicine's rules for scoring hypopneas have changed thrice over the past 20 years, but their clinical effects on the prevalence of obstructive sleep apnea and their association with hypertension, diabetes, and metabolic syndrome in the general population are unknown.
Study Impact: Our findings indicate that the method used for scoring hypopneas significantly influences the prevalence of obstructive sleep apnea and its association with cardiometabolic outcomes. We could provide predictive equations to translate the differences in apnea-hypopnea indexes within three recommended criteria of the American Academy of Sleep Medicine in a general population-based sample. Further, this study highlights the need for standardization of the scoring method to allow compatibility among epidemiological studies.

INTRODUCTION

Obstructive sleep apnea (OSA) is characterized by recurrent partial (hypopneas) or total (apneas) episodes of upper airway obstruction during sleep,[1] and has been widely recognized as an important and treatable risk factor for cardiovascular and metabolic conditions.[2,3] Polysomnography (PSG) is considered the gold standard for identifying individuals with OSA. Among the several parameters measured by PSG, the apnea-hypopnea index (AHI), which comprises the average number of apneas and hypopneas per hour of sleep, is the main metric for diagnosing OSA, as well as for assessing the disease severity and responsiveness to the treatment. A recent systematic review showed that, in general populations, OSA prevalence as AHI ≥ 5 events/h varies considerably among studies (9% to 38%).[4] Higher estimates were also observed over time in the most recent epidemiological studies.[5] Among the possible explanations for these findings, ethnical composition, equipment-related issues, and changes in respiratory events definition might have an important role.

Indeed, several definitions of hypopnea have been used in research and the clinical setting, leading to large interlaboratory variations in AHI depending on the definition used.[6–10] These differences relate to the degree of airflow reduction, the amplitude of oxygen desaturation, and the association with electroencephalographic arousal required to define a hypopnea.

Because OSA diagnosis and treatment decision are largely based on AHI, the definition of hypopnea may have a direct effect on OSA prevalence estimates and the patients' management. Thus, the aim of our study was to evaluate the effect of three hypopnea definitions on the prevalence and severity of OSA in a middle-aged general population sample. We compared three standard definitions for identifying hypopneas: the 1999 American Academy of Sleep Medicine (AASM) criteria (also known as Chicago criteria),[11] and the recommended definitions from The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications (AASM Scoring Manual) in 2007[12] and 2012.[13] Next, we sought to establish the AHI thresholds that could predict the presence of hypertension, diabetes, and metabolic syndrome as well as to compare the association between OSA severity and these cardiometabolic outcomes using each hypopnea definition.

METHODS

Population Sample

This is a cross-sectional study that analyzed data from HypnoLaus, a population-based sleep cohort study (Lausanne, Switzerland) performed between September 1, 2009 and June 30, 2013. HypnoLaus participants were recruited among individuals from the CoLaus/PsyCoLaus cohort.[14] CoLaus/PsyCoLaus is a population-based cohort of 6,734 participants (52.5% women) aged 35 to 75 years, identified from a random sample of all age-eligible adults living in the city of Lausanne, Switzerland (117,161 habitants). The CoLaus/PsyCoLaus study was conducted to assess the prevalence of cardiovascular risk factors and to identify new determinants of these risk factors and their association with mental disorders.[15] For the HypnoLaus nested study, participants of the CoLaus/PsyCoLaus study were invited to answer sleep questionnaires regarding their sleep habits and potential sleep disorders, and the first consecutive 3,043 were contacted to have a full sleep study at home. Of these, 71% (n = 2,168) accepted the invitation and underwent PSG, among which 3% (n = 60) had technical problems. Of these, 6 participants declined to undergo a second PSG, and 54 participants agreed.[16] Therefore, 2,162 PSG recordings composed the HypnoLaus cohort and were included in this study. The Institutional Review Board in Lausanne approved the study, and all participants gave their written informed consent.

Clinical Data Collection

Participants from HypnoLaus study were invited to attend the outpatient clinic at the University Hospital of Lausanne (Centre Hospitalier Universitaire Vaudois [CHUV], Lausanne, Switzerland). After an overnight fasting they were also invited for questionnaires completion, clinical assessment, and blood samples collection. Body weight and height were measured using a calibrated scale and a vertical stadiometer, respectively (Seca, Hamburg, Germany). Body mass index (BMI) was calculated as body mass in kg divided by the square of the participant's height in meters. Waist circumference (at the level of the umbilicus) was measured to within 0.5 cm with plastic tape. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were evaluated in triplicate on the left arm at 5-minute intervals with the participant seated and resting for at least 10 minutes using a calibrated automated oscillometric sphygmomanometer (Omron HEM-907, Matsusaka, Japan).[17] Overnight fasting blood samples were taken of each participant. Glucose, total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglycerides were quantified by colorimetric assays as previously described.[14] These assays were performed on fresh blood samples by the CHUV Clinical Laboratory (Lausanne, Switzerland).

Polysomnography

In-home overnight full PSG was performed, using a digital portable sleep-wake recording system (EMBLA Titanium, Embla Systems, Inc, Broomfield, Colorado, United States). A trained technician hooked up the participant in the CIRS facility (Center for Investigation and Research in Sleep, CHUV, Lausanne, Switzerland). The electrodes and recorder were installed at the laboratory and recordings were done in the normal home environment. PSG measurements included: electroencephalograms (EEG) from frontal, central, and occipital areas (F3-M2, C3-M2, O1-M2, F4-M1, C4-M1, O2-M1) according to the international 10/20 electrode configuration system, right and left electrooculograms, mental-submental electromyogram (EMG), right and left leg EMG, thoracic and abdominal breathing movements by respiratory inductance plethysmography, respiratory airflow by a nasal-cannula connected to a pressure transducer, oxygen saturation (SpO_2) by pulse oximetry, heart rate by electrocardiogram (ECG), and body position.

Scoring of PSG

PSG test results were scored using Somnologica software (Embla Systems, Inc) by two experienced scorers (DA, NT), with an interagreement concordance greater than 90%. Sleep, arousal, and movements during sleep were scored based on the 2007 AASM Scoring Manual.[12] Concerning respiratory events, an apnea was defined by a complete or almost complete (> 90%) cessation of airflow (measured by nasal pressure) lasting 10 seconds or longer. Hypopneas were initially scored based on the Chicago criteria ($AASM_{1999}$), being defined by criterion 1 or 2, plus criterion 3:

1. A clear decrease (> 50%) of airflow amplitude from the baseline. Baseline was defined as the mean amplitude of stable breathing and oxygenation in the 2 minutes preceding onset of the event (in individuals who have a stable breathing pattern during sleep) or the mean amplitude of the three largest breaths in the two minutes preceding onset of the event (in individuals without a stable breathing pattern).
2. A clear reduction of airflow amplitude, not reaching the aforementioned criterion but associated with either an oxygen desaturation of ≥ 3% or an arousal. From an operational standpoint, a discernible reduction in airflow was considered a > 30% reduction in the airflow signal.
3. The event lasts 10 seconds or longer.

An AHI for each individual was calculated, consisting of the number of apneas and hypopneas per hour of sleep. Each recording was reviewed for validation of the respiratory scoring by a single investigator (JHR).

Because both recommended 2007 and 2012 AASM criteria represent a subset of Chicago criteria's events, we derived the other two AHI definitions from the first scoring. For the recommended 2007 AASM Scoring Manual criteria ($AASM_{2007}$), we removed hypopneas that did not fulfill the stricter AASM hypopnea definition, that is, hypopneas that were not associated with ≥ 4% oxygen desaturation. For the recommended 2012 AASM Scoring Manual criteria ($AASM_{2012}$), we removed hypopneas that were not associated with either an arousal or a ≥ 3% oxygen desaturation (**Table S1**).

OSA severity was classified according to standard criteria as mild (AHI 5 to < 15 events/h), moderate (AHI 15 to < 30 events/h), and severe (AHI ≥ 30 events/h). AHI < 5 events/h was defined as no-OSA.

Outcomes

Hypertension was defined as a SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg, and/or use of antihypertensive medication. Diabetes was considered positive when fasting plasma glucose levels were ≥ 7.0 mmol/L or there was use of antidiabetic medication.[18] Metabolic syndrome was defined according to the Joint Interim Statement,[19] as the presence of at least three risk factors among: high blood pressure (SBP ≥ 130 mmHg or DBP ≥ 85 mmHg or use of antihypertensive medication); visceral obesity (waist circumference ≥ 88 cm in women or ≥ 102 cm in men); high triglycerides (≥ 1.7 mmol/L, or use of fibrates or nicotinic acid); low HDL levels (< 1.30 mmol/L in women or < 1.03 mmol/L in men, or use of fibrates or nicotinic acid); and high fasting plasma glucose (≥ 5.6 mmol/L or use of antidiabetic medication).

Statistical Analysis

We used AHI as the primary variable in this study for analysis of the differences between hypopnea scoring criteria. AHI is displayed according to the median and interquartile range (IQR) values. The differences between the three different AHIs obtained through $AASM_{1999}$, $AASM_{2007}$, and $AASM_{2012}$ criteria were assessed using the Friedman test, with pairwise comparisons performed by Wilcoxon signed-rank test. Bar graphs were constructed to represent the prevalence of OSA using each AASM criteria at AHI thresholds of ≥ 5, ≥ 15, and ≥ 30 events/h. Equivalent thresholds for the three AHIs were estimated using the receiver operating characteristic curve (ROC) with each AHI as the gold standard, giving equal weight to maximize both sensitivity and specificity. Bland-Altman plots representing the mean difference between each pair of AHIs according to each scoring criteria were built to illustrate the agreement between AHIs. Conversion equations between each pair of AHI were established with linear or quadratic regressions, with the latter being employed when appropriate. AHI thresholds significantly associated with the presence of hypertension, diabetes, and metabolic syndrome were estimated by ROC analysis using each hypopnea criteria. Multivariable logistic regression was used for testing the association between OSA severity (mild, moderate, or severe OSA versus no-OSA) and the presence of hypertension, diabetes, and metabolic syndrome using each scoring criteria.

Table 1—Sample characteristics.

n	2,162
Age, years	57.2 ± 19.2
Sex, M/F	1,056/1,106
BMI, kg/m^2	25.7 ± 5.4
TST, minutes	404.0 ± 89.0
Sleep onset latency, minutes	10.9 ± 16.5
Sleep efficiency, %	87.6 ± 13.0
Stage N1 sleep, %TST	10.2 ± 7.5
Stage N2 sleep, %TST	45.6 ± 12.8
Stage N3 sleep, %TST	19.3 ± 10.9
Stage R sleep, %TST	22.3 ± 7.9
Arousal index	18.9 ± 12.4
3% ODI	10.0 ± 15.2
4% ODI	4.1 ± 9.1
Mean SpO_2, %	94.3 ± 2.2
TST with SpO_2 < 90%, %	0.2 ± 2.1

Data expressed as median ± interquartile range or number of participants. BMI = body mass index, M/F = male/female, n = sample size, ODI = oxygen desaturation index, REM = rapid eye movement, SpO_2 = percutaneous oxygen saturation, TST = total sleep time.

RESULTS

Population Sample and OSA Prevalence

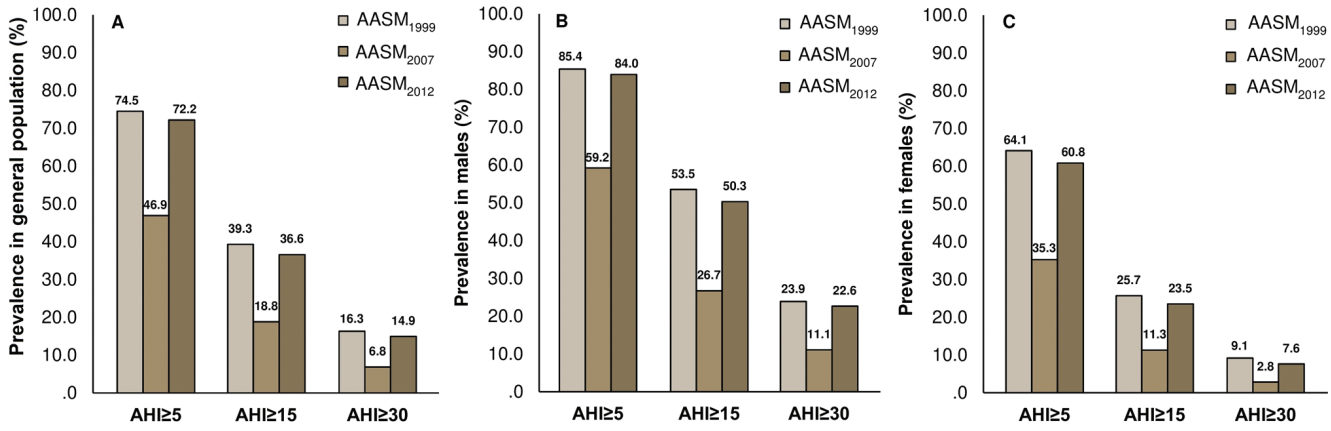
The patient characteristics and PSG results are shown in **Table 1**. Participants were 57.2 ± 19.2 (median ± IQR) years of age with a BMI of 25.7 ± 5.4 kg/m^2. The sample included 51% of women. The average total sleep time was 404.0 ± 89.0 minutes and the sleep efficiency was 87.6 ± 13 %.

The prevalence of OSA in the HypnoLaus cohort based on different AASM scoring criteria is presented in **Figure 1**. When using AHI thresholds of ≥ 5, ≥ 15, and ≥ 30 events/h, respectively, $AASM_{2007}$ would provide 34.9%, 48.6%, and 54.2% lower OSA diagnosis rate compared to $AASM_{2012}$ as well as 37.0%, 52.1%, and 58.1% lower OSA diagnosis rate compared to $AASM_{1999}$ criteria. Compared to $AASM_{1999}$ criteria, $AASM_{2012}$ would provide 3.2%, 6.8%, and 8.5% lower OSA diagnosis rate when using the same AHI thresholds.

AHI Agreement

Table 2 shows median ± IQR of AHI in the HypnoLaus population according to the three scoring criteria. All AHIs were significantly different from each other ($P < .001$) by Friedman test and *post hoc* comparisons. The median AHI of $AASM_{2007}$ and $AASM_{2012}$ criteria were approximately 40% and 93% of the median AHI of $AASM_{1999}$. In turn, the median AHI of $AASM_{2007}$ was approximately 44% of the median AHI of $AASM_{2012}$. Bland-Altman plots (**Figure 2**) show the agreement

Figure 1—Prevalence of obstructive sleep apnea.



Prevalence of apnea-hypopnea index (AHI) thresholds ≥ 5, ≥ 15 and ≥ 30 events/h according to three different recommended American Academy of Sleep Medicine (AASM) criteria (1999, 2007 and 2012) in the whole **(A)**, male **(B),** and female **(C)** sample of HypnoLaus cohort (n = 2,162).

Table 2—Apnea-hypopnea index changes according to hypopnea definitions in the HypnoLaus cohort.

	Apnea-Hypopnea Index			
	$AASM_{1999}$	$AASM_{2007}$	$AASM_{2012}$	*P*
Whole sample	10.9 ± 17.5	4.4 ± 10.1*	10.1 ± 16.9*#	< .0001
Male sample	16.0 ± 20.9	6.8 ± 13.5*	15.1 ± 20.4*#	< .0001
Female sample	7.6 ± 12.1	2.6 ± 6.2*	7.0 ± 11.4*#	< .0001

Data expressed as median ± interquartile range and analyzed using Friedman test with pairwise comparisons performed by Wilcoxon signed-ranked test. * = *P* < .0001 compared with $AASM_{1999}$. # = *P* < .0001 compared with $AASM_{2007}$. AASM = American Academy of Sleep Medicine, $AASM_{1999}$ = "Chicago criteria" hypopnea definition, $AASM_{2007}$ = 2007 AASM recommended hypopnea definition, $AASM_{2012}$ = 2012 AASM recommended hypopnea definition.

Table 3—Equivalent apnea-hypopnea index thresholds for different hypopnea definitions in the HypnoLaus cohort.

Gold Standard AHI	Whole Sample Equivalent AHI Thresholds		Male Sample Equivalent AHI Thresholds		Female Sample Equivalent AHI Thresholds	
$AASM_{2012}$	$AASM_{1999}$	$AASM_{2007}$	$AASM_{1999}$	$AASM_{2007}$	$AASM_{1999}$	$AASM_{2007}$
5 events/h	5.7 (99.8, 98.0, 97.5)	2.0 (97.6, 90.9, 91.2)	5.9 (99.8, 98.0, 98.2)	2.1 (97.9, 92.0, 92.3)	5.7 (99.8, 97.3, 97.7)	1.9 (97.1, 90.2, 90.8)
15 events/h	15.6 (99.7, 98.6, 97.5)	6.6 (98.3, 93.0, 92.9)	15.8 (99.8, 98.7, 97.1)	6.7 (97.9, 92.5, 92.4)	15.2 (99.6, 98.8, 97.6)	6.5 (98.5, 93.8, 93.1)
30 events/h	30.4 (99.9, 100.0, 98.6)	14.9 (99.1, 94.7, 94.3)	30.2 (99.9, 100.0, 98.7)	15.0 (98.6, 92.9, 92.7)	30.5 (99.9, 100.0, 98.6)	16.0 (99.5, 98.8, 97.2)
$AASM_{2007}$	$AASM_{1999}$	$AASM_{2012}$	$AASM_{1999}$	$AASM_{2012}$	$AASM_{1999}$	$AASM_{2012}$
5 events/h	11.8 (97.3, 90.0, 90.5)	10.9 (97.7, 91.0, 91.3)	13.0 (96.8, 90.2, 88.9)	12.4 (97.4, 90.2, 91.9)	10.7 (97.4, 91.0, 91.3)	9.4 (97.8, 93.3, 90.8)
15 events/h	23.9 (98.7, 94.3, 94.2)	22.4 (99, 95.1, 94.1)	25.5 (98.2, 93.3, 93.3)	24.0 (98.6, 95.0, 93.9)	21.0 (99.1, 99.2, 94.6)	20.2 (99.3, 99.2, 95.2)
30 events/h	38.2 (99.3, 97.3, 96.1)	37.0 (99.5, 99.3, 96.4)	40.9 (99.0, 97.4, 95.5)	39.8 (99.2, 97.4, 96.1)	35.9 (99.5, 100.0, 96.8)	35.9 (99.6, 100.0, 98.1)
$AASM_{1999}$	$AASM_{2007}$	$AASM_{2012}$	$AASM_{2007}$	$AASM_{2012}$	$AASM_{2007}$	$AASM_{2012}$
5 events/h	1.7 (97.0, 90.7, 91.5)	4.9 (99.8, 97.3, 99.6)	1.7 (93.7, 93.6, 90.3)	4.9 (99.7, 98.6, 99.4)	1.6 (96.4, 90.7, 89.2)	4.6 (99.8, 97.2, 98.5)
15 events/h	6.4 (97.7, 90.2, 93.6)	13.9 (99.8, 97.4, 98.5)	6.4 (97.3, 90.1, 92.9)	13.9 (99.8, 97.7, 98.6)	5.9 (97.9, 93.3, 91.8)	13.9 (99.7, 96.8, 98.4)
30 events/h	13.0 (98.7, 96.3, 92.2)	26.5 (99.9, 98.6, 97.9)	14.4 (98.3, 92.5, 92.9)	28.2 (99.9, 98.8, 99.0)	11.4 (99.1, 100.0, 93.3)	25.9 (99.9, 99.0, 98.8)

Data expressed as threshold (area under the curve, sensitivity, specificity) and analyzed using receiver operating characteristic curve. AASM = American Academy of Sleep Medicine, $AASM_{1999}$ = "Chicago criteria" hypopnea definition, $AASM_{2007}$ = 2007 AASM recommended hypopnea definition, $AASM_{2012}$ = 2012 AASM recommended hypopnea definition, AHI = apnea-hypopnea index.

between each pair of AHI according to the different scoring criteria. The variation in the mean AHI difference between each pair of scoring criteria was greater according to the AHI magnitude, except for the comparison between $AASM_{1999}$ and $AASM_{2012}$ criteria, which was more stable. The Bland-Altman plots demonstrate a mean increase of 6.4 events/h when comparing AHI definitions between $AASM_{2007}$ and $AASM_{2012}$; a mean reduction of 0.9 events/h when comparing $AASM_{2012}$ and $AASM_{1999}$; and a mean reduction of 7.3 events/h when comparing $AASM_{2007}$ and $AASM_{1999}$ criteria.

Equivalent AHIs and Prediction Equations

Table 3 shows the equivalence between the scoring criteria for each AHI threshold. For instance, when using $AASM_{2012}$

according to AHI thresholds of ≥ 5, ≥ 15 and ≥ 30 events/h, to achieve a similar OSA prevalence $AASM_{2007}$ would have to shift its thresholds down to about 2.0, 6.6, and 14.9 events/h, respectively. In male and female subsamples, the equivalent AHI threshold conversion factors were similar to those of the whole sample.

Prediction equations to determine the relationship between each pair of AHI are represented in **Figure 3**. All equations showed a $R^2 \geq 0.90$ as high collinearity was present between criteria (R = 0.996 for correlation between $AASM_{1999}$ and $AASM_{2012}$ derived AHI; R = 0.959 for correlation between $AASM_{2007}$ and $AASM_{2012}$ derived AHI; and R = 0.951 for correlation between $AASM_{2007}$ and $AASM_{1999}$ derived AHI). In the prediction equations between $AASM_{2007}$ and $AASM_{2012}$ as well as $AASM_{2007}$ and $AASM_{1999}$, a quadratic regression better fitted the relationship, but with a small increase in R^2 of 0.02 compared to the linear regression.

Effect of Scoring Criteria on the Association Between OSA and Outcomes

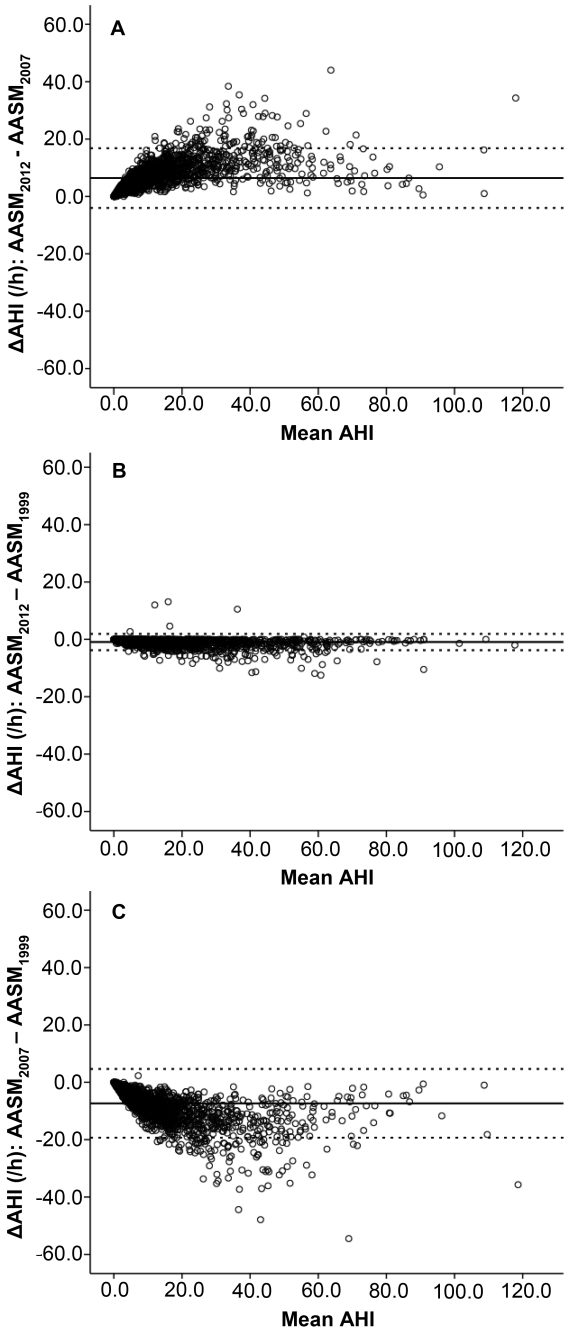
The AHI thresholds significantly associated with hypertension, diabetes, and metabolic syndrome according to the three scoring criteria are represented in **Table 4**. For all outcomes assessed, the area under the curves (AUCs) as well as the sensitivity and specificity were similar among the three scoring criteria. Overall, higher AHI thresholds emerged from $AASM_{1999}$, followed by $AASM_{2012}$. AHI thresholds derived from $AASM_{2007}$ criteria were approximately half of the respective AHI thresholds derived from both $AASM_{1999}$ and $AASM_{2012}$.

The association between OSA severity and the presence of cardiometabolic outcomes adjusted for age, sex, and BMI is represented in **Figure 4**. For hypertension, we observed an independent association with severe OSA versus no-OSA using both $AASM_{2012}$ (odds ratio [OR] = 1.46, 1.01–2.10) and $AASM_{1999}$ (OR = 1.55, 1.08–2.22), but not $AASM_{2007}$ (OR = 1.30, 0.83–2.05). For diabetes, there was significant associations with all OSA groups versus no-OSA in both $AASM_{2012}$ (mild OSA: OR = 2.13, 1.16–3.91; moderate OSA: OR = 2.31, 1.23–4.32; severe OSA: OR = 2.44, 1.28–4.68) and $AASM_{1999}$ (mild OSA: OR = 1.92, 1.02–3.62; moderate OSA: OR = 2.34, 1.23–4.43; severe OSA: OR = 2.35, 1.21–4.55). Regarding $AASM_{2007}$, diabetes was significantly associated with moderate (OR = 1.61, 1.02–2.56) and severe OSA (OR = 1.81, 1.07–3.05), but not with mild OSA (OR = 1.46, 0.99–2.17) when compared to no-OSA.

For metabolic syndrome, we found significant associations with all OSA groups versus no-OSA using the three scoring criteria as follows: $AASM_{2012}$ (mild OSA: OR = 1.58, 1.12–2.22; moderate OSA: OR = 1.68, 1.16–2.43; severe OSA: OR = 2.38, 1.58–3.60); $AASM_{2007}$ (mild OSA: OR = 1.48, 1.13–1.93; moderate OSA: OR = 1.66, 1.17–2.35; severe OSA: OR = 2.26, 1.42–3.59); $AASM_{1999}$ (mild OSA: OR = 1.63, 1.14–2.33; moderate OSA: OR = 1.68, 1.15–2.46; severe OSA: OR = 2.41, 1.59–3.64).

There was no association between the different AHI thresholds and self-reported sleepiness (Epworth Sleepiness Scale) regardless the hypopnea scoring criteria used (**Figure S1** and **Table S2**).

Figure 2—AHI agreement among different hypopnea criteria.

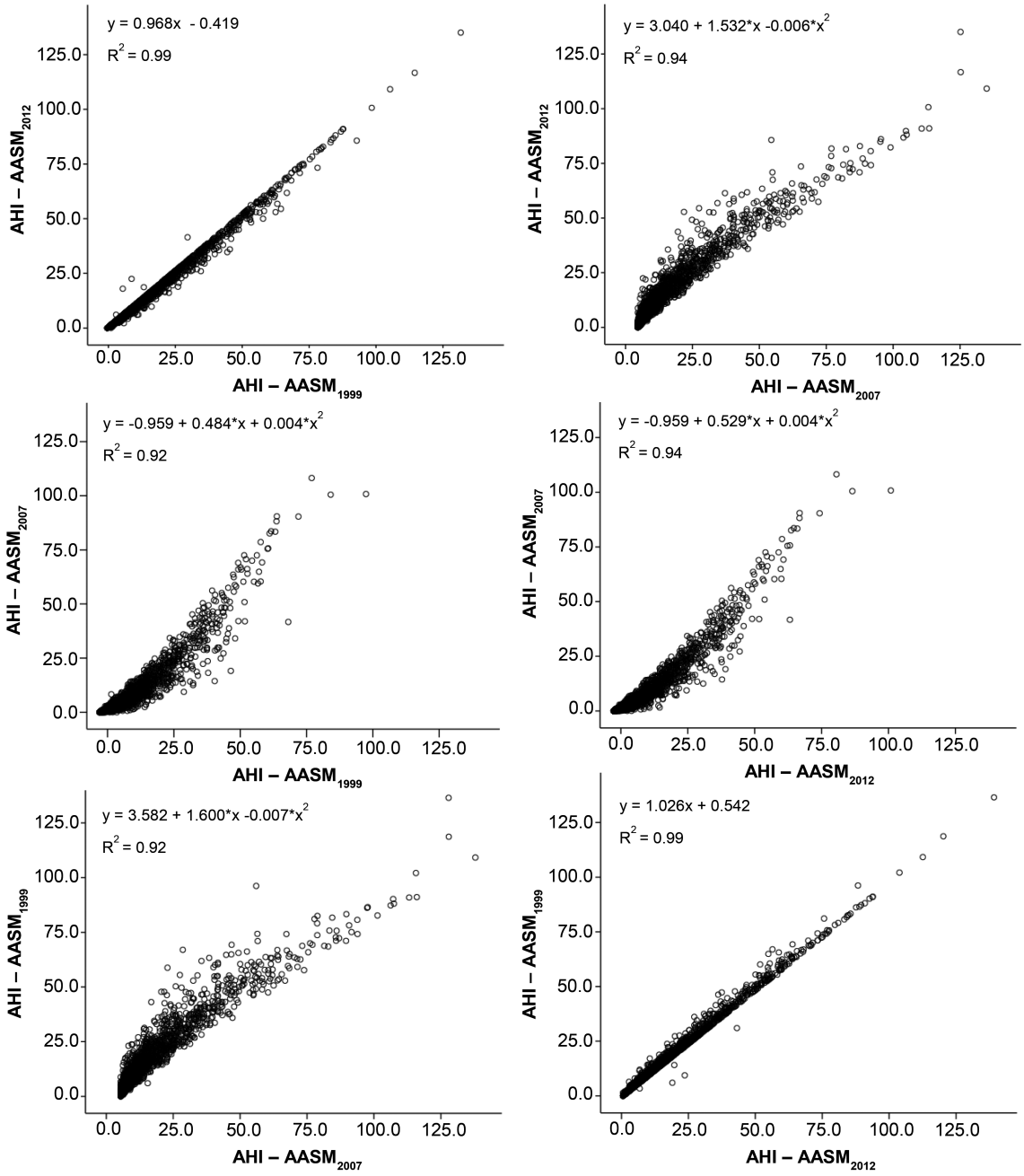


Bland-Altman plots demonstrating the level of agreement for apnea-hypopnea index (AHI) between American Academy Sleep Medicine (AASM) criteria from 2012 versus 2007, 2012 versus 1999, and 2007 versus 1999, respectively in the HypnoLaus cohort (n = 2,162). The dashed line represents the mean difference between the two measured AHIs and the dotted lines represent the mean difference ± 1.96 standard deviation (SD). The x-axis presents the mean of the two AHIs and the y-axis presents the difference (Δ) between the two measurements.

DISCUSSION

To the best of our knowledge, this is the first study that explored the extent to which different hypopnea definitions influence OSA recognition and its association with

Figure 3—AHI equivalence equations among different hypopnea criteria.



Least squares regression showing the apnea-hypopnea indexes (AHIs) equations of equivalence according to the different recommended American Academy of Sleep Medicine (AASM) criteria in the HypnoLaus cohort (n = 2,162).

cardiometabolic outcomes in a general population sample. Using three standard hypopnea definitions with airflow assessed by nasal cannula pressure transducer, we could provide conversion equations between AHIs and equivalent thresholds among the scoring criteria. Our results show up to twofold difference in AHI level above which an association was found with cardiometabolic outcomes between $AASM_{2007}$ and $AASM_{1999}$/$AASM_{2012}$. Last, an independent association between severe OSA and hypertension was only found using $AASM_{1999}$ or $AASM_{2012}$ criteria after adjusting for confounders.

To date, all studies that aimed to evaluate the association between OSA and metabolic syndrome,[20–24] diabetes,[25–31] or hypertension[32–40] have used older AASM criteria ($AASM_{1999}$/$AASM_{2007}$) or non-AASM criteria for hypopnea scoring, hampering a reliable comparison among them. In addition to the differences in scoring criteria, important heterogeneity in study design, sample size, outcome definition, and demographic factors may have played a role in the inconsistent results found, as shown in **Table 5**, **Table 6**, and **Table 7**.

Previous studies have examined the agreement between different approaches to determine AHI, showing significant

Table 4—Equivalent apnea-hypopnea index thresholds associated with cardiometabolic outcomes according to different hypopnea criteria in the HypnoLaus cohort.

AHI	AUC	95% CI	*P*	Threshold	Sensitivity	Specificity
Hypertension						
$AASM_{2012}$	0.67	0.65–0.69	< .0001	10.7	0.62	0.62
$AASM_{2007}$	0.68	0.65–0.70	< .0001	4.8	0.63	0.63
$AASM_{1999}$	0.67	0.65–0.69	< .0001	11.5	0.62	0.61
Diabetes						
$AASM_{2012}$	0.71	0.68–0.75	< .0001	14.4	0.64	0.65
$AASM_{2007}$	0.72	0.68–0.75	< .0001	7.1	0.66	0.67
$AASM_{1999}$	0.71	0.67–0.74	< .0001	15.7	0.65	0.66
Metabolic Syndrome						
$AASM_{2012}$	0.71	0.69–0.74	< .0001	11.8	0.65	0.65
$AASM_{2007}$	0.73	0.70–0.75	< .0001	5.5	0.66	0.66
$AASM_{1999}$	0.71	0.68–0.73	< .0001	12.8	0.65	0.64

Data expressed as AUC, 95% CI, AHI threshold, sensitivity and specificity, and analyzed using receiver operating characteristic (ROC) operating curve. Number of participants with missing data: hypertension (2), diabetes (2). AASM = American Academy of Sleep Medicine, $AASM_{1999}$ = "Chicago criteria" hypopnea definition, $AASM_{2007}$ = 2007 AASM recommended hypopnea definition, $AASM_{2012}$ = 2012 AASM recommended hypopnea definition, AHI = apnea-hypopnea index, AUC = area under the curve, CI = confidence interval.

Table 5—Population-based studies on the association between obstructive sleep apnea and metabolic syndrome.

Study, Year	Country	Sample Size	Male (%)	Mean Age (years)	Mean BMI (kg/m^2)	Outcome Definition	Study Design	Diagnostic Method	Hypopnea Criteria	OSA Category (AHI)	Results	Association
Nieto et al. 2009	USA	546	56.0	59.9	31.1	NCEP ATPIII	Cross-sectional	Standard PSG	Discernible decrease in airflow with at least a 4% desaturation	≥ 15 events/h	OR = 2.20 (1.20–3.90)	Yes
										5 to < 15 events/h	OR = 2.50 (1.50–4.20)	Yes
										< 5 events/h		
Chin et al. 2010	Japan	275	100	44.0	23.9	NCEP ATPIII	Cross-sectional	Portable PSG	> 50% decrease in airflow with at least a 3% desaturation	≥ 30 events/h	OR = 2.57 (0.68–9.69)	No
										15 to < 30 events/h	OR = 0.77 (0.30–1.99)	No
										5 to < 15 events/h	OR = 1.00 (0.47–2.13)	No
										< 5 events/h		
Troxel et al. 2010	USA	290	N/A	N/A	N/A	NCEP ATPIII	Case-control	PG	≥ 30% but < 80% decrease in airflow	As continuous variable	OR = 1.23 (1.02–1.47) per 5 units	Yes
Theorell-Haglow et al. 2011	Sweden	400	0	50.1	26.7	NCEP ATPIII	Cross-sectional	Standard PSG	> 50% decrease in airflow with at least a 3% desaturation or an arousal	As continuous variable	OR = 1.04 (1.01–1.07) per 1 unit	Yes
Hall et al. 2012	USA	340	0	51.2	29.8	NCEP ATPIII	Case-control	Standard PSG	Discernible reduction in airflow or a < 50% decrease in airflow with at least 3% desaturation or an arousal	As continuous variable	OR = 1.36 (0.97–1.92) per 1 unit	No

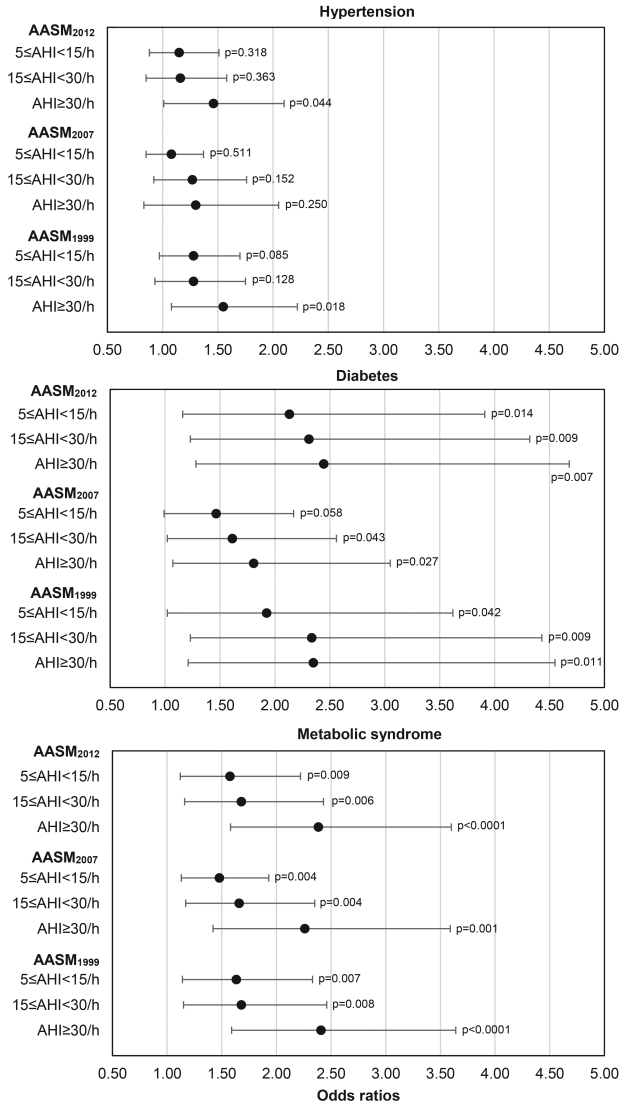
AHI = apnea-hypopnea index, BMI = body mass index, N/A = not available, NCEP ATPIII = National Cholesterol Education Program Adult Treatment panel III, OR = odds ratio, OSA = obstructive sleep apnea, PG = polygraphy, PSG = polysomnography.

differences in OSA frequency and mean AHI scores using different hypopnea scoring definitions.[41,42] These studies were conducted in small clinical populations using a thermistor to assess airflow. It is also important to highlight that these results may not be relevant any longer considering the technical differences with current clinical practice, as most sleep centers use the nasal-cannula pressure transducer to evaluate hypopneas.

As in our study, Ruehland et al. compared AHIs derived from $AASM_{1999}$ criteria, $AASM_{2007}$ recommended criteria, and $AASM_{2007}$ alternative criteria (≥ 50% airflow reduction associated with 3% desaturation or an arousal).[10] They explored the effect of hypopnea definition on the prevalence of OSA in a clinical population using nasal pressure for airflow assessment and demonstrated that using these standard hypopnea definitions leads to marked differences in AHI. For example, the median AHI obtained using the $AASM_{2007}$ recommended criteria for scoring hypopneas was approximately 30% of the median AHI obtained using the $AASM_{1999}$ criteria. In our study, this correspondence was a little higher, 40% of the $AASM_{1999}$ criteria and could be explained by the differences in the source of sample used (clinical versus general population), the sample size (328 versus 2,162), and the more liberal interpretation of "discernible" difference in flow used by the authors.[10]

Few studies have evaluated the effect of different hypopnea scoring criteria in population-based research samples. Redline et al. analyzed data from the Sleep Heart Health Study.[43] They

Figure 4—Association between AHIs and cardiometabolic outcomes.



Odds ratio and 95% confidence intervals of the association between apnea-hypopnea index (AHI) categories (AHI 5 to < 15, AHI 15 to < 30, and AHI ≥ 30 events/h compared to AHI < 5 events/h) derived from three different recommended AASM criteria (1999, 2007, and 2012) and the presence of hypertension (n = 2,147), diabetes (n = 2,147) and metabolic syndrome (n = 2,149) in the HypnoLaus cohort. Data analyzed with multivariable logistic regression adjusted for age, body mass index, and sex.

examined the effect of using 11 different criteria for scoring hypopneas on the prevalence of disease and found that the median values of respiratory disturbance index (RDI) varied by approximately tenfold for definitions that used the most liberal criteria for event identification (using amplitude changes without any requirement for associated desaturation or arousal) to the most conservative definition (requiring an associated > 5% desaturation with amplitude changes).

Our findings showing that the $AASM_{2012}$ recommended criteria results in higher AHI compared to the $AASM_{2007}$ recommended criteria and doubles approximately the number of patients in whom OSA is diagnosed are in agreement with previous studies.[8,9] BaHammam et al.[9] showed that the AHI derived from $AASM_{2007}$ recommended was 62% lower than the $AASM_{2012}$ recommended criteria. Considering the AHI thresholds of ≥ 5, ≥ 15, and ≥ 30 events/h, they found that the $AASM_{2007}$ recommended criteria underestimated by 45%, 52%, and 32%, respectively, the patients with OSA identified by the $AASM_{2012}$ recommended criteria. In our study, we found a lower underdiagnosis rate for mild (34.9%) and moderate OSA (48.6%), but higher for severe OSA (54.2%). This could be because they used a clinical sample suspected for OSA, in which the proportion of OSA severity was overestimated compared to a general population sample.

In a retrospective study performed in 112 consecutive patients of an Australian clinical sleep laboratory in a tertiary hospital, Duce et al.[8] investigated the equivalent AHI thresholds regarding the $AASM_{1999}$, $AASM_{2012}$ recommended, and both the $AASM_{2007}$ recommended and alternative criteria. To achieve the same OSA prevalence as the $AASM_{2012}$ recommended criteria at AHI thresholds of ≥ 5, ≥ 15, and ≥ 30 events/h, they showed that the $AASM_{2007}$ recommended criteria would have to change their thresholds to 2.6, 7.2, and 14.1 events/h, respectively and the $AASM_{1999}$ criteria to 7.3, 17.4, and 31.7 events/h, respectively. Overall, these findings are in agreement with our results from a general population sample. They also established equations to convert the different AHIs to one another, which were close to ours.

In terms of clinical relevance, our study additionally compared the association of OSA, based on different AHI thresholds, with the presence of cardiometabolic outcomes using the three scoring criteria. We observed more significant associations with hypertension and diabetes using the $AASM_{2012}$ and $AASM_{1999}$ criteria, both of which require a lower oxygen desaturation and consider arousal for defining a hypopnea when compared to the $AASM_{2007}$ recommended criteria. Although there is apparently an equivalence in the 3% or 4% criterion of oxygen desaturation for hypopnea definition in terms of increased cardiovascular risk,[44,45] a debate about the clinical relevance of the arousal as part of the hypopnea definition exists. The inclusion of an arousal or the decrease in oxygen desaturation threshold (4% versus 3%) from the $AASM_{2007}$ to $AASM_{2012}$ recommended criteria seem to contribute almost equally to the resulting AHI increase.[8] When testing 3% oxygen desaturation index (ODI), 4% ODI and arousal index as predictors of hypertension, diabetes, and metabolic syndrome in our sample (data not shown), we found independent associations of both 3% ODI and 4% ODI with diabetes and metabolic syndrome, but not with hypertension. No significant association was observed with arousal index alone. However, the treatment of sleep-disordered breathing associated with sleep fragmentation, but not with oxygen desaturation, has shown benefits on daytime sleepiness,[46,47] suggesting that the inclusion of arousals may be clinically relevant. Through ROC analysis, we observed that the AHIs derived from the three scoring criteria were significantly and similarly associated with the presence of hypertension, diabetes, and metabolic syndrome. However, the AHI thresholds (considering equal weight to sensitivity and specificity) that better predicted each

Table 6—Population-based studies on the association between obstructive sleep apnea and diabetes.

Study, Year	Country	Sample Size	Male (%)	Mean Age (years)	Mean BMI (kg/m^2)	Outcome Definition	Study Design	Diagnostic Method	Hypopnea Criteria	OSA Category (AHI)	Results	Association
Resnick et al. 2003	USA	4,872	44.5	62.3	28.4	Self-reported diabetes and use of antidiabetic medications	Cross-sectional	Standard PSG	70% decrease in airflow	≥ 15 events/h	OR = 1.02 (0.82–1.26)	No
										< 5 events/h		
Reichmuth et al. 2005	USA	1,387	56.4	49.0	28.9	Self-report of physician-diagnosed diabetes	Cross-sectional	Standard PSG	Discernible reduction in airflow with at least a 4% desaturation	≥ 15 events/h	OR = 2.30 (1.28–4.11)	Yes
										5 to < 15 events/h	OR = 1.25 (0.75–2.07)	
										< 5 events/h		
Ronksley et al. 2009	Canada	2,149	62.6	50.1	31.3	Self-reported diabetes and use of antidiabetic medications	Cross-sectional	Portable PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 2.18 (1.22–3.89)	Yes
										15 to < 30 events/h	OR = 1.02 (0.54–1.93)	No
										5 to < 15 events/h	OR = 0.95 (0.53–1.71)	
										< 5 events/h		
Reichmuth et al. 2005	USA	978	N/A	N/A	N/A	Fasting glucose ≥ 126 mg/dL or self-report of physician-diagnosed diabetes	Pro-spective	Standard PSG	Discernible reduction in airflow with at least a 4% desaturation	≥ 15 events/h	OR = 0.91 (0.36–2.33)	No
										5 to < 15 events/h	OR = 1.00 (0.49–2.02)	
										< 5 events/h		
Botros et al. 2009	USA	544	93.4	61.5	33.2	Fasting glucose ≥ 126 mg/dL and self-report of physician-diagnosed diabetes	Pro-spective	Standard PSG	Discernible reduction in airflow or a < 50% decrease in airflow with at least 3% desaturation or an arousal	Quartiles	HR = 1.43 (1.10–1.86) per quartile	Yes
Kendzerska et al. 2014	Canada	8,678	62	48	28.4	Validated algorithm that identifies people with diabetes as those having at least 1 hospitalization record or at least 2 physician services claims bearing a diagnosis of diabetes within 2-years	Pro-spective	Standard PSG	Discernible reduction in airflow or a < 50% decrease in airflow with at least 3% desaturation or an arousal	≥ 30 events/h	OR = 1.31 (1.07–1.61)	Yes
										15 to < 30 events/h	OR = 1.23 (1.00–1.51)	No
										5 to < 15 events/h	OR = 1.23 (1.00–1.50)	No
										< 5 events/h		
Appleton et al. 2015	Australia	736	100	59.7	28.4	Fasting glucose ≥ 126 mg/dL or HbA1c ≥ 6.5% or self-report of physician-diagnosed diabetes or use of antidiabetic medication	Pro-spective	Standard PSG	Discernible reduction in airflow or a < 50% decrease in airflow with at least 3% desaturation or an arousal	AHI ≥ 30 events/h	OR = 2.6 (1.1–6.1)	Yes
										20 to < 30 events/h	OR = 1.1 (0.4–3.0)	No
										10 to < 20 events/h	OR = 1.5 (0.7–3.4)	No
										< 10 events/h		
Nagayoshi et al. 2016	USA	1,453	46.3	62.5	28.3	Self-report of physician-diagnosed diabetes or use of antidiabetic medication	Pro-spective	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 2.03 (1.20–3.44)	Yes
										15 to < 30 events/h	OR = 1.18 (0.72–1.95)	No
										5 to < 15 events/h	OR = 0.59 (0.36–0.96)	No
										< 5 events/h		

AHI = apnea-hypopnea index, BMI = body mass index, N/A = not available, HbA1c = glycated hemoglobin, HR = hazard ratio, OR = odds ratio, OSA = obstructive sleep apnea, PSG = polysomnography.

of these outcomes using the $AASM_{2007}$ recommended criteria were approximately half of the AHI values established for both the $AASM_{2012}$ recommended and the $AASM_{1999}$ criteria. Thus, we believe that the most important is that AHI thresholds need to be adjusted when using stricter hypopnea criteria for a proper interpretation and decision to treat OSA. In our study, we could provide correction factors, reliably translating AHIs from $AASM_{1999}$, $AASM_{2007}$ and $AASM_{2012}$ criteria in a large middle-aged general population sample.

There are several limitations in our study. First, it could be argued that scoring respiratory effort-related arousals (RERAs) would capture events scored with the $AASM_{1999}$ criteria that do not fulfill the hypopnea requirements of the $AASM_{2012}$ criteria, and the RDI would be similar using both scoring criteria. Although we did not look specifically at this point, Ruehland et al. have shown that the AHI differences between $AASM_{1999}$ and $AASM_{2012}$ were mostly due to events with ≥ 50% flow reduction, and not associated with significant desaturation or arousal, so these events could not be scored as RERAs (as they are not associated with arousal).[10] We do not believe that including RERAs in the analysis could explain the differences found because these events are rather rare in our population.[48] Second, in this study, OSA was estimated in the presence of respiratory events at different AHI thresholds, but we did not consider other elements as symptoms (sleepiness, fatigue, headache) or associated comorbidities as suggested by the International Classification of Sleep Disorders (ICSD-3).[1] Although we believe that symptoms such as sleepiness are important for clinical decision, a very inclusive ICSD-3 definition for OSA syndrome would have led to a much higher and

Table 7—Population-based studies on the association between obstructive sleep apnea and hypertension.

Study, Year	Country	Sample Size	Male (%)	Mean Age (years)	Mean BMI (kg/m²)	Outcome Definition	Study Design	Diagnostic Method	Hypopnea Criteria	OSA Category (AHI)	Results	Association
Young et al. 1997	USA	1,069	57.7	45.3	29.4	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Cross-sectional	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 3.07 (1.65–1.74)	Yes
										15 to < 30 events/h	OR = 1.75 (1.28–2.40)	Yes
										5 to < 15 events/h	OR = 1.21 (1.09–1.34)	Yes
										0 events/h		
Nieto et al. 2000	USA	6,132	47.2	N/A	28.5	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Cross-sectional	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 1.37 (1.03–1.83)	Yes
										15 to < 30 events/h	OR = 1.25 (1.00–1.56)	No
										5 to < 15 events/h	OR = 1.20 (1.01–1.42)	Yes
										1.5 to < 5 events/h	OR = 1.07 (0.91–1.26)	No
										< 1.5 events/h		
Durán et al. 2001	Spain	555	58.4	N/A	N/A	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Cross-sectional	Portable PSG	Discernible 50% reduction in airflow with at least a 4% desaturation or an arousal	≥ 15 events/h	OR = 2.28 (0.92–5.66)	No
										5 to < 15 events/h	OR = 1.30 (0.54–4.14)	No
										0 to < 5 events/h	OR = 2.47 (1.06–5.76)	Yes
										0 events/h		
Haas et al. 2005	USA	2,477	45.7	40–59	28.9	SBP ≥ 140 mmHg and DBP ≥ 90 mmHg or SBP < 140 mmHg and DBP ≥ 90 mmHg	Cross-sectional	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 2.27 (1.13–4.56)	Yes
										15 to < 30 events/h	OR = 2.32 (1.27–4.24)	Yes
										5 to < 15 events/h	OR = 1.78 (1.09–2.92)	Yes
										1.5 to < 5 events/h	OR = 1.30 (0.80–2.12)	No
										< 1.5 events/h		
Haas et al. 2005	USA	3,643	48.1	≥ 60	28.2	SBP ≥ 140 mmHg and DBP ≥ 90 mmHg or SBP < 140 mmHg and DBP ≥ 90 mmHg	Cross-sectional	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 1.30 (0.63–2.71)	No
										15 to < 30 events/h	OR = 1.04 (0.56–1.94)	No
										5 to < 15 events/h	OR = 0.93 (0.55–1.55)	No
										1.5 to < 5 events/h	OR = 1.14 (0.69–1.91)	No
										< 1.5 events/h		
Kapur et al. 2008 (sleepy)	USA	787	44.9	61.8	29.3	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Cross-sectional	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 2.83 (1.33–6.04)	Yes
										15 to < 30 events/h	OR = 1.94 (0.97–3.89)	No
										5 to < 15 events/h	OR = 1.26 (0.77–2.07)	No
										1.5 to < 5 events/h	OR = 1.04 (0.63–1.70)	No
										< 1.5 events/h		
Kapur et al. 2008 (not sleepy)	USA	5,259	47.6	63.2	28.4	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Cross-sectional	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 1.22 (0.89–1.68)	No
										15 to < 30 events/h	OR = 1.07 (0.84–1.36)	No
										5 to < 15 events/h	OR = 1.16 (0.97–1.40)	No
										1.5 to < 5 events/h	OR = 1.05 (0.88–1.25)	No
										< 1.5 events/h		
Redline et al. 2014	USA	14,440	39.8	41.2	29.4	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Cross-sectional	PG	30% decrease in airflow with at least a 3% desaturation	≥ 15 events/h	OR = 1.4 (1.2–1.7)	Yes
										< 15 events/h		
Peppard et al. 2000	USA	893	56	47	29	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Pro-spective	Standard PSG	Discernible reduction in airflow with at least a 4% desaturation	≥ 15 events/h	OR = 2.89 (1.46–5.64)	Yes
										5 to < 15 events/h	OR = 2.03 (1.13–1.78)	Yes
										0 to < 5 events/h	OR = 1.42 (1.13–1.78)	Yes
										0 events/h		
O'Connor et al. 2009	USA	2470	44.7	59.6	27.9	SBP ≥ 140 mmHg or DBP ≥ 90 mmHg or use of antihypertensive medication	Pro-spective	Standard PSG	30% decrease in airflow with at least a 4% desaturation	≥ 30 events/h	OR = 1.50 (0.91–2.46)	No
										15 to < 30 events/h	OR = 1.09 (0.77–1.54)	No
										5 to < 15 events/h	OR = 0.94 (0.73–1.22)	No
										< 5 events/h		
Guillot et al. 2013	France	372	34.7	68.1	24.4	Mean 24-hour SBP > 140 mmHg and DBP > 85 mmHg or the use of antihypertensive medication	Pro-spective	PG	Discernible 50% reduction in airflow with at least a 3% desaturation	≥ 30 events/h	OR = 1.77 (1.11–2.80)	Yes
										15 to < 30 events/h	OR = 1.31 (0.86–1.99)	No
										< 15 events/h		

AHI = apnea-hypopnea index, BMI = body mass index, DBP = diastolic blood pressure, N/A = not available, HR = hazard ratio, OR = odds ratio, OSA = obstructive sleep apnea, PG = polygraphy, PSG = polysomnography, SBP = systolic blood pressure.

unrealistic rate of OSA.[49] Third, due to the cross-sectional design of the study, we cannot infer causality regarding the associations between OSA severity derived from each scoring criteria and the cardiometabolic outcomes.

Last, this study focused on different AHI definitions but other biomarkers such as autonomic activation, inflammation, and genetic and demographic-related factors may prove to be a better predictor or may be used in combination with AHI to stratify OSA-associated risks. Prospective studies are thus required to better understand the parameters that should be used to determine OSA associated risk.

In conclusion, our study demonstrates that using different standard hypopnea definitions leads to marked differences in AHI. The use of $AASM_{2007}$ hypopnea criteria leads to lower equivalent AHI cutoffs for the association with OSA-related comorbidities compared to both $AASM_{1999}$ and $AASM_{2012}$ criteria. However, prospective studies are necessary to further evaluate the extent to which cardiovascular and other health

outcomes may be differentially predicted by different AHI definitions, and to identify other sleep-related metrics that may be even more efficient to do so.

ABBREVIATIONS

AASM, American Academy of Sleep Medicine
$AASM_{1999}$, "Chicago criteria" hypopnea definition
$AASM_{2007}$, 2007 AASM recommended hypopnea definition
$AASM_{2012}$, 2012 AASM recommended hypopnea definition
AHI, apnea-hypopnea index
AUC, area under the curve
BMI, body mass index
CHUV, Centre Hospitalier Universitaire Vaudois
DBP, diastolic blood pressure
ECG, electrocardiogram
EEG, electroencephalogram
EMG, electromyogram
HDL, high-density lipoprotein
ICSD, International Classification of Sleep Disorders
IQR, interquartile range
no-OSA, without obstructive sleep apnea
OR, odds ratio
OSA, obstructive sleep apnea
PSG, polysomnography
RDI, respiratory disturbance index
RERA, respiratory effort related arousal
ROC, receiver operating characteristic curve
SBP, systolic blood pressure
SpO_2, oxygen saturation

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