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Somesthetic perception of upper airway airflow in individuals with and without obstructive sleep apnea: a prospective study

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Abstract

Purpose Patients with obstructive sleep apnea (OSA) often present altered upper airways (UA) receptors. This study aimed to validate conscious sensory abilities related to oropharyngeal airflow perception in individuals with OSA and controls, as a first step toward developing a clinical screening approach based on airflow perception.

Methods The oropharynx was subjected to experimenter-induced mechanical modifications, generating variations in its volume and wall tension. Seven conditions modified airflow in an aggravating or facilitating manner, each item scored 1 when matching the expected response and 0 otherwise, yielding a total sensitivity score ranging from 0 to 7. This prospective study included 112 participants: 41 with OSA and 71 controls (60 questionnaire-negative and 11 PSG-confirmed non-OSA). To limit bias, experimenters were blinded to participants' group assignment, and participants were blinded to their PSG results and questionnaire scores.

Results Participants demonstrated significant somesthetic perception of airflow variations, with scores above zero ($p < 0.01$) and exceeding predefined pragmatic thresholds (up to 51%). Between-group differences were small ($p = 0.0367$ or > 0.05) and largely compatible with clinical equivalence ($\delta \pm 1$).

Conclusion All participants perceived airflow variations, consistent with expected somesthetic perceptions. This proof-of-concept supports measuring airflow perception in at-risk OSA populations.

Trial Registration Registered at clinicaltrials.gov, ID: NCT06092710, URL: https://clinicaltrials.gov/study/NCT06092710

Keywords OSA, Upper airway collapsibility, Somesthetic perception, Airflow perception, Somatosensory perception

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Brief Summary

Current knowledge/study rationale

The diagnosis of OSA remains challenging given its medical implications and impact on overall health. This study aims at establishing the conceptual basis for a clinical screening approach, by assessing participants' somatosensory ability to consciously perceive variations in airflow through their upper airways.

Study impact

This preliminary study shows that individuals with and without OSA are able to perceive airflow variations in their upper airways. This comparable somatosensory ability may provide a basis for developing protocols that quantify airflow perception sensitivity to identify individuals at risk of OSA.

Introduction

Obstructive sleep apnea (OSA) is a disorder characterized by upper airway (UA) collapse, leading to reductions or cessations of airflow, oxygen desaturation, and fragmented sleep accompanied by respiratory effort (Sateia 2014; Osman et al. 2018). This syndrome is associated with complications including daytime sleepiness, neurocognitive disturbances, and cardiovascular diseases. The prevalence of OSA is estimated to range between 6 and 17% for adults, according to studies conducted in predominantly Western populations, with a two- to threefold higher risk for men (Senaratna et al. 2017a). The prevalence increases with obesity and age, underscoring the need for effective screening (Gauld et al. 2020; Moeller et al. 2021). OSA is a major public health concern and remains frequently underdiagnosed (Simpson et al. 2013). Polysomnography (PSG) is the gold standard examination for diagnosis, but its accessibility is limited due to costs and the requirement for specialized equipment (Kapur et al. 2017). The pharynx consists of a musculoaponeurotic gutter bounded by its dorsolateral walls. Pharyngeal lumen patency is influenced by its viscoelastic properties, particularly during inspiration (Koka et al. 2021). Head position, tongue posture during sleep, fluid shifts in the supine position, surface tension forces, ventilatory responses to transient stimuli, and oral breathing all exert combined effects. The OSA mechanism involves neurological control, muscular reactivity, and muscular efficiency, which tends toward hypotonia during sleep (Edwards et al. 2017; Broderick and Guilleminault 2008). Before hypoxemia/hypercapnia come into play, UA patency is maintained through the control of the pharyngeal dilatory muscles (Kubin 2016). This constant regulation of UA patency is ensured by the combined role of all pharyngeal dilatory muscles and those forming the pharyngeal gutter (Sokoloff 2004). The reactivity of these muscles depends in particular on the quality of afferent inputs from the numerous receptors located within the UA. When this feedback is impaired, neuromuscular responses can contribute to reduced pharyngeal patency in OSA. The arrangement of muscles surrounding the pharynx is complex and characterized by a three-dimensional topography combining parallel, perpendicular, and oblique orientations of muscle fibers relative to the longitudinal axis of the pharyngeal gutter. This configuration implies a biomechanical behavior analogous to muscular hydrostats (Kairaitis 2010), more commonly observed in animal biology (e.g., the elephant trunk or octopus tentacles). The orientation of these muscle fibers dynamically changes with the shape of the pharyngeal lumen and with positional adjustments of surrounding structures (head, mandible, shoulder girdle, tongue, and hyoid bone). Numerous somatosensory receptors sensitive to shape deformations, airflow, temperature, and pressure variations are distributed across both superficial and deep layers of the pharyngeal mucosa. This mechanical linkage enables neuromuscular coupling between the muscular content of the pharynx and tongue (Mu And Sanders 2010) and their mucosal and submucosal envelope. This sensorimotor system controls the shape of the elastic segments constituting the pharynx (Mu And Sanders 2007) and adjusts cavity geometry to ventilatory requirements (Eastwood et al. 2005). Consequently, UA stability depends on the integrity and functional quality of these receptors. Multiple factors can impair receptor function (Talmant et al. 2009; Friberg et al. 1998), including palatal vibration during snoring, edema, inflammation, hypoxia, gastroesophageal reflux, mucosal dryness, postnasal drip, tobacco smoke, environmental pollutants, and neurodegenerative processes. The affective dimension related to the sensation of 'breathing sufficiently' is intrinsically tied to the central nervous system's processing of sensory signals and is shaped by the subject's prior ventilatory experiences, whether intrinsically positive or negative. Participants can consciously perceive somesthetic information transmitted by sensory receptors. This study represents an initial step toward supporting the feasibility of a clinical approach based on somesthetic perception, with the aim of creating a predictive score to identify individuals at risk for OSA. The primary objective of this study was to assess whether both OSA and control participants demonstrate clinically relevant sensory abilities, as measured by a sensitivity score.

Material and methods

This prospective study was conducted at the Sleep Medicine Center of Clinique André Renard in Liège (Belgium) and in private practices located in Saive (Belgium) and Nantes (France). The study period extended from January 1, 2023, to November 30, 2024. All participants provided written informed consent. The study was approved by

the Ethics Committee of Clinique André Renard and registered at *ClinicalTrials.gov* (Identifier: NCT06092710, URL: https://clinicaltrials.gov/study/NCT06092710).

Population

Participants selected by two neurologists specialized in sleep medicine at André Renard Clinic were assigned to four groups: non-OSA (AHI < 5), mild OSA (5 ≤ AHI < 15), moderate OSA (15 ≤ AHI < 30), and severe OSA (AHI ≥ 30), according to AASM recommendations. These patients underwent in-laboratory type 1 PSG without knowledge of their results. Participants recruited from the investigators' private osteopathic practices constituted the control group. They completed self-assessment questionnaires screening for OSA (Berlin Questionnaire (Senaratna et al. 2017b)), fatigue (Pichot Fatigue Scale (Pichot And Brun 1984; Gardenas 2002) and Fatigue, Fatigability and Function Scale—FFF—(Cambron et al. 2006), and sleepiness (Epworth Sleepiness Scale (Johns 1991)), also without access to their results.

Inclusion criteria

- Age > 18 years
- Understanding of the absence of risk and provision of written informed consent
- No prior diagnosis of OSA and no treatment related to suspected OSA

Exclusion criteria

- Recent surgery under general anesthesia causing pain or discomfort during testing
- Any respiratory, neurological, systemic, or cognitive condition interfering with test performance
- Absence of data at the time of unblinding
- For the control group: a score above the suspicion threshold in any of the screening questionnaires — OSA (Berlin Questionnaire > 2 positive categories), fatigue (Pichot > 22/32 or FFF > 10/24), or sleepiness (Epworth > 8/24) — at the time of unblinding

Assessment protocol

A sensory input screening protocol was designed to evaluate somesthetic perception of airflow through the pharynx. During the examination, the oropharynx was subjected to variations in geometry, volume, and wall tension, inducing changes in ventilatory flow (Fig. 1).

The procedure lasted 15 min, during which a scoring grid was completed for each item (Fig. 2). It was conducted in a consultation room equipped with an examination table. The environment was kept comfortable

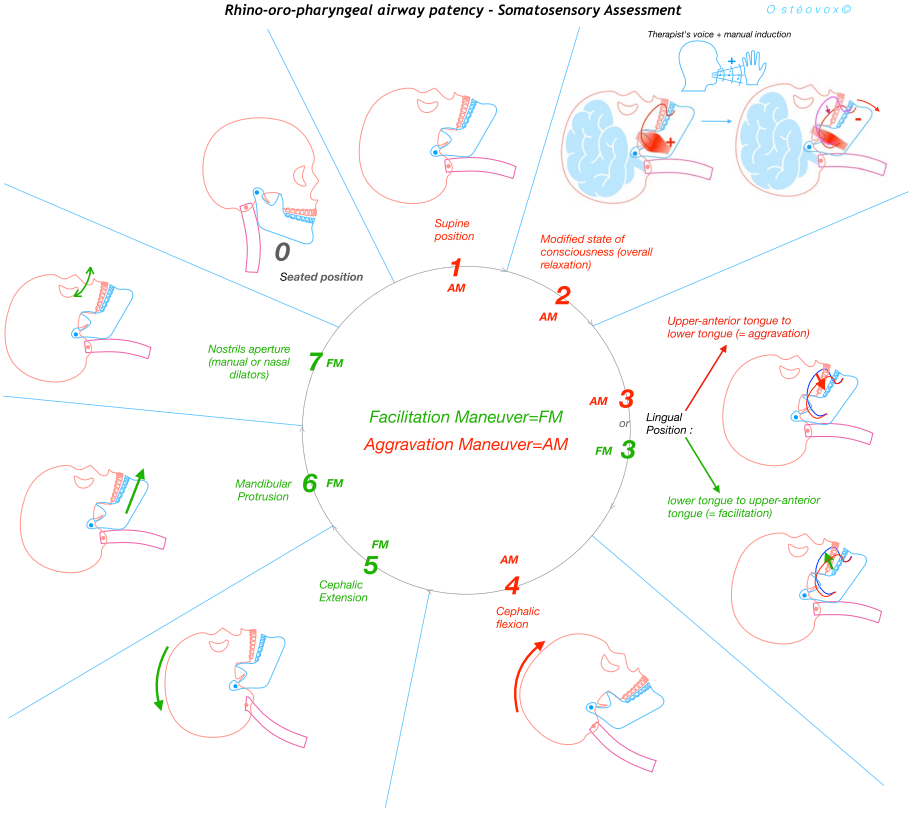

Fig. 1 Description of Osteovox© protocol to induce variations on the oropharynx

Oropharyngeal Sensitivity Score — Ostéovox© —				
Date :	Name :		Age:	
Examination	Item	*Scoring rule:* *- Aggravation or facilitation felt= **1*** *- No aggravation or no facilitation felt= **0***	*Scores*	
			1	0
Supine position	*1*	*Aggravation maneuver*		
Modified state of consciousness (overall relaxation)	*2*	*Aggravation maneuver*		
Cephalic Flexion	*3*	*Aggravation maneuver*		
depending on the initial tongue position: - Upper-anterior tongue to lower tongue or - Lower tongue to upper-anterior tongue	*4*	*- Aggravation maneuver if the tongue moves from up to low* *- Facilitation maneuver if the tongue moves from low to up*		
Cephalic Extension	*5*	*Facilitation maneuver*		
Mandibular advancement	*6*	*Facilitation maneuver*		
Nostrils aperture	*7*	*Facilitation maneuver*		
Total Score			… / 7	

Fig. 2 Oropharyngeal sensitivity score grid (Osteovox.©)

(temperature, lighting, and acoustics) to allow participants to lie down and relax throughout the session. As described above in Osteovox protocol, the investigators were jointly trained to ensure consistent verbal and procedural routines when evaluating somesthetic information related to airflow through the naso-oropharyngeal airway. To avoid confirmation and observation bias, both investigators and participants were blinded to PSG and questionnaire results (Epworth, Berlin, FFF, and Pichot). Participants were instructed to focus their attention on perceiving the passage of air through the nasopharyngeal area. They were guided by the investigator through a somatosensory awareness process. The reference somatosensory perception was defined as the conscious somesthetic sensation of airflow in the upright position during wakefulness. Participants were informed about the manual signaling system used to answer the investigator's questions. Possible responses were: "aggravation," "facilitation," or "no change."

Each response was compared to the theoretical prediction of the tested item and scored as follows:

- 1: if the response matched the predicted "aggravating" or "facilitating" condition
- 0: if no variation was perceived or the response contradicted the theoretical prediction

The selected items, each designed to induce variations in oropharyngeal behavior, formed the somesthetic sensitivity score, defined as follows:

1. Supine position: 1 = aggravating (Iftikhar et al. 2014); 0 = facilitation or no change
2. Modified state of consciousness (near sleep onset): 1 = aggravating (Eastwood et al. 2005, 2002); 0 = facilitation or no change
3. Perception of an aggravating or facilitating change related to tongue posture (Sokoloff 2004; Eastwood et al. 2005) 1 = perceived change; 0 = no perception
4. Head flexion: 1 = aggravating (Walsh et al. 2008); 0 = facilitation or no change
5. Head extension: 1 = facilitation (Walsh et al. 2008; Kobayashi et al. 2011); 0 = aggravating or no change
6. Mandibular advancement: 1 = facilitation (Ng et al. 2005; Ramar et al. 2015); 0 = aggravating or no change
7. Nasal ala dilation: 1 = facilitation (Garcia And Woodson 2020; Lavie et al. 1981); 0 = aggravating or no change

The total score ranged from **0** (no sensitivity) to **7** (high sensitivity).

Statistical analysis

The main comparison contrasted participants with obstructive sleep apnea (OSA) and control participants (including questionnaire-negative controls and PSG-confirmed non-OSA individuals). Exploratory subgroup analyses examined differences across the five predefined participant groups (questionnaire-negative controls, PSG non-OSA, mild OSA, moderate OSA, and severe OSA).

The statistical analysis was designed to address two sequential research questions.

First, do participants perceive the theoretically expected airflow variations across the test maneuvers?

To address the first question, sensitivity scores were calculated for aggravating maneuvers (AM), facilitating maneuvers (FM), and the total score (AM + FM) for each groups. Descriptive analyses of score distributions (median, IQR, and range) were performed for each group. One-sample Wilcoxon signed-rank tests were applied to assess whether sensitivity scores were significantly greater than a floor reference value of zero, which represents the absence of sensitivity to airflow variations. Hodges-Lehmann (HL) estimates and 95% confidence intervals (CI) were calculated, and effect sizes (r) were reported. The null hypothesis (score = 0) was rejected when $p < 0.01$, indicating that participants perceived the expected airflow variations. The proportion of participants achieving scores above predefined pragmatic thresholds (AM/FM ≥ 3 and AM + FM ≥ 5) were reported.

Second, do all participant groups demonstrate sufficient somesthetic perception of the expected airflow variations?

Differences in sensitivity scores between OSA and control groups were evaluated using Mann–Whitney U test, with HL estimates of median differences and 95% CI.

Differences in sensitivity across the five predefined participant groups were assessed using Kruskal–Wallis tests. When appropriate, pairwise comparisons were performed using Wilcoxon tests with adjustment for multiple comparisons.

To facilitate interpretation of non-significant between-group differences, equivalence analyses were conducted using the 95% CI of median differences. Clinical equivalence margins of ± 0.5 and ± 1 point were prespecified. Equivalence was considered present when the 95% CI of the between-group difference was fully contained within these margins.

Given observed baseline differences in age and body mass index (BMI) between groups, additional analyses were conducted using median (quantile) regression models. Sensitivity scores (AM, FM, AM + FM) were modeled as dependent variables, with OSA status, age, and BMI included as predictors. Bootstrap standard errors were used to estimate statistical significance.

Demographic characteristics were compared between the OSA and control groups using Welch's t-tests for normally distributed continuous variables, Wilcoxon rank-sum tests for non-normally distributed continuous variables, and Fisher's exact tests for categorical variables. Normality was assessed using Q-Q plots.

All statistical tests were two-sided unless otherwise specified, and statistical significance was defined as $p < 0.05$.

All analyses were performed by an independent biostatistician (mystat.be) using R software (version 4.4.1). Microsoft Excel was used for data handling and preparation of summary tables.

Results

A total of 112 participants were enrolled. Following unblinding, group assignments were as follows (Fig. 3):

- Negative-questionnaire control group: 60 subjects
- PSG group: 52 subjects, subdivided into four groups: Non-OSA ($n = 11$), Mild OSA ($n = 9$), Moderate OSA ($n = 18$) and Severe OSA ($n = 14$)

For primary analyses, participants were grouped into a Control group (questionnaire-negative controls and PSG-confirmed non-OSA, $n = 71$) and an OSA group (mild, moderate, and severe OSA, $n = 41$).

Characteristics of the two groups are presented in Table 1. Participants with OSA were significantly older than controls (Welch's t-test, $p = 0.001$). Sex distribution also differed between groups, with a higher proportion of men in the OSA group compared with controls (Fisher's exact test, $p = 0.008$). BMI was significantly higher in participants with OSA than in controls (Wilcoxon rank-sum test, $p < 0.001$). Median (quantile) regression analyses adjusting for age and BMI confirmed that OSA status was not independently associated with sensitivity scores. None of the predictors (OSA status, age, or BMI) showed a significant association with AM, FM or AM + FM (all $p > 0.35$), although BMI showed a non-significant trend toward higher AM + FM ($p = 0.057$). These findings indicate that the perception of airflow variations was not influenced by OSA status, age, or BMI.

Score distributions for each group are presented as boxplots (Figs. 4 and 5a–c) and summarized in Tables 2 and 3.

Sensitivity scores were significantly greater than zero in both groups for aggravating maneuvers, facilitating maneuvers, and total scores (all $p < 0.01$). Hodges–Lehmann estimates for AM and FM scores were 2 (95% CI [1.5–4]) in both groups, and 4–5 for AM + FM (95% CI), with large effect sizes ($r \approx 0.85–0.90$), indicating that participants reliably perceived the expected airflow variations. Participants in both groups reached predefined pragmatic thresholds (AM ≥ 3, FM ≥ 3, AM + FM ≥ 5). When tested against these thresholds, sensitivity scores were not statistically greater in either group (one-sided Wilcoxon tests, all $p \approx 1$). Corresponding HL estimates and their 95% CI remained close to, but did not consistently exceed, the predefined thresholds. Proportion-based analyses provided further insight. A substantial proportion of participants reached these thresholds, particularly in the OSA group. For AM ≥ 3,

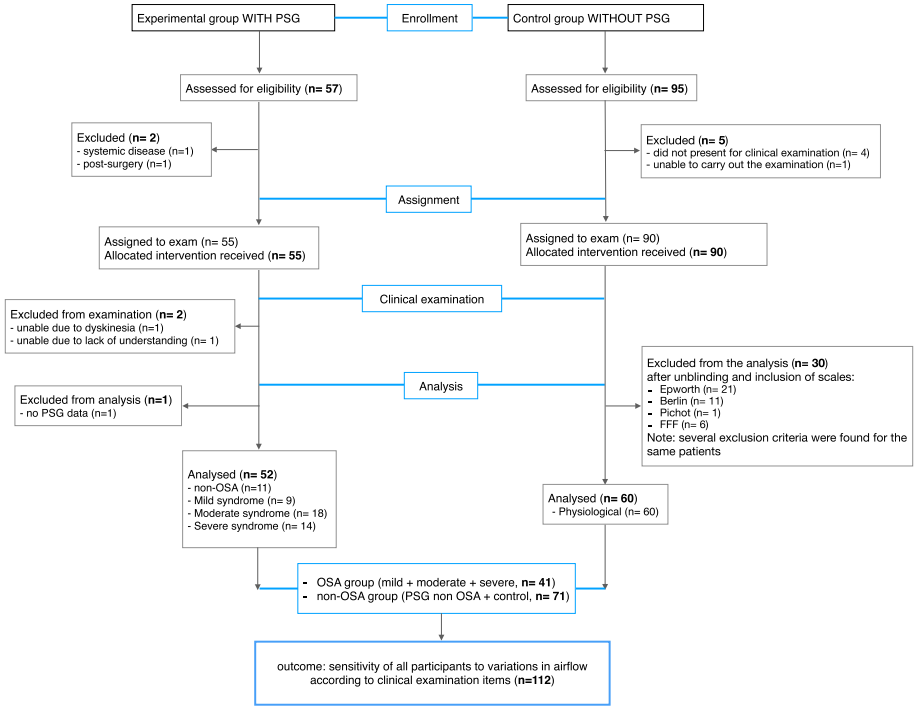

Fig. 3 Flow diagram of participant allocation

Table 1 Participant characteristics

Demographic Characteristics	OSA Group	Control Group	p-value
Women/Men	16/25	48/23	0.008
Age (years)	50 ± 11.5	42 ± 13	0.001
BMI (kg/m^2)	30 [21–45]	23 [17–35]	< 0.001

41% of participants with OSA reached the threshold compared with 20% of controls. For FM ≥ 3, the proportions were 44% and 38%, respectively. For the total score (AM + FM ≥ 5), 51% of participants with OSA and 38% of controls achieved the threshold.

Between-group comparisons showed small differences overall. A modest difference was observed for AM scores ($p = 0.0367$), whereas no significant differences were found for FM scores ($p = 0.412$) or total scores ($p = 0.0557$). These differences were generally small and largely compatible with clinical equivalence within predefined margins, except for total scores, for which equivalence could not be established. Taken together, these findings indicate that airflow perception is consistently present across participants, although its magnitude varies between individuals. Clinically relevant levels of

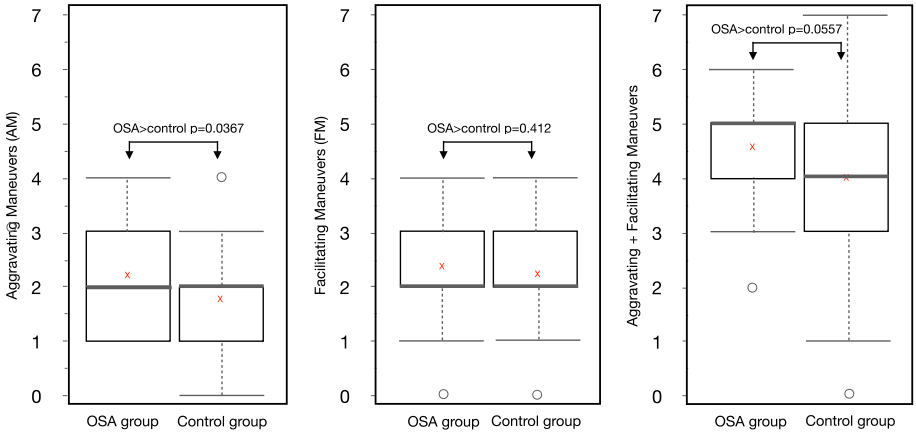

Fig. 4 Distribution of scores for AM (left), FM (center), and AM + FM (right) in the OSA and control groups. Legend: box = interquartile range (IQR; Q1 to Q3), bold black line = median, red x = mean, whiskers = min/max, open circles = outliers. All scores > 0 ($p < 0.0001$). Comparison OSA > control for AM ($p = 0.036$), FM ($p = 0.41$) and AM + FM ($p = 0.055$)

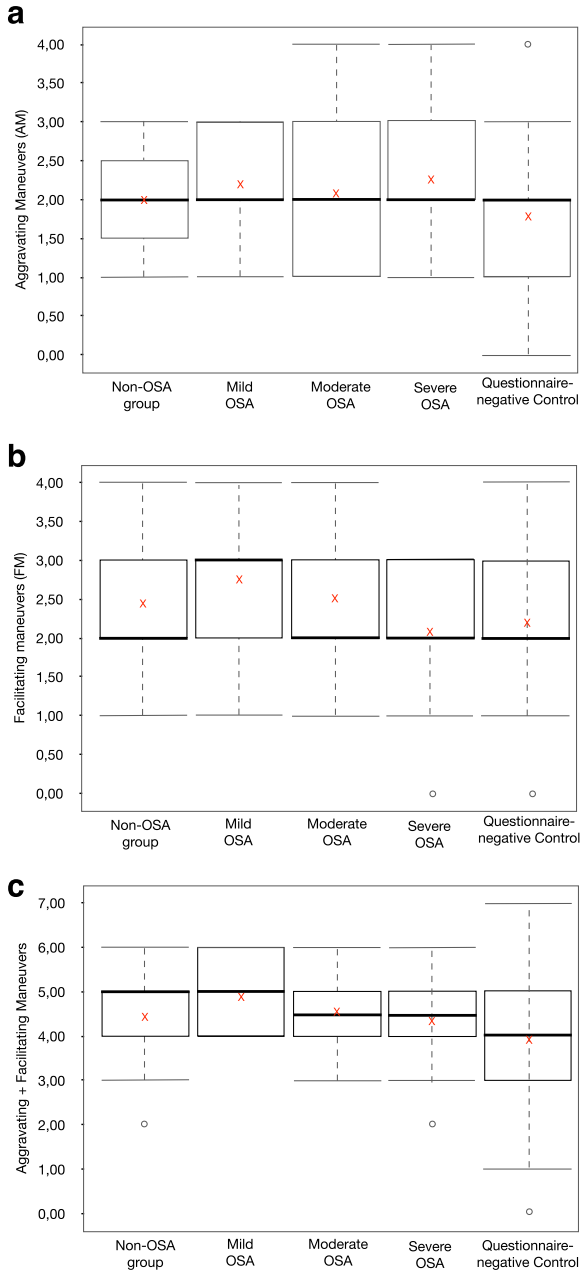

Fig. 5 **a** Distributions of AM scores for PSG groups (Non-OSA, Mild OSA, Moderate OSA, Severe OSA) and questionnaire-negative control group. Legend: box = interquartile range (IQR; Q1 to Q3), bold black line = median, red x = mean, whiskers = min/max, open circles = outliers. **b** Distributions of FM scores for PSG groups (Non-OSA, Mild OSA, Moderate OSA, Severe OSA) and questionnaire-negative control group. Legend: box = interquartile range (IQR; Q1 to Q3), bold black line = median, red x = mean, whiskers = min/max, open circles = outliers. **c** Distributions of total scores (AM + FM) for PSG groups (Non-OSA, Mild OSA, Moderate OSA, Severe OSA) and questionnaire-negative control group. Legend: box = interquartile range (IQR; Q1 to Q3), bold black line = median, red x = mean, whiskers = min/max, open circles = outliers

sensitivity were reached in a substantial subset of participants, particularly among those with OSA.

Discussion

These results confirm the presence of somesthetic perception of airflow variations in response to the tested item and reveal a relative homogeneity of clinical performance across groups. Participants demonstrated an expressible and reproductible somesthetic perception, for each theoretically facilitating or aggravating maneuvers. Notably, item-level analyses (Supplementary Material 1) revealed particularly high correct perception rates for cephalic flexion (OSA: 98%, controls: 90%), cephalic extension (OSA: 88%, controls: 89%), and nostrils aperture (OSA: 73%, controls: 82%). Several studies have previously assessed the sensory function of the oropharynx using protocols based on two-point discrimination, vibration, cold, or electrical stimulation (Guilleminault et al. 2002; Jeong et al. 2016; An et al. 2019; Hagander et al. 2009). To our knowledge, this is the first study to investigate the feasibility of directly questioning participants about their perception of airflow through the upper airways in a pragmatic clinical context. Participants with OSA typically present greater mechanical instability of their pharynx compared to controls, leading to earlier or more pronounced responses to aggravating or facilitating stimuli. This hypothesis is supported by prior research (Fogel et al. 2001, 2005; Remmers 2001) showing that sensory inputs can be heightened to enhance the reflex activation of upper airway dilator muscles. Conversely, other data (Mu And Sanders 2007; Nguyen et al. 2005) highlight somesthetic receptor impairment, which may contribute to upper airway collapsibility in OSA. These findings demonstrate that both OSA and control participants can reliably perceive airflow variations. Despite anatomical and physiological alterations associated with the disorder, patients with OSA demonstrated airflow perception comparable to control participants. These results provide the conceptual foundation for a future clinical tool based on the accuracy of somesthetic perception to support screening for OSA, with a new score based on measurements of the degrees of flexion and extension or the amplitude of mandibular advancement.

Several limitations should be considered when interpreting the findings of this study. First, although quality of sensory feedback and neuromuscular reflexes likely varies according to the severity of OSA (Mu And Sanders 2007; Guilleminault et al. 2002; Patel et al. 2018) the study was underpowered to evaluate subgroups with OSA ($n = 41$), which limits the ability to detect small or moderate differences, results should therefore be interpreted as exploratory. Second, the scoring system used in this study warrants clarification. A score of zero corresponds to the absence of correctly perceived responses

Table 2 Data of AM, FM and AM + FM scores in the OSA and control groups

	Aggravating Maneuvers (AM)						
Groups	**n**	**median**	**range [min–max]**	**IQR [Q3–Q1]**	**AM > 0 HL + effect sizes [95% CI]**	**AM ≥ 3 [95% CI]**	**OSA > control**
OSA	41	2	[1–4]	2	$p = 8.5 \times 10^{-9}$ HL: 2 [2–4] r = 0.880 [0.88–0.89]	42% ≥ 3 p ≈ 1 HL: 2 [1.5–4]	$p = 0.0367$ Equiv: δ = 1 only
Control	71	2	[0–4]	1	$p = 5.06 \times 10^{-13}$ HL: 2 [1.5–4] r = 0.873 [0.86–0.88]	20% ≥ 3 p ≈ 1 HL: 2 [1.5–4]	
	Facilitating Maneuvers (FM)						
Groups	**n**	**median**	**range [min–max]**	**IQR [Q3–Q1]**	**FM > 0 HL + effect sizes [95% CI]**	**FM ≥ 3 [95% CI]**	**OSA > control**
OSA	41	2	[0–4]	1	$p = 1.01 \times 10^{-8}$ HL: 2 [2–4] r = 0.884 [0.88–0.9]	44% ≥ 3 p ≈ 1 HL: 2 [2–4]	$p = 0.41207$ Equiv: δ = 0.5 and 1
Control	71	2	[0–4]	1	$p = 8.08 \times 10^{-14}$ HL: 2[2–4] r = 0.880 [0.88–0.89]	38% ≥ 3 p ≈ 1 HL: 2 [1.5–4]	
	Aggravating Maneuvers (AM) + Facilitating Maneuvers (FM)						
Groups	**n**	**median**	**range [min–max]**	**IQR [Q3–Q1]**	**AM + FM > 0 [95% CI]**	**AM + FM ≥ 5 [95% CI]**	**OSA > control**
OSA	41	5	[2–6]	1	$p = 8.96 \times 10^{-9}$ HL: 5 [4.5–7] r = 0.879 [0.88–0.89]	51% ≥ 5 p ≈ 1 HL: 5 [4–7]	$p = 0.05572$ not equivalent
Control	71	4	[0–7]	2	$p = 1.29 \times 10^{-13}$ HL: 5 [4–7] r = 0.873 [0.87–0.88]	38% ≥ 5 p ≈ 1 HL: 4 [3.5–7]	

across all items, which is substantially lower than what would be expected by chance alone. To address this limitation, additional analyses were performed using predefined pragmatic thresholds (AM ≥ 3, FM ≥ 3, AM + FM ≥ 5), as well as the proportion of participants exceeding these thresholds, providing a more clinically meaningful interpretation of perceptual performance. High p-values reflect the conservative nature of the test rather than absence of effect. Third, the composition of the control group represents an important limitation. A majority of control participants ($n = 60$) were classified as non-OSA based solely on negative screening questionnaires, without polysomnographic (PSG) confirmation. This approach, although motivated by ethical and logistical considerations—namely avoiding the use of limited sleep laboratory resources in asymptomatic individuals—introduces a risk of misclassification. Furthermore, PSG-confirmed non-OSA participants ($n = 11$) were combined with questionnaire-negative controls in the primary analyses, despite the fact that these individuals were referred for sleep evaluation and frequently presented other sleep disorders, including neurological conditions. This heterogeneity within the control group constitutes a potential confounder and may have increased variability, thereby reducing the sensitivity to detect true group differences. Fourth, while OSA manifests during sleep, our protocol assessed airflow perception in a modified state of consciousness. To assess the physiological relevance of our approach, we conducted pilot electroencephalographic and electromyographic recordings in a subset of participants. These recordings revealed patterns partially consistent with early-stage N1 sleep, such as reduced alpha activity, suggesting that our protocol induces a relaxed, sleep-like state. However, this state—distinct from true sleep—introduces interpretative limitations. Fifth, the study did not assess the reliability (e.g., test–retest reliability), which is a necessary step before considering clinical implementation.

Taken together, these results support the concept that airflow perception is a graded and variable sensory ability rather than a binary phenomenon. While not sufficient at this stage for diagnostic purposes, these findings provide a conceptual basis for the development of future protocols aimed at quantifying the precision of this perception, for example using graded or stepwise measurements, to identify individuals at risk of OSA.

Conclusion

This study aimed to address the question: "Do individuals consciously perceive variations in airflow?". The results are clear: they do. The observed clinical equivalence across groups suggests that measuring perceptual

Table 3 Data of AM, FM and AM + FM scores for each PSG subgroup and questionnaire-negative control group

	Aggravating Maneuvers (AM)						
Groups	**n**	**median**	**IQR [Q3–Q1]**	**range [min–max]**	**AM > 0 [95% CI]**	**OSA > control**	**equivalence OSA/control**
Non-OSA	11	2	1	[1–3]	$p = 0.0014$ HL: 2 [1.5–4] r = 0.897 [0.9–0.93]	$p = 0.2272$	
Mild OSA	9	2	1	[1–3]	$p = 0.0034$ HL: 2 [1.5–4] r = 0.9 [0.9–0.94]		not equivalent
Moderate OSA	18	2	2	[1–4]	$p = 8.4 \times 10^{-5}$ HL: 2 [1.5–4] r = 0.886 [0.88–0.91]		Equiv: δ = 1 only
Severe OSA	14	2	1	[1–4]	$p = 0.0004$ HL: 2 [2–4] r = 0.890 [0.89–0.91]		not equivalent
questionnaire-negative control	60	2	1	[0–4]	$p = 3.9 \times 10^{-11}$ HL: 2 [1.5–4] r = 0.871 [0.85–0.89]		
	Facilitating Maneuvers (FM)						
Groups	**n**	**median**	**IQR [Q3–Q1]**	**range [min–max]**	**FM > 0 [95% CI]**	**OSA > control**	**equivalence OSA/control**
Non OSA	11	2	1	[1–3]	$p = 0.0015$ HL: 2[2–4] r = 0.891 [0.89–0.91]	$p = 0.4697$	
Mild OSA	9	3	1	[1–3]	$p = 0.0033$ HL: 2 [2–4] r = 0.905 [0.9–0.96]		not equivalent
Moderate OSA	18	2	1	[1–4]	$p = 6.9 \times 10^{-5}$ HL: 2 [2–4] r = 0.897 [0.89–0.93]		Equiv: δ = 1 only
Severe OSA	14	2	1	[0–3]	$p = 0.0006$ HL: 2 [2–4] r = 0.885 [0.84–0.92]		Equiv: δ = 1 only
questionnaire-negative control	60	2	1	[0–4]	$p = 5.8 \times 10^{-12}$ HL: 2 [2–4] r = 0.882 [0.88–0.89]		
	Aggravating + Facilitating Maneuvers (AM + FM)						
Groups	**n**	**median**	**IQR [Q3–Q1]**	**range [min–max]**	**AM + FM > 0 [95% CI]**	**OSA > control**	**equivalence OSA/control**
Non-OSA	11	5	1	[2–6]	$p = 0.0015$ HL: 5 [4–7] r = 0.891 [0.89–0.92]	$p = 0.204$	
Mild OSA	9	5	2	[4–6]	$p = 0.0034$ HL: 5 [4–7] r = 0.9 [0.9–0.94]		not equivalent
Moderate OSA	18	4.5	1	[3–5]	$p = 8.6 \times 10^{-5}$ HL: 4.5 [4–7] r = 0.884 [0.88–0.9]		not equivalent
Severe OSA	14	4.5	1	[2–5]	$p = 0.0004$ HL: 4.5 [4–7] r = 0.887 [0.89–0.91]		not equivalent
questionnaire-negative control	60	4	2	[0–7]	$p = 9.1 \times 10^{-12}$ HL: 4 [3.5–7] r = 0.873 [0.87–0.98]		

accuracy could help distinguish individuals, including those at risk for OSA. These findings should be interpreted as a proof-of-concept supporting the feasibility of measuring airflow perception, rather than as evidence of immediate clinical applicability (Turnbull And Stradling 2017). Participants must first consciously perceive variations in airflow before they can report them to the examiner—a phenomenon known as "subjective reportability,"

which stems from the theory of global neuronal workspace (Dehaene And Changeux 2011). This underscores the importance of perceptual processes and opens perspectives for rehabilitation approaches focused on sensory deficits.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s41606-026-00189-4.

Supplementary Material 1. Percentage of correct somesthetic perception responses per test item in the OSA group ($n = 41$) and control group ($n = 71$). Each value represents the proportion of participants whose response matched the theoretically expected direction (aggravating or facilitating) for the corresponding maneuver. Items are listed in the order of the Osteovox© assessment protocol.

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Authors' contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Alain PIRON and Cédric GARCION. The first draft of the manuscript was written by Alain PIRON and Cédric GARCION, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
Request at cedric.garcion.osteo@gmail.com.

Declarations

Ethics approval and consent to participate
This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of André Renard Clinic (February 3, 2023/n°01343320231005160713).
Informed consent was obtained from all individual participants included in the study.

Consent for publication
Additional informed consent was obtained from all individual participants for whom identifying information is included in this article.

Competing interests
The authors declare no competing interests.

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