



# Impacts of conservative treatment on the clinical manifestations of obstructive sleep apnea—systematic review and meta-analysis

I. O. M. Costa<sup>1,2</sup> · M. O. Cunha<sup>1</sup> · M. T. Bussi<sup>1</sup> · A. J. Cassetari<sup>1</sup> · E. Zancanella<sup>1</sup> · M. F. Bagarollo<sup>2</sup>

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## Abstract

**Introduction** Obstructive sleep apnea (OSA) is a chronic disease with a high populational prevalence that is characterized as airway closure during sleep. Treatment is multidisciplinary and varies according to each case. Continuous positive airway pressure (CPAP), oral appliances, and surgery are the primary therapeutic options. Non-invasive conservative treatments such as sleep hygiene, positional therapy, physical exercises, and weight loss aim to reduce the worsening of the disease while being complementary to the invasive primary treatment.

**Objective** To analyze the impact of non-invasive conservative therapies on the clinical manifestations of OSA syndrome (OSA), compared with other interventions.

**Method** This was a systematic review with meta-analysis. The searches were performed without filters for the time period, type of publication, or language. Randomized clinical trials on subjects over 18 years of age diagnosed with untreated OSA were included. Responses to non-invasive conservative treatment were compared with responses to the primary intervention. Primary outcomes were assessed using the Epworth Sleepiness Scale and/or Functional Outcomes of Sleep Questionnaire (FOSQ).

**Results** A total of eight studies were included in the review. The heterogeneity of the effect was estimated at 89.77%. Six studies compared conservative treatment with CPAP, one with oral appliances, and one with oropharyngeal exercises. Using the Epworth Sleepiness Scale measurements, the standardized difference in the estimated means, based on the random-effects model, was 0.457 (95% CI (1.082 to 0.169)) and the mean result did not differ significantly from zero ( $z = 1.43$ ;  $p = 0.153$ ). The conservative therapies assessed in this study improved the subjective quality of sleep, although the post-treatment ESE scores did not show significant results. The reduction in AHI and better outcomes in the evaluated domains, as well as in cognition and mood, were superior in the groups that received CPAP and IOD.

**Conclusion** The most commonly used treatments of choice for OSA are invasive, including the use of CPAP, oral appliances, and surgeries, being the most utilized options. This study demonstrated that non-invasive conservative treatments, such as sleep hygiene, yield results as effective as invasive treatments. Further studies are needed to confirm this result and to predict whether invasive treatment can be used as the primary treatment or only as a supplement.

**Keywords** OSA · Conservative treatment · CPAP · Sleep hygiene

## Introduction

Obstructive sleep apnea (OSA) is a condition characterized by repetitive pharyngeal collapses during sleep, which results in fragmentation and desaturation of sleep and sympathetic surges. It affects 2 to 14% of the adult population, provokes excessive daytime sleepiness [1, 2], and increases the risk of severe diseases that could overload healthcare systems and worsen quality of life [2–4].

Treatments for OSA are multidisciplinary and vary according to the severity of the case. Continuous positive

✉ I. O. M. Costa  
itamagalhaescosta@gmail.com

<sup>1</sup> Department of Otorhinolaryngology, University of Campinas, Campinas, Brazil

<sup>2</sup> Department of Human Development and Rehabilitation, University of Campinas, Campinas, Brazil

airway pressure (CPAP) is an effective type of treatment that improves clinical symptoms and reduces the apnea–hypopnea index (AHI) [5]. However, adherence to CPAP treatment is an important problem that needs to be considered [3–5]. Oral devices for advancing the mandible and retaining the tongue present satisfactory responses for controlling mild OSA [6, 7], although the results are inferior to those from CPAP [8]. Surgical procedures are applicable for correcting anatomical alterations and have a good cost–benefit relationship for patients with severe apnea who cannot tolerate CPAP [3, 9]. In comparison with CPAP and oral devices, orthognathic surgery to advance the maxilla and mandible is considered to be the most invasive type of treatment [10].

Simple interventions such as sleep hygiene, adjustment of body position during sleep, weight loss, physical exercise, and lifestyle change [11–14] are used as conservative treatment with the aim of minimizing and/or delaying the worsening of the disease. In addition, conservative treatments involve the reduction of the apnea–hypopnea index and sleep fragmentation, lifestyle changes, diminution of risk factors, elimination of snoring, and reduction of daytime sleepiness and fatigue [15, 16].

Studies have shown that there are relationships between weight loss and reduction of respiratory events during sleep [14], between alcohol intake and increased incidence of obstructive apnea [17], and between sleep deprivation/fragmentation and greater collapsibility of the upper airways [18]. Conservative treatments favor overall health, improved respiratory abnormalities, and, consequently, improved sleep quality and clinical manifestations [11, 19]. They have also been recommended as a complementary therapy in cases in which CPAP, oral devices, or surgery is used [8]. Sleep hygiene integrated with the treatment options favors the organization of the sleep routine and helps in rehabilitation and adherence to treatments [20, 21]. These are simple measures, but managing them requires considerable clinical skill [22, 23].

There is a shortage of data in the literature correlating sleep hygiene with clinical improvement of OSA. These good habits are recommended for diminishing daytime sleepiness and depression and for improving quality of life, independent of any sleep disorder [12, 14, 20]. Positional devices are simple public utility measures that can be used in combination with or separately from other treatment options and can also be chosen as therapy for individuals who cannot tolerate CPAP or for low-income individuals [23–25].

## Objectives

The aim of this review was to compare and analyze the impact of conservative treatments such as sleep hygiene, weight loss, positional therapy, and/or physical exercise on

the clinical manifestations of OSA, in comparison with other interventions.

## Methods

### Design

This study consisted of a systematic review of the literature. The registration in Prospective Register of Systematic Reviews (PROSPERO) was requested twice: in November 2020 and in February 2021. We received the number 209699 as provisional. However, the team did not verify eligibility because they focused their efforts on COVID-19 records throughout 2021, the period during which this review was proceeding to be finalized. It followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

### Search and study selection criteria

The search for studies was conducted by a non-author colleague, comprehensively among published papers that met the eligibility criteria of this study. The following electronic databases were examined: PubMed, PubMed Central, VBS (Lilacs, Medline), Cochrane, Scopus, Embase, Web of Science, and EBSCOhost. The search strategies were personalized for each database and involved the use of keywords relating to the population and intervention. No additional filters for time of publication or language were used (Fig. 1).

The guidelines represented by the acronym PICO (population, intervention, comparison, outcome) were used in elaborating the present review. The population was formed by adults over the age of 18 years of both sexes with an untreated previous diagnosis of OSA syndrome in accordance with the standardized definitions of the American Academy of Sleep Medicine (AASM) [26]. The trials included used either or both of the following measurement instruments: the Epworth Sleepiness Scale (ESS), which assesses excessive daytime sleepiness due to OSA; and the Functional Outcomes of Sleep Questionnaire (FOSQ), which assesses the impact of sleepiness on daily activities. Studies in which conservative treatment was compared with another type of intervention were also included. The type of study considered was restricted to randomized controlled trials, and these needed to present results in a form that was usable for meta-analysis, including the availability of unadjusted means and standard deviations (SD) or 95% confidence intervals. The inclusion and exclusion criteria used are detailed in Table 1. The present review sought to investigate and answer the following question: in patients with OSAS, what is the effect of conservative treatment on clinical manifestations, in comparison with other interventions?

SOURCE	STRATEGIES
PUBMED	((((Adult OR Adults) OR ("Young Adult" OR "Adult, Young" OR "Adults, Young" OR "Young Adults")) OR ("Middle Aged" OR "Middle Age")) OR (Aged OR Elderly) OR ("Aged, 80 and over" OR "Oldest Old" OR Nonagenarians OR Nonagenarian OR Octogenarians OR Octogenarian OR Centenarians OR Centenarian) AND ((Sleep Apnea, Obstructive[MeSH Terms] OR "Sleep Apnea, Obstructive"[Title/Abstract] OR "Apneas, Obstructive Sleep"[Title/Abstract] OR "Obstructive Sleep Apnea Syndrome"[Title/Abstract] OR "Obstructive Sleep Apnea"[Title/Abstract] OR OSAHS[Title/Abstract] OR "Syndrome, Sleep Apnea, Obstructive"[Title/Abstract] OR "Sleep Apnea Syndrome, Obstructive"[Title/Abstract] OR "Apnea, Obstructive Sleep"[Title/Abstract] OR "Sleep Apnea Hypopnea Syndrome"[Title/Abstract] OR "Syndrome, Obstructive Sleep Apnea"[Title/Abstract] OR "Upper Airway Resistance Sleep Apnea Syndrome"[Title/Abstract] OR "Syndrome, Upper Airway Resistance, Sleep Apnea"[Title/Abstract])) AND (((Sleep Hygiene[MeSH Terms] OR "Sleep Hygiene"[Title/Abstract] OR "Hygiene, Sleep"[Title/Abstract] OR "Good Sleep Habits"[Title/Abstract] OR "Good Sleep Habit"[Title/Abstract] OR "Habit, Good Sleep"[Title/Abstract] OR "Habits, Good Sleep"[Title/Abstract] OR "Sleep Habit, Good"[Title/Abstract] OR "Sleep Habits, Good"[Title/Abstract])) OR ((Conservative Treatment[MeSH Terms] OR "Conservative Treatment"[Title/Abstract] OR "Conservative Treatments"[Title/Abstract] OR "Treatment, Conservative"[Title/Abstract] OR "Treatments, Conservative"[Title/Abstract] OR "Conservative Management"[Title/Abstract] OR "Conservative Managements"[Title/Abstract] OR "Management, Conservative"[Title/Abstract] OR "Managements, Conservative"[Title/Abstract] OR "Conservative Therapy"[Title/Abstract] OR "Conservative Therapies"[Title/Abstract] OR "Therapies, Conservative"[Title/Abstract] OR "Therapy, Conservative"[Title/Abstract]))
PUBMED PMC	((((Adult OR Adults) OR ("Young Adult" OR "Adult, Young" OR "Adults, Young" OR "Young Adults")) OR ("Middle Aged" OR "Middle Age")) OR (Aged OR Elderly) OR ("Aged, 80 and over" OR "Oldest Old" OR Nonagenarians OR Nonagenarian OR Octogenarians OR Octogenarian OR Centenarians OR Centenarian) AND ((Sleep Apnea, Obstructive[MeSH Terms] OR "Sleep Apnea, Obstructive"[Title/Abstract] OR "Apneas, Obstructive Sleep"[Title/Abstract] OR "Obstructive Sleep Apnea Syndrome"[Title/Abstract] OR "Obstructive Sleep Apnea"[Title/Abstract] OR OSAHS[Title/Abstract] OR "Syndrome, Sleep Apnea, Obstructive"[Title/Abstract] OR "Sleep Apnea Syndrome, Obstructive"[Title/Abstract] OR "Apnea, Obstructive Sleep"[Title/Abstract] OR "Sleep Apnea Hypopnea Syndrome"[Title/Abstract] OR "Syndrome, Obstructive Sleep Apnea"[Title/Abstract] OR "Upper Airway Resistance Sleep Apnea Syndrome"[Title/Abstract] OR "Syndrome, Upper Airway Resistance, Sleep Apnea"[Title/Abstract])) AND (((Sleep Hygiene[MeSH Terms] OR "Sleep Hygiene"[Title/Abstract] OR "Hygiene, Sleep"[Title/Abstract] OR "Good Sleep Habits"[Title/Abstract] OR "Good Sleep Habit"[Title/Abstract] OR "Habit, Good Sleep"[Title/Abstract] OR "Habits, Good Sleep"[Title/Abstract] OR "Sleep Habit, Good"[Title/Abstract] OR "Sleep Habits, Good"[Title/Abstract])) OR ((Conservative Treatment[MeSH Terms] OR "Conservative Treatment"[Title/Abstract] OR "Conservative Treatments"[Title/Abstract] OR "Treatment, Conservative"[Title/Abstract] OR "Treatments, Conservative"[Title/Abstract] OR "Conservative Management"[Title/Abstract] OR "Conservative Managements"[Title/Abstract] OR "Management, Conservative"[Title/Abstract] OR "Managements, Conservative"[Title/Abstract] OR "Conservative Therapy"[Title/Abstract] OR "Conservative Therapies"[Title/Abstract] OR "Therapies, Conservative"[Title/Abstract] OR "Therapy, Conservative"[Title/Abstract]))
BVS/BIREME MEDLINE IBECS LILACS	(adult OR adulto OR adulto OR "Adulto Joven" OR "Adulto Jovem" OR "Young Adult" OR "Middle Aged" OR "Persona de Mediana Edad" OR "Pessoa de Meia-Idade" OR "Aged OR anciano OR idoso OR "Aged, 80 and over" OR "Anciano de 80 o más Años" OR "Idoso de 80 Anos ou mais") AND ("Sleep Apnea, Obstructive" OR "Apneas, Obstructive Sleep" OR "Obstructive Sleep Apneas" OR "Sleep Apneas, Obstructive" OR "Obstructive Sleep Apnea Syndrome" OR "Obstructive Sleep Apnea" OR osahs OR "Syndrome, Sleep Apnea, Obstructive" OR "Sleep Apnea Syndrome, Obstructive" OR "Apnea, Obstructive Sleep" OR "Sleep Apnea Hypopnea Syndrome" OR "Syndrome, Obstructive Sleep Apnea" OR "Upper Airway Resistance Sleep Apnea Syndrome" OR "Syndrome, Upper Airway Resistance, Sleep Apnea") AND ("Sleep Hygiene" OR "Higiene del Sueño" OR "Higiene del Sono") OR ("Tratamiento Conservador" OR "Conservative Treatment" OR "Tratamiento Conservador")
EBSCOHOST MEDLINE	((Adult OR Adults) OR ("Young Adult" OR "Adult, Young" OR "Adults, Young" OR "Young Adults")) OR ("Middle Aged" OR "Middle Age") OR (Aged OR Elderly) OR ("Aged, 80 and over" OR "Oldest Old" OR Nonagenarians OR Nonagenarian OR Octogenarians OR Octogenarian OR Centenarians OR Centenarian) AND ((Sleep Apnea, Obstructive" OR "Apneas, Obstructive Sleep" OR "Obstructive Sleep Apneas" OR "Sleep Apneas, Obstructive" OR "Obstructive Sleep Apnea Syndrome" OR "Obstructive Sleep Apnea" OR OSAHS OR "Syndrome, Sleep Apnea, Obstructive" OR "Sleep Apnea Syndrome, Obstructive" OR "Apnea, Obstructive Sleep" OR "Sleep Apnea Hypopnea Syndrome" OR "Syndrome, Obstructive Sleep Apnea" OR "Upper Airway Resistance Sleep Apnea Syndrome" OR "Syndrome, Upper Airway Resistance, Sleep Apnea")) AND ((Sleep Hygiene" OR "Hygiene, Sleep" OR "Good Sleep Habits" OR "Good Sleep Habit" OR "Habit, Good Sleep" OR "Habits, Good Sleep" OR "Sleep Habit, Good" OR "Sleep Habits, Good" OR "Conservative Treatment" OR "Conservative Treatments" OR "Treatment, Conservative" OR "Treatments, Conservative" OR "Conservative Management" OR "Conservative Managements" OR "Management, Conservative" OR "Managements, Conservative" OR "Conservative Therapy" OR "Conservative Therapies" OR "Therapies, Conservative" OR "Therapy, Conservative"))
SCOPUS	((( ALL ( adult OR adults ) OR ALL ( "Young Adult" OR "Adult, Young" OR "Adults, Young" OR "Young Adults" ) OR ALL ( "Middle Aged" OR "Middle Age" ) OR ALL ( aged OR elderly ) OR ALL ( "Aged, 80 and over" OR "Oldest Old" OR nonagenarians OR nonagenarian OR octogenarians OR octogenarian OR centenarians OR centenarian ))) AND ( TITLE-ABS-KEY ( "Sleep Apnea, Obstructive" OR "Apneas, Obstructive Sleep" OR "Obstructive Sleep Apneas" OR "Sleep Apneas, Obstructive" OR "Obstructive Sleep Apnea Syndrome" OR "Obstructive Sleep Apnea" OR osahs OR "Syndrome, Sleep Apnea, Obstructive" OR "Sleep Apnea Syndrome, Obstructive" OR "Apnea, Obstructive Sleep Apnea" OR "Upper Airway Resistance Sleep Apnea Syndrome" OR "Syndrome, Upper Airway Resistance, Sleep Apnea" ) ) AND ( TITLE-ABS-KEY ( "Sleep Hygiene" OR "Hygiene, Sleep" OR "Good Sleep Habits" OR "Good Sleep Habit" OR "Habit, Good Sleep" OR "Habits, Good Sleep" OR "Sleep Habit, Good" OR "Sleep Habits, Good" ) OR TITLE-ABS-KEY ( "Conservative Treatment" OR "Conservative Treatments" OR "Treatment, Conservative" OR "Treatments, Conservative" OR "Conservative Management" OR "Conservative Managements" OR "Management, Conservative" OR "Managements, Conservative" OR "Conservative Therapy" OR "Conservative Therapies" OR "Therapies, Conservative" OR "Therapy, Conservative" ) )
WEB OF SCIENCE	Todos os campos: (Adult OR Adults) OR Todos os campos: ("Young Adult" OR "Adult, Young" OR "Adults, Young" OR "Young Adults") OR Todos os campos: ("Middle Aged" OR "Middle Age") OR Todos os campos: (Aged OR Elderly) OR Todos os campos: ("Aged, 80 and over" OR "Oldest Old" OR Nonagenarians OR Nonagenarian OR Octogenarians OR Octogenarian OR Centenarians OR Centenarian) Índices=SCI-EXPANDED, SSCI, A&HCI, CPPI-S, CPPI-SSH, ESCI Tempo estipulado=Todos os anos AND TÓPICO: ("Sleep Apnea, Obstructive" OR "Apneas, Obstructive Sleep" OR "Obstructive Sleep Apneas" OR "Sleep Apneas, Obstructive" OR "Obstructive Sleep Apnea Syndrome" OR "Obstructive Sleep Apnea" OR OSAHS OR "Syndrome, Sleep Apnea, Obstructive" OR "Sleep Apnea Syndrome, Obstructive" OR "Apnea, Obstructive Sleep" OR "Sleep Apnea Hypopnea Syndrome" OR "Syndrome, Obstructive Sleep Apnea" OR "Upper Airway Resistance Sleep Apnea Syndrome" OR "Syndrome, Upper Airway Resistance, Sleep Apnea") Índices=SCI-EXPANDED, SSCI, A&HCI, CPPI-S, CPPI-SSH, ESCI Tempo estipulado=Todos os anos AND TÓPICO: ("Sleep Hygiene" OR "Hygiene, Sleep" OR "Good Sleep Habits" OR "Good Sleep Habit" OR "Habit, Good Sleep" OR "Habits, Good Sleep" OR "Sleep Habit, Good" OR "Sleep Habits, Good" OR TÓPICO: ("Conservative Treatment" OR "Conservative Treatments" OR "Treatment, Conservative" OR "Treatments, Conservative" OR "Conservative Management" OR "Conservative Managements" OR "Management, Conservative" OR "Managements, Conservative" OR "Conservative Therapy" OR "Conservative Therapies" OR "Therapies, Conservative" OR "Therapy, Conservative") Índices=SCI-EXPANDED, SSCI, A&HCI, CPPI-S, CPPI-SSH, ESCI Tempo estipulado=Todos os anos
EMBASE	(adult OR adults OR "young adult" OR "adult, young" OR "adults, young" OR "young adults" OR "middle aged" OR "middle age" OR aged OR elderly OR "aged, 80 and over" OR "oldest old" OR nonagenarians OR nonagenarian OR octogenarians OR octogenarian OR centenarians OR centenarian) AND (sleep disordered breathing/exp OR "sleep disordered breathing"/syn) AND ("sleep hygiene"/exp OR "sleep hygiene"/syn OR "conservative treatment"/exp OR "conservative treatment"/syn) AND (embase/lim NOT (embase/lim AND (medline)/lim)
COCHRANE LIBRARY	(Adult OR Adults) OR ("Young Adult" OR "Adult, Young" OR "Adults, Young" OR "Young Adults") OR ("Middle Aged" OR "Middle Age") OR (Aged OR Elderly) OR ("Aged, 80 and over" OR "Oldest Old" OR Nonagenarians OR Nonagenarian OR Octogenarians OR Octogenarian OR Centenarians OR Centenarian) AND ("Sleep Apnea, Obstructive" OR "Apneas, Obstructive Sleep" OR "Obstructive Sleep Apneas" OR "Sleep Apneas, Obstructive" OR "Obstructive Sleep Apnea Syndrome" OR "Obstructive Sleep Apnea" OR OSAHS OR "Syndrome, Sleep Apnea, Obstructive" OR "Sleep Apnea Syndrome, Obstructive" OR "Apnea, Obstructive Sleep" OR "Sleep Apnea Hypopnea Syndrome" OR "Syndrome, Obstructive Sleep Apnea" OR "Upper Airway Resistance Sleep Apnea Syndrome" OR "Syndrome, Upper Airway Resistance, Sleep Apnea") AND ("Sleep Hygiene" OR "Hygiene, Sleep" OR "Good Sleep Habits" OR "Good Sleep Habit" OR "Habit, Good Sleep" OR "Habits, Good Sleep" OR "Sleep Habit, Good" OR "Sleep Habits, Good") OR ("Conservative Treatment" OR "Conservative Treatments" OR "Treatment, Conservative" OR "Treatments, Conservative" OR "Conservative Management" OR "Conservative Managements" OR "Management, Conservative" OR "Managements, Conservative" OR "Conservative Therapy" OR "Conservative Therapies" OR "Therapies, Conservative" OR "Therapy, Conservative");ti,ab,kw

Fig. 1 Search strategies

A total of seven studies were included in the meta-analysis. Among these, one study allocated three groups to intervention, and the use of CPAP, intraoral devices (IOD), and conservative therapy was compared, and another study divided the participants into hypertensive and non-hypertensive groups.

The analysis of these seven studies was conducted using the standardized difference in the means as the outcome measurement. A random-effects model was fitted to the data. The degree of heterogeneity ( $\tau^2$ ) was estimated using a limited maximum likelihood estimator. In addition to estimating  $\tau^2$ , Cochran's  $Q$  test for heterogeneity and the  $I^2$

**Table 1** Inclusion and exclusion criteria

Inclusion	<ul style="list-style-type: none"> <li>• Patients with a diagnosis of OSA</li> <li>• Studies conducted only among individuals over 18 years of age</li> <li>• Intervention among patients with apnea using conservative therapies of sleep hygiene, positional therapy, weight loss, and/or physical exercise</li> <li>• Studies that addressed alterations to the clinical manifestations of OSA, such as daytime sleepiness, tiredness, snoring, and difficulty in concentrating</li> <li>• Assessment using the Epworth Sleepiness Scale and/or FOSQ</li> <li>• Randomized controlled trials</li> <li>• Statistical results that included the presentation of means and standard deviations or 95% confidence intervals</li> </ul>
Exclusion	<ul style="list-style-type: none"> <li>• Patients without a diagnosis of OSA</li> <li>• Studies conducted among individuals under the age of 18 years</li> <li>• Interventions among patients with apnea using conservative therapies other than sleep hygiene, positional therapy, weight loss, and/or physical exercise</li> <li>• Conservative therapy provided for reasons other than OSA</li> <li>• Conservative therapy implemented concomitantly with other types of therapy</li> <li>• Studies in which assessments using the Epworth Sleepiness Scale and/or FOSQ were not done</li> <li>• Studies without a comparison group and case studies</li> <li>• Studies conducted among individuals with OSA and associated diseases</li> <li>• Reviews of the literature</li> </ul>

statistic were reported. Correlation classification and regression tests using the standard error of the observed result as a predictor were implemented to assess the asymmetry of funnel plots. The Jamovi 1.6.16 software was used.

## Results

The data set that formed the input to screening was finalized as 1579 references. Within the computerized screening tool, 496 studies were excluded because they were either duplicates or systematic reviews. The remaining studies formed the input to a selection process according to the article title and abstract, which was conducted independently by two authors of this review. Any divergences in this selection were resolved by a third member of the study group. Following this, a complete analysis of the text of 28 studies was conducted blindly by three authors, and any divergences were resolved by reaching a consensus. As shown in Fig. 2, three studies were excluded because their analyses were not conducted using the ESS and/or FOSQ, eight because they presented insufficient data, five because they did not have a comparison group, three because they were follow-up studies, and one because it was a protocol. Although contacts were made with study authors to request further data, no responses were obtained. In the end, a total of eight articles were included in the present review for meta-analysis.

### Risk-of-bias analysis

The Cochrane Collaboration tool was used to assess the risk of bias for each randomized controlled trial, in seven categories (Fig. 3). Domain 3 (blinding of the participants and professional personnel) was not applicable as a significant

risk of bias given that it was not possible to blind either of the parties involved for the type of intervention received. The risk of bias for each study was considered low when the required information was presented in the article or when the methodological quality pointed towards low risk. Three studies showed unclear risk in domain 1 (random sequence generation), four in domain 2 (allocation concealment), five in domain 3 (blinding of participants and researchers), and five in domain 4 (verification of results). Situations of the absence of information on allocation and blinding were considered to present an unclear risk of bias. No risk of bias was considered to have had an impact on the results from the meta-analysis.

### Data collection process

In all the studies, polysomnography examinations were conducted over an entire night in order to diagnose OSA, and sleep parameters (AHI) were reported based on the standardized definitions of the American Academy of Sleep Medicine. The experimental groups of conservative therapies were compared with the use of CPAP, intraoral devices, and oropharyngeal exercises.

### Study characteristics

The characteristics of the studies included in the meta-analysis are described in Table 2. These eight studies had a total of 671 participants with OSA, which was predominantly mild to moderate and/or moderate to severe, with a wide range of adult ages. Not all the studies specified the percentages of men and women, and thus, it was not possible to calculate means according to sex. Six studies made comparisons with the use of CPAP, one with the use of an intraoral device, and

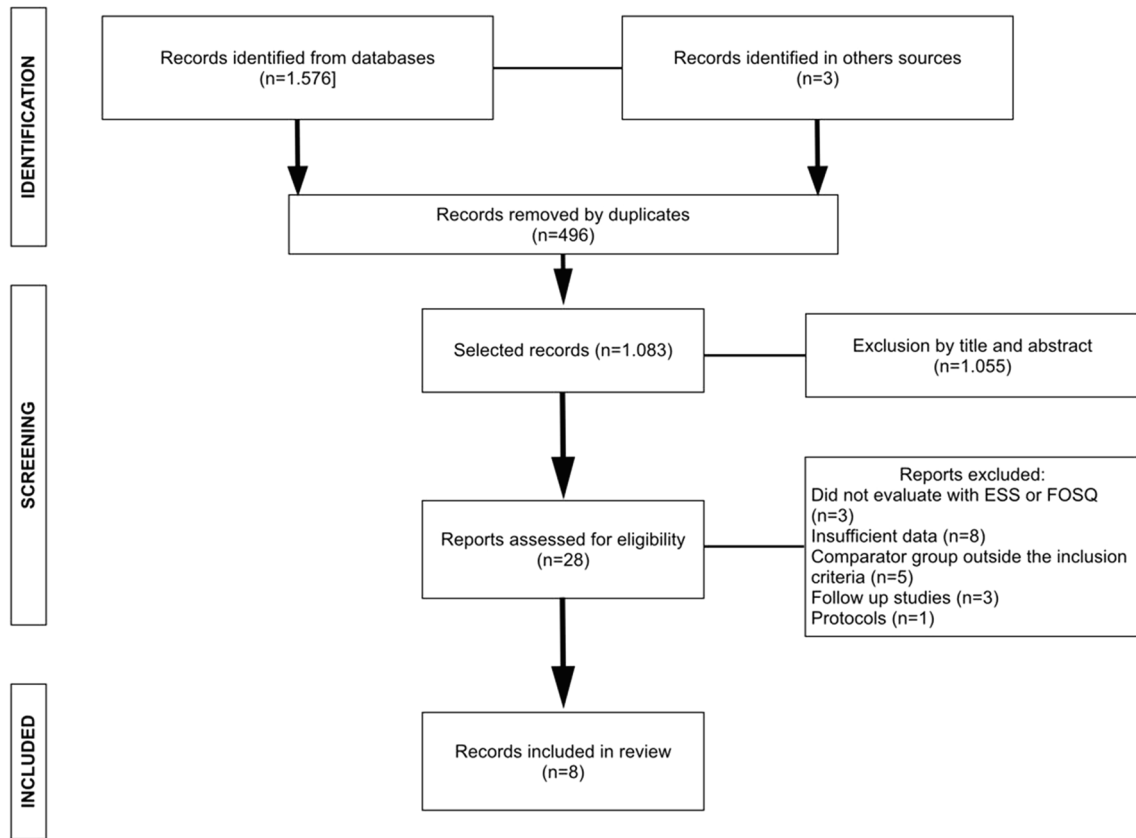


Fig. 2 Flow diagram

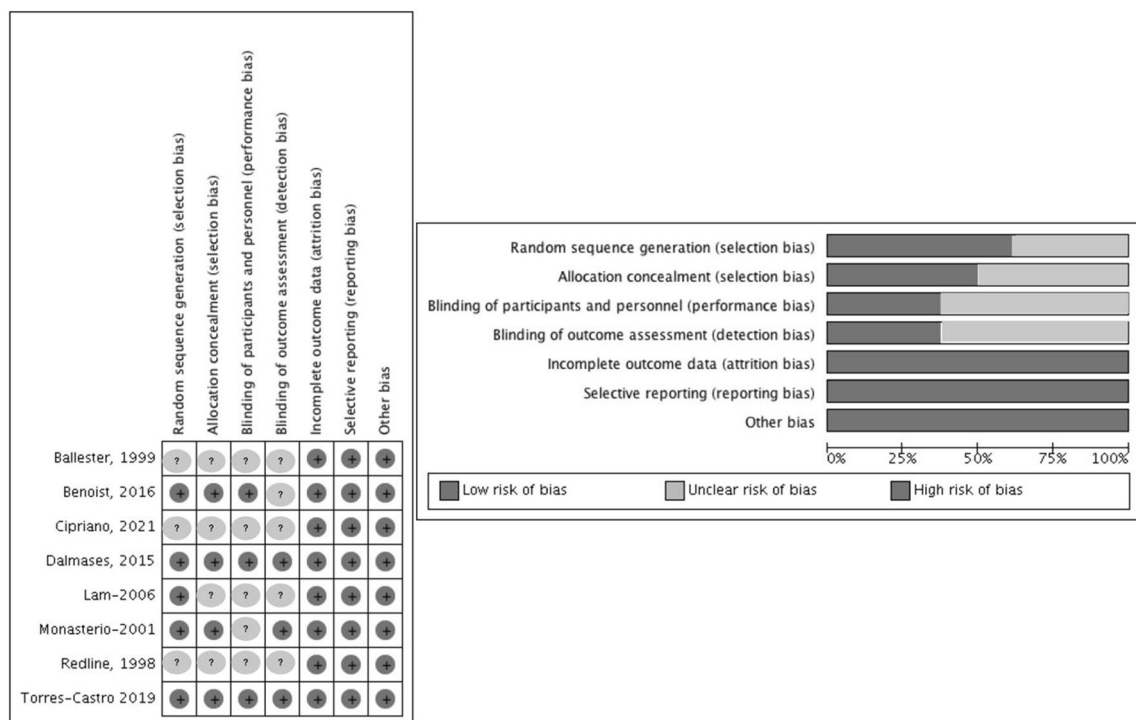


Fig. 3 Risk-of-bias analysis

**Table 2** Summary of study characteristics

Reference	<i>n</i> total	Age group (years)	Severity of OSA	Objectives	Duration of treatment	Experimental intervention	Comparator intervention
Ballester et al. 1999 [40]	105	Mean 53	Moderate to severe	To evaluate the efficacy of CPAP for improving OSA: symptoms, daytime function, perceived state of health, and quality of life	12 weeks	Sleep hygiene + weight loss ( <i>n</i> =37)	CT + CPAP ( <i>n</i> =68)
Redline et al. 1999	111	25 to 65	Mild to moderate	To evaluate treatment with CPAP versus CT regarding well-being, mood, and functional status among individuals with mild sleep respiratory disorders	12 weeks	CT + use of mechanical nasal dilator ( <i>n</i> =52)	CPAP ( <i>n</i> =59)
Monasterio et al. 2001 [35]	142	Mean 54	Mild	To evaluate the efficacy of CPAP in patients with mild OSA	6 months	CT + sleep hygiene + weight loss ( <i>n</i> =65)	CT + CPAP ( <i>n</i> =77)
Lam et al. 2006	106	Over 18	Mild to moderate	To evaluate the efficacy of three types of nonsurgical treatment commonly used in mild to moderate OSA, regarding daytime sleepiness, quality of life, and physiological parameters	10 weeks	CT + sleep hygiene + weight control ( <i>n</i> =33)	Pretitrated CPAP ( <i>n</i> =34) Non-adjustable IOD ( <i>n</i> =34)
Dalmases et al. 2015 [53]	33	Over 65	Severe	To investigate whether elderly patients with OSA present cognitive deficits and functional and structural brain alterations that might be improved through CPAP treatment	3 months	Sleep hygiene + diet ( <i>n</i> =15)	CT + CPAP ( <i>n</i> =16)
Benoist et al. 2016	99	Mean 48	Mild to moderate	To evaluate the efficacy of positional therapy in comparison with oral device therapy in patients with mild to moderate positional OSA	3 months	Positional therapy with trainer (vibratory device) ( <i>n</i> =51)	Oral devices ( <i>n</i> =48)
Torres-Castro et al. 2019 [41]	27	40 to 85	Moderate to severe	To investigate the effects of a combined program of physical activity and OE on AHI scores in patients with moderate to severe OSA	8 weeks	Diet + sleep hygiene + physical activity ( <i>n</i> =13)	Physical activity, OE, diet, and sleep hygiene ( <i>n</i> =14)

Table 2 (continued)

Reference	n total	Age group (years)	Severity of OSA	Objectives	Duration of treatment	Experimental intervention	Comparator intervention
Cipriano et al. 2021 [44]	48	30 to 70	Moderate to severe	To compare the effects of short-term CPAP (2 months) with those of aerobic physical training on autonomic modulation in patients with moderate to severe OSA, through analysis on heart rate variation with and without hypertension	6 months	Physical training Hypertensive (n = 7) Non-hypertensive (n = 14)	CPAP Hypertensive (n = 9) Non-hypertensive (n = 9)

OSA, obstructive sleep apnea syndrome; CT, conservative treatment; CPAP, continuous positive airway pressure; IOD, intraoral device; OE, oropharyngeal exercises; AHI, apnea–hypopnea index

Table 3 FOSQ results summarized

Monasterio et al. 2001 [35]	Conservative treatment Before: 100 (15) After: 102 (21) CPAP Before: 101 (18) After: 106 (20)
Benoist et al. 2016	Positional therapy Before: 16.4 (12.9–18.1) After: 16.2 (13.1–18.6) IOD therapy Before: 15.8 (12.4–18.3) After: 15.8 (12.5–18.8)

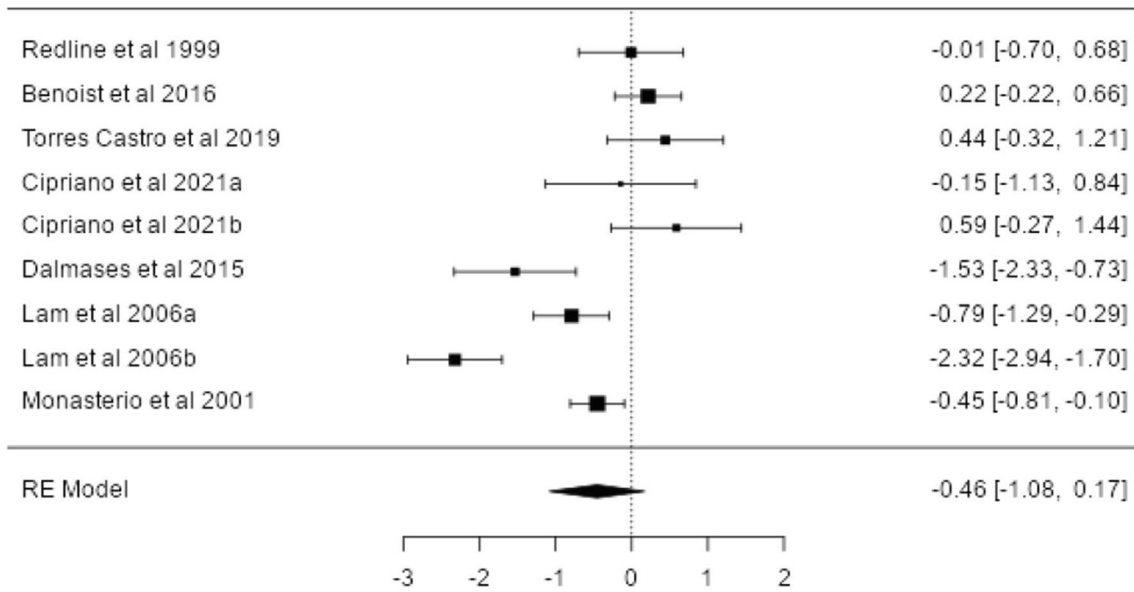
one with oropharyngeal exercises. One study integrated the experimental intervention with conservative treatment consisting of the use of a nasal dilator with the placebo effect, and for this reason, it was considered that this study fulfilled the inclusion criteria. Moreover, although the presence of OSA plus associated diseases was an exclusion criterion, it was decided to include a study in which the results were separated into groups of hypertensive and non-hypertensive participants.

### Synthesis of results and meta-analysis

Table 3 summarizes the scores from the FOSQ applied before and after the intervention in two studies. Figure 4 shows the standardized mean differences from the ESS, which ranged from  $-2.3234$  to  $0.5873$ . Most of these estimates were negative (67%).

The standardized mean difference estimated based on the random-effects model was  $0.457$  (95% confidence interval (CI),  $1.082$  to  $0.169$ ). Therefore, the mean result did not differ significantly from zero ( $z = 1.43$ ;  $p = 0.153$ ). In the  $Q$  test on the random-effects model, the true results seemed to be heterogenous ( $Q(8) = 65.559$ ;  $p < 0.001$ ;  $\tau^2 = 0.7959$ ;  $I^2 = 89.77\%$ ). The 95% CI for the true results was  $-2.3136$  to  $1.400$ . Therefore, although the mean result was estimated as negative, the true result in some studies may in fact have been positive.

The classification correlation of the Begg-Mazumbar test ( $p = 0.919$ ) and the Egger regression test ( $p = 0.722$ ) indicated that there was no asymmetry in the funnel plot (Fig. 5). Studentized residuals and Cook distances were used to examine whether the studies might have been discrepant and/or influenced by the model. The studentized examination on the residuals showed that the study by Ballester et al. (1999) had a value greater than  $\pm 2.8070$  and may have been a potential outlier in the context of this model. According to the Cook distances, this study could be considered excessively influential. Therefore, it was decided to exclude Ballester (1999) and redo the meta-analysis.



**Fig. 4** Forest plot. Results between 0 and -3 show that the interventions using CPAP and IOD were better than conservative treatment

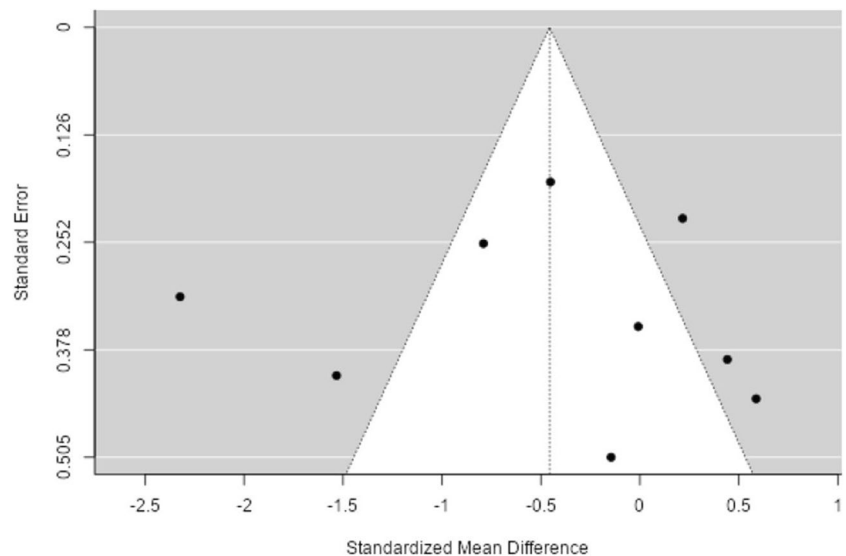
### Discussion

This was the first meta-analysis to evaluate the impact of conservative treatment consisting of sleep hygiene, weight loss, positional therapy, and physical exercise on the clinical manifestations of OSA. Although there is evidence showing that treatment with CPAP is effective, no study has compared subgroups of different severities of OSA, a point that was previously identified by Sánchez (2008). The heterogeneity of the severity of this disease was one of the limitations of the present review. The clarity regarding

CPAP titration was not achieved. Regarding patient tolerance, only those who completed the research without major discomfort were included in the final results.

The first review addressing this topic was not concluded due to a lack of published trials [12]. A bibliographic survey on randomized controlled trials that was published in 2008 investigated the effectiveness of CPAP in relation to daytime sleepiness, depression, and cognitive functions among patients who received CPAP, compared with more conservative measures [27]. However, the impact of these therapies was not quantified, and this formed the main objective of the present review.

**Fig. 5** Funnel plot





Among the studies included in this review, only two of them assessed the impact of OSA on daily activities using the FOSQ tool. Monasterio (2001) showed that the group that received CPAP achieved a slight improvement after the intervention. Benoist (2016) found that there was a minimal change in the group that received conservative treatment, while the IOD group remained unchanged. In both of these studies, the changes observed were not clinically relevant. However, the reasons for this result were not explored by the authors.

In the analysis of the studies included in this meta-analysis, four of them showed results ranging between positive and negative, while in three, the results of conservative treatment were inferior. The reason for this discrepancy is not clear, since the only methodological characteristic widely prevalent in most studies was the combination of CPAP with conservative treatment. In the treatment of obstructive sleep apnea, the literature shows favorable outcomes for CPAP therapy and oral appliances, while the results for conservative treatment are less significant. However, the statistical analysis of this current review indicates that CPAP therapy, IOD, and oropharyngeal exercises do not show superior results compared to conservative treatment.

The heterogeneity of effect, which was estimated to be 89.77%, came from the difference in the procedures used in the studies that were included. The factors that may have contributed to this difference in our analyses were disparities in the total sample size, age group studied, severity of apnea, and type of intervention. One of the limitations of the review was the lack of homogeneity in the study data, which hindered a more detailed analysis of subgroups. This issue underscores the need for future studies to address these risk factors separately, enabling the acquisition of more concrete data. Another important factor to be raised concerns the length of follow-up which was between 2 and 6 months; i.e., each group had a different amount of time within which to adapt to and consolidate the proposed treatment. Furthermore, in four studies, the intervention in the comparison group was combined with guidance about sleep hygiene, weight loss, and/or physical activity.

The conservative therapies consisting of guidance about sleep hygiene, weight loss, positional therapy, and physical activity improved the subjective quality of sleep, but the ESS scores post-treatment were not statistically significant. The reduction in the AHI was greater in the groups that received CPAP and IOD. Previous studies demonstrated the efficacy of CPAP for reducing excessive daytime sleepiness, one of the main symptoms relating to OSA, through ESS scores and the objective multiple sleep latency test (MSLT) [27–30]. However, Zhao (2017) showed that conservative measures have important clinical implications in apnea treatments, even if the ESS score remains unchanged [31], and that finding was confirmed in the present review. Although

daytime sleepiness is the main complaint among patients with OSA, it may be a marker for other sleep-related issues [32]. Moreover, even though CPAP is more effective for reducing respiratory disorders, oral devices present better adherence [33].

## Sleep hygiene

Positive-pressure interventions in the airways presented better results in the domains evaluated in all the studies that compared conservative treatment with CPAP. Sleep hygiene did not show any significant reduction in the AHI or in OSA symptoms. However, it was unanimously concluded that conservative treatment can be the first approach and/or a resource associated with any therapeutic option [23, 34, 35]. More recent studies have shown that the daytime sleepiness that impacts the quality of life of people with OSA was strongly related to poor sleep hygiene among the individuals investigated [20, 36, 37]. In addition to presenting a positive correlation with patients' subjective symptoms, good sleep hygiene may be related to good general quality of sleep, even if to a lesser degree than other interventions addressed in this review [38].

Redline (1999) was the first study to investigate and compare types of nonsurgical treatment for mild to moderate OSA. The results from that study showed that the impact of CPAP was significantly greater with regard to well-being, mood, and functional status than that of sleep hygiene advice. Lam (2006) compared CPAP, IOD, and sleep hygiene advice, three types of nonsurgical treatment that are commonly used for OSA. The ESS score decreased significantly in all three groups but the results for the CPAP group were superior despite being inconsistent in milder cases. A study conducted in 2019 contradicted that finding, through affirming that patients with mild OSA feel the benefit from regular use of CPAP, and suggested that further studies should be conducted to assess whether other therapies might be as effective as CPAP in that population [38]. Redline and Lam showed that the group that received sleep hygiene advice did not achieve improvements in sleep parameters and health-related quality of life [34, 39]. These results were also confirmed through the study by Ballester (1999), even though the ESS score diminished in both groups: the improvement in the domains evaluated was greater in the group that received CPAP plus conservative treatment, including in the cases of mild apnea [40].

## Physical exercises and weight loss

Torres-Castro (2019) and Benoist (2016) can be highlighted among the studies because they did not include CPAP in any intervention or control group. Torres-Castro [41] explored the impact of physical activity plus sleep hygiene plus diet

in group 1, and in their group 2, used the same interventions plus oropharyngeal exercises. The AHI did not differ between the groups, but after dividing the subjects according to age, those under 60 years of age showed a significant reduction after the intervention, while the older participants presented worsened sleep. It has been shown in the literature that physical activity reduces the severity of OSA, improves sleep efficiency, and diminishes daytime sleepiness with minimal alterations to body weight [42, 43].

Cipriano et al. compared CPAP with physical training and divided their two groups into hypertensive and non-hypertensive individuals. Their findings showed that there was no significant difference in daytime sleepiness between the groups, and they explained this in terms of the short duration of the treatment [44]. Studies indicate that more than 50% of moderate to severe OSA cases are related to obesity [45]. In these circumstances, lifestyle changes such as physical exercise and diet can favor significant improvements. A study from 2022 showed that these habits significantly reduced the AHI, with 15% of the observed group achieving complete remission of OSA and 45% not requiring CPAP [46]. According to Gambino and colleagues (2022), even if the expected effects do not meet the estimates, weight loss and physical activity should always be recommended to obese patients with OSA. [47]

### Positional therapy

Benoist [48] analyzed the efficacy of positional therapy in comparison with the use of an oral device and observed that these treatments were equally effective for reducing the AHI. However, these authors left open the need for further studies combining these two therapies, with the suggestion that non-supine OSA could potentially be eliminated. Regarding adherence, positional therapy was better because it did not present side effects. According to the literature, the better the adherence is, the greater the efficacy of the treatment will be [49–51]. Although its effect is smaller than CPAP, the emergence of technological devices is very promising, as they have shown good effectiveness, sparked interest among CPAP-intolerant individuals, and increased long-term adherence [52].

### Impact on cognition and mood

Two studies investigated the impact of interventions on daytime functioning and cognition. Ballester reported that there were improvements in daytime functioning, energy, and emotional reactions in the group that received CPAP [53]. Dalmases found that elderly people with severe OSA, over 65 years of age, presented cognitive impairment that mainly affected tasks requiring attention. These difficulties could be resolved through CPAP, which improved the

functioning of the frontal lobe, but no improvement was seen through conservative therapy [54]. Efforts to elucidate the impact of OSA on cognition have been made in studies in the literature. It has been shown that patients with OSA have problems with attention and declining short- and long-term memory [55, 56], complaints relating to emotional control and motivation [57], and problems regarding executive functions and the ability to learn new things. It has also been shown that individuals with apnea present significantly worse performance in verbal memory tests [58, 59], resolution of problems and judgment [60], and flexibility and strategic planning [61].

In addition to surveying cognitive impairment, studies have addressed mood changes among people with OSA. These individuals have shown a high prevalence of depression and anxiety, even in cases of mild OSA [31, 62, 63]. A study conducted in 2004 reported that more than 40% of the patients with apnea presented clinically significant depression [64]. These data correlate with findings from other clinical studies in which a high prevalence of depression and anxiety among individuals with OSA was identified [65, 66].

## Conclusion

The most commonly used treatments of choice for OSA are invasive, including the use of CPAP, oral appliances, and surgeries, being the most utilized options. This study demonstrated that non-invasive conservative treatments, such as sleep hygiene, yield results as effective as invasive treatments. Further studies are needed to confirm this result and to predict whether invasive treatment can be used as the primary treatment or only as a supplement.

**Data availability** All data on the measured ecosystem variables indicating ecosystem functions that support the findings of this study are included within this paper and its Supplementary Information files.

## Declarations

**Ethical approval** For this type of study, formal consent is not required.

**Conflict of interest** The authors declare no competing interests.

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