The effect of playing a wind instrument or singing on risk of sleep apnea: a systematic review and meta-analysis

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Study Objectives: To systematically survey the scientific literature concerning the effect of playing a wind instrument or singing on sleep, snoring, and/or obstructive sleep apnea.

Methods: The PubMed, EMBASE, and Cochrane databases were searched up to December 2019. Observational studies and (Randomized) Controlled Clinical Trials that assessed sleep, snoring, or obstructive sleep apnea as clinical outcome or via a questionnaire were included. For the individual studies, the potential risk of bias was scored. Data between oral musicians and control participants were extracted. Descriptive analysis and meta-analysis were performed.

Results: Six eligible studies (5 cross-sectional, 1 randomized controlled trial) were retrieved, with an estimated potential bias ranking from low to high. The sample sizes ranged from 25 to 1,105 participants. Descriptive analysis indicated that players of a double-reed instrument have a lower risk of obstructive sleep apnea and that singers snore less compared with control participants. Playing a didgeridoo showed a positive effect on apnea-hypopnea index, daytime sleepiness, and partner’s rating for sleep disturbance. The descriptive analysis could not be substantiated in the meta-analysis. The magnitude of the effect was zero to small, and the generalizability was limited because of long (professional) rehearsal time or small sample size.

Conclusions: Playing a wind instrument and singing may have a small but positive effect on sleep disorders. Considering the practicality and investment of (rehearsal) time, didgeridoo and singing are the most promising interventions to reduce obstructive sleep apnea and snoring, respectively. However, the results of this review are based on few studies and the synthesis of the evidence is graded to have low certainty.

Keywords: wind instrument, singing, sleep, snoring, OSA, sleep apnea

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INTRODUCTION

Human beings spend about one-third of their life either sleeping or attempting to sleep. Sleep is essential for normal cognitive functioning and survival. Yet it can be disturbed or abnormal.1

The pharyngeal airway lacks substantial bony or rigid support. Thus, the patency of the pharyngeal airway is largely dependent on the activity of various pharyngeal dilator muscles. As long as these muscles are sufficiently active, the patency of the airway is maintained.2 When the muscles relax during sleep, soft tissue in the back of the throat can collapse, causing turbulence and vibration (snoring) or even partial or complete obstruction of the upper airway (obstructive sleep apnea, OSA).3,4 In the case of OSA, the (largely) obstructed pharyngeal airway prevents effective ventilation, producing either partial reductions (hypopneas) or complete stops (apneas) in breathing. In either case, these (hypo)apneas will lead to reduced oxygen levels and elevated carbon dioxide levels in the blood. The brain responds to this by alerting the body, causing a brief arousal from sleep that re-establishes the airway patency and normal breathing. This pattern can occur hundreds of times in 1 night.2,4 The severity of OSA is expressed according to the apnea-hypopnea index (AHI), a measure that represents the combined number of apneas and hypopneas that occur per hour of sleep.4

The result of OSA is a fragmented sleep that often produces excessive daytime sleepiness,7 which in turn can compromise safety on the roads and reduce work productivity.5–7 OSA is also associated with an increased risk of hypertension,8 cardiovascular disease,9 incident heart failure,10 and myocardial infarction,11 among other possible consequences. The susceptibility for OSA may vary by individual and can be influenced by several factors, such as the size of the pharyngeal airway, the size of the tongue and/or the tonsils, and mandibular retrognathism.5

Several treatments have been developed over the years to treat snoring and OSA. Many of them are invasive and involve either surgery or wearing a device during sleep.5,12 Therefore, an alternative treatment approach that is noninvasive, safe, and effective would be beneficial. Because the dilator muscles of the upper airway play a critical role in maintaining an open airway during sleep, researchers have explored exercises that target oral cavity and oropharyngeal structures as an alternative method to treat OSA,13 such as oropharyngeal exercises. These are derived from speech therapy and consist of isomeric (continuous) and isotonic (intermittent) movements involving the tongue, soft palate, and facial muscles, as well as stomatognathic functions like suction, swallowing, chewing, breathing, and speech. The series of exercises are based on the concept that muscle training while awake will reduce upper airway collapsibility during sleep.14 A significant decrease in snoring frequency, snoring intensity, daytime sleepiness, sleep quality score, and OSA severity (measured using AHI) has been observed among patients who had performed these exercises for...
3 months, as has a significant reduction in neck circumference. The latter suggests that the exercises induced upper airway remodeling.\textsuperscript{14} A meta-analysis performed by Camacho et al\textsuperscript{13} demonstrated that oropharyngeal exercises decrease AHI by approximately 50\% in adults and 62\% in children. Lowest oxygen saturations, snoring, and sleepiness outcomes improved. The authors concluded that oropharyngeal exercises could serve as an adjunct to other OSA treatments. A more recent systematic review by the same authors based on both subjective questionnaires and objective sleep studies indicated that, with oropharyngeal exercises, a reduction in snoring by approximately 50\% in adults can be achieved.\textsuperscript{15}

If oropharyngeal exercises are indeed effective for reducing snoring and the risk of OSA, it could be useful to explore those individuals who have spent years engaging in training of the airway muscles as part of their hobby or profession: wind-instrument musicians. The whole complex of anatomical structures around the instrument, is called “embouchure.”\textsuperscript{16} The 3 main embouchure components are the tongue, the teeth, and the cheek and lip muscles, but the palate and pharynx also play an important role.\textsuperscript{16,17} Other airway training involves singing, which requires control of the muscles of the larynx, hypopharynx, oral pharynx, and oral cavity.\textsuperscript{18}

To our knowledge, no systematic review or meta-analysis has been published of studies evaluating sleep, snoring, or OSA among oral musicians compared with controls. Therefore, the aim of this systematic review is to comprehensively search the scientific literature to identify, critically appraise, analyze, and synthesize studies that address the effect of playing a wind instrument or singing on sleep, snoring, and/or OSA.

### METHODS

#### Protocol

The recommendations for strengthening reporting were followed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA),\textsuperscript{15} in combination with the guidelines for Meta-analyses Of Observational Studies in Epidemiology (MOOSE),\textsuperscript{20} and the PRISMA extension for abstracts.\textsuperscript{21} The protocol that details the review method was developed a priori following an initial discussion among the members of the research team, and registered in PROSPERO (International Prospective Register of Systematic Reviews) (CRD42019134672).

#### Focused question and eligibility criteria

The PICOS-question (Population, Intervention, Comparison, Outcomes and Study)\textsuperscript{22} to be answered in the present review is: In observational studies and (randomized) controlled clinical trials, what is the observed effect on sleep, snoring, and OSA in people who play a wind instrument or are singers compared with those who do not play a wind instrument or do not sing?

The following criteria were imposed for inclusion in the systematic review:

- Observational studies and (randomized) controlled clinical trials describing the effect of playing a wind instrument or singing compared with controls.
- Any clinical outcome or questionnaire evaluating sleep, snoring, and OSA, such as daytime sleepiness, quality of sleep, snoring score, risk of OSA, diagnosis of OSA, or AHI.

The exclusion criteria were as follows:

- Editorial letters, narrative reviews, case series, case reports, protocols, and abstracts.

#### Information sources and search

The PubMed-MEDLINE, EMBASE, and Cochrane-CENTRAL databases were searched from initiation up to December 2019 (F.N.W.). The search strategy is listed in Table 1. Gray literature was also searched via Google Scholar. Additionally, the reference lists of all selected studies were hand-searched for additional relevant articles (F.N.W., D.E.S.).

#### Study selection

The titles and abstracts of the studies obtained from the searches were screened independently by two reviewers (F.N.W., D.E.S.) and were categorized as definitely eligible, definitely not eligible, or questionable. No language restrictions were imposed. No attempt was made to conceal the names of authors, institutions, or journals from the reviewers while making the assessment. If eligible criteria were present in the title, the paper was selected for further reading. If none of these criteria were mentioned in the title, the abstract was read in detail to screen for suitability. Papers that could potentially meet the inclusion criteria were obtained and read in detail by the 2 reviewers (F.N.W., D.E.S.). Disagreements in the screening and selection process concerning eligibility were resolved by consensus or, if disagreement persisted, by arbitration through a third reviewer (F.L.). The papers that fulfilled all of the inclusion criteria were processed for data extraction.

#### Data collection process, summary measures, and synthesis of results

When provided, information about the characteristics of the study sample population, intervention, comparison, and outcomes were extracted independently from the selected studies by two reviewers (F.N.W., D.E.S.). As age, BMI, and male sex are well-known risk factors for snoring and OSA, these data were also extracted when reported for further analysis. Means and standard deviations were extracted (Table S1 and Table S2 in the supplemental material) or, if missing, requested from the original authors. If a confidence interval was reported, the standard deviation was calculated based on the mean and the number of participants.\textsuperscript{23} As a summary, a descriptive data presentation was used for all the studies.

If feasible, the data from the included studies were synthesized into a meta-analysis (D.E.S., F.N.W.). In studies consisting of multiple comparisons and data from one particular group compared with more than one other group, the number of subjects (n) in the group was divided by the number of comparisons. A meta-analysis was only performed if at least 2 studies could be included. The difference of means or risk ratio between test and control was calculated for each index/scale using a “random effects” model (Review Manager, version 5.3 for Windows, The Nordic Cochrane Centre, The Cochrane...
Table 1—Search strategy for PubMed.

<table>
<thead>
<tr>
<th>AND</th>
<th>OR</th>
<th>OR</th>
<th>OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>(&lt;wind instrument*&gt; OR &lt;music AND instrument&gt; OR &lt;didgeridoo OR didjeridu OR yidaki&gt; OR &lt;singing OR “singing”[MeSH]&gt;)</td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td>AND</td>
<td>OR</td>
<td>OR</td>
<td>OR</td>
</tr>
<tr>
<td>(&lt;“Sleep Apnea, Obstructive”[MeSH]&gt; OR &lt;“sleep or nocturnal” AND (apnea OR hypopnea OR apnea OR (breath* AND disorder*))&gt; OR &lt;OSA OR OSAS OR OSAHS&gt; OR &lt;“snoring”[MeSH]&gt; OR “snore” OR &lt;“sleepiness OR somnolence OR (quality AND sleep)&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The search strategy was customized according to the database being searched. The asterisk was used as a truncation symbol.

RESULTS

Study selection

The search on PubMed-MEDLINE, EMBASE, and Cochrane-CENTRAL resulted in 194 unique papers (Figure 1). Screening of the titles and abstracts resulted in 18 potentially suitable papers, of which 3 experiments each had 2 publications. The full text of 7 papers was not retrievable: 3 were registered protocols and could not be retrieved as full manuscripts, and 4 were congress abstracts. For 8 papers, the full texts were obtained and read in full. Two studies were excluded. One had no control group, and the other was a summary of 1 of the included papers. Google Scholar and the reference lists of the selected full text papers yielded no additional suitable papers. Thus, in total, 6 papers (Figure 2) were included in the present systematic review.

Study characteristics

The study characteristics of the 6 included papers are listed in Table 2. Five of the eligible papers had a cross-sectional study design, whereas one was an RCT. In the RCT, the intervention consisted of didgeridoo lessons. Three cross-sectional studies compared professional wind and nonwind instrument players, one study compared experienced (> 10 years) wind instrument players with participants who did not play a wind instrument and were not singers either, and one study compared singers with healthy volunteers. The sample sizes ranged from 25 to 1,105 participants. Three continents were represented (Europe, North America, Asia).

Risk of bias within studies

To estimate the potential risk of bias, the methodological qualities of the included studies were assessed (Table S3 and Table S4). Overall, the potential risk of bias in the included studies was estimated to be “high” for 1, “moderate” for 2, and “low” for the remaining 3. In the studies that were judged to have a moderate risk of bias, the sample size was not justified and satisfactory. Besides that, in the study with an estimated potential high risk of bias, the study participants were not described in detail.

Descriptive analysis

Data extracted from the included studies are presented in Table 3, which provides a summary overview of sleep/snoring/OSA parameters between wind instrument players/singers and a control group. According to the results of 3 of the included studies, there seems generally to be no difference in sleep, snoring, and OSA between wind instrument players and controls. Two exceptions are double-reed instrument players,
who are found to have a lower risk of OSA compared with controls,\textsuperscript{40,44} and didgeridoo players, who are found to have lower AHI, daytime sleepiness, and partners’ rating for sleep disturbance compared with controls.\textsuperscript{39} Singers are found to have a lower Snoring Scale Score (SSS) compared with controls,\textsuperscript{42} but no difference was found in daytime sleepiness.

Meta-analysis

A meta-analysis was feasible for the following outcome parameters: Epworth Sleepiness Scale (ESS), high risk of OSA (measured using the Berlin Questionnaire [BQ]), and diagnosis of OSA (by a physician). The following studies could be included in the meta-analysis: Brown et al,\textsuperscript{44} Puhan et al,\textsuperscript{39} Ward et al,\textsuperscript{40} Wardrop et al,\textsuperscript{41} and Subramanian et al.\textsuperscript{43} (Table 4). Meta-analysis shows no difference in the ESS, high risk of OSA (BQ), or diagnosis of OSA (by a physician) between wind instrument players and controls, with a heterogeneity of 0%, except for high risk of OSA ($I^2 = 81\%$, $P < .001$).

Risk factors, heterogeneity, sensitivity analysis, and publication bias

A meta-analysis was also performed on the risk factors: age\textsuperscript{29}, body mass index (BMI), and sex (Table 4). There was no significant difference in the means or risk ratio between wind instrument players and controls. BMI and male sex were factors that showed significant heterogeneity ($I^2 = 80–87\%$, $P < .001$).

The large heterogeneity for the high risk of OSA parameter ($I^2 = 81\%$, $P < .001$) is due to the fact that some studies/subgroups point in different directions (Figure S2a). The study by Brown et al\textsuperscript{44} showed higher risk of OSA among wind instrument players compared with controls. BMI and male sex were factors that showed significant heterogeneity ($I^2 = 80–87\%$, $P < .001$). The double-reed instrument players subgroup in the study by Ward et al\textsuperscript{40} also showed a tendency for a lower risk of OSA compared with controls. These discrepancies correspond to the significant heterogeneity of the BMI and male sex risk factors. The wind instrument group in the study by Brown et al\textsuperscript{44} consisted of more males and a higher BMI compared with the control group (Figure S2, c and e). The double-reed instrument players subgroup in the study by Ward et al\textsuperscript{40} had more women and a lower BMI compared with the control group, whereas the high and low brass instrument players subgroups had more men and a higher BMI (Figure S1, b and d, Figure S2, c and e). In the study by Wardrop et al,\textsuperscript{41}
Table 2—Study characteristics of the included papers.

<table>
<thead>
<tr>
<th>Study (Risk of Bias)</th>
<th>Study Design</th>
<th>Population (Country)</th>
<th>Participants</th>
<th>Conclusions of the Original Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown et al(^{44}) (Low)</td>
<td>Cross-sectional</td>
<td>Professional orchestra members registered by the International Conference of Symphony and Opera Musicians (ICSOM), (USA and Puerto Rico)</td>
<td>369 wind instrument players: 175 brass players, 194 woodwind instrument players, 233 men, 110 women, 26 missing sex, mean age 46.7 (12.26) years</td>
<td></td>
</tr>
<tr>
<td>Pai et al(^{42}) (Moderate)</td>
<td>Cross-sectional</td>
<td>Singers from two London-based, mixed-sex choirs. The nonsinger group consisted of healthy volunteers also recruited in London. (United Kingdom)</td>
<td>52 singers: 20 men, 32 women, mean age 46.3 (26–70) years</td>
<td>Singing practice may have a role in the treatment of snoring but does not appear to influence daytime somnolence.</td>
</tr>
<tr>
<td>Puhan et al(^{39}) (Low)</td>
<td>RCT</td>
<td>Participants aged &gt; 18 years with self-reported snoring and an AHI of 15–30 (determined by a specialist in sleep medicine within the past year). (Switzerland)</td>
<td>Intervention group: 12 men, 2 women, mean age 49.9 (6.7) years</td>
<td>Regular didgeridoo playing is an effective treatment alternative well accepted by patients with moderate OSA.</td>
</tr>
<tr>
<td>Subramanian et al(^{43}) (Serious)</td>
<td>Cross-sectional</td>
<td>Participants mainly from villages in and around Madurai who have been playing the instrument for nearly more than 10 years. (India)</td>
<td>64 wind instrument players: 45 Nathasvaram (= double reed instrument), 10 trumpet (= brass instrument), 10 clarinet (= single reed instrument)</td>
<td>OSA risk is reduced in wind instrument players.</td>
</tr>
<tr>
<td>Ward et al(^{40}) (Moderate)</td>
<td>Cross-sectional</td>
<td>Collegiate instrumental music instructors and other professional musicians. (USA)</td>
<td>76 double-reed instrument players: 27 men, 49 women, mean age 41.7 (14.5) years</td>
<td>Playing a double-reed musical instrument was associated with a lower risk of OSA.</td>
</tr>
<tr>
<td>Wardrop et al(^{41}) (Low)</td>
<td>Cross-sectional</td>
<td>Professional orchestra members. (United Kingdom)</td>
<td>81 wind instrument players: mean age 41.58 (10.16) years</td>
<td>No significant difference between the snoring severity or daytime sleepiness of brass/wind players and other professional orchestral musicians.</td>
</tr>
</tbody>
</table>
Table 3—Summary of significant differences between wind instrument players/singers and controls for sleep/snoring/OSA parameters.

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Sleep</th>
<th>Snoring</th>
<th>OSA</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PQS</td>
<td>ESS</td>
<td>PRSD</td>
<td>SOS</td>
</tr>
<tr>
<td>Pai et al42</td>
<td>Singers</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wardrop et al41</td>
<td>Wind instrument players</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Subramanian et al43</td>
<td>Wind instrument players (70% double reed)</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ward et al40</td>
<td>Double-reed instrument players</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ward et al40</td>
<td>Single-reed and flute instrument players</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brown et al44</td>
<td>Woodwind* instrument players</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brown et al44</td>
<td>Brass instrument players</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ward et al40</td>
<td>High brass instrument players</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ward et al40</td>
<td>Low brass instrument players</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Brown et al44</td>
<td>Wind instrument players using circular breathing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Puhan et al41</td>
<td>Didgeridoo lessons</td>
<td>0</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Woodwind instrument players = double-reed + single-reed + flute. - = significantly lower for the wind instrument/singer group. 0 = no significant difference. Empty boxes indicate that no data are available. AHI = apnea-hypopnea index, BQ = Berlin Questionnaire (Risk of OSA), DO = diagnosis of OSA (by a physician), ESS = Epworth Sleepiness Score (daytime sleepiness), OSA = obstructive sleep apnea, PQS = Pittsburgh Sleep Quality index, PRSD = Partner’s Rating for Sleep Disturbance, SOS = Snore Outcomes Survey score (snore severity), SSS = Snoring Scale Score.

the wind instrument group consisted of more men than the control group (Figure S1d).

For the sensitivity analysis (Table 5), studies/subgroups were removed if there was a significant difference between the test and control group for any of the risk factors. Consequently, for the ESS, 4 of the 6 studies/subgroups were excluded; only the study by Puhan et al41 and the subgroup of single-reed instrument and flute players from the study by Ward et al40 remained. A sensitivity analysis with these 2 groups also showed no significant difference in the ESS between wind instrument players and controls ($I^2 = 0\%$ (Figure S3a)). The overall result was not affected by the sensitivity analysis, although it did have an effect on the statistical heterogeneity expressed by $I^2$. The result for the ESS can be regarded with a higher degree of certainty. For high risk of OSA (BQ) and diagnosis of OSA (by a physician), 5 of the 6 studies/subgroups were excluded. Only the single-reed instrument and flute players subgroup from the study by Ward et al40 remained. As a result, the predefined minimum of 2 studies for a meta-analysis was not reached.

Testing for publication bias could not be performed, because fewer than 10 studies could be included in the meta-analysis.25

Rating the certainty of the evidence (GRADE)

Table 6 summarizes the various factors used to rate the strength of the evidence according to the criteria as proposed by the GRADE working group.31,32 Table S3 and Table S4 show that the estimated potential risk of bias is low to high. The data that emerged are rather consistent and rather precise; however, the generalizability is limited because of long (professional) rehearsal time or small sample size. Reporting bias could not be ruled out. The magnitude of the effect is zero to small. Consequently, the degree of certainty surrounding the effect is low.

### DISCUSSION

**Answer to the focused question**

This review was initiated to evaluate various aspects of sleep disturbance in oral musicians. The results of the descriptive analysis (Table 3) show that playing a double-reed instrument or didgeridoo as well as singing have a positive effect on sleep, snoring, and/or OSA. The descriptive analysis could not be substantiated by meta-analysis (Table 4 and Table 5), in which all wind instruments were pooled. The single study that evaluated the effect of singing (Table 3) showed a positive effect on snoring compared with nonsingers. The only RCT that evaluated the effect of playing a didgeridoo showed a positive effect on AHI, daytime sleepiness, and partner’s rating for sleep disturbance.

**Risk factors**

Well-known risk factors for snoring and OSA are ageing,45–47 excess body weight,46–50 and male sex.45–48,51 A systematic review found a prevalence of OSA (AHI ≥ 5 events/h) to be 9–38% and higher in men. It increased with age and, in some groups of older people, was as high as 90% in men and 78% in women. With an AHI ≥ 15 events/h, the prevalence in the general adult population ranged from 6 to 17%, and was as high as 49% in advanced ages. OSA prevalence was also greater in men and women with obesity.46

The meta-analysis showed a large heterogeneity for high risk of OSA, which can be explained by the heterogeneity for BMI and male sex between the study groups. The results of 2 included studies did not show a difference between wind instrument players and control participants (Table 3). These 2 studies, however, did confirm that age, BMI, and male sex were positively associated with snoring severity,41 a high risk of OSA,44 or physician’s diagnosis of OSA.44
Of the 4 studies that did show a positive effect of singing or playing the didgeridoo or a double-reed instrument, 3 studies adjusted outcomes for the risk factors of age, BMI, and sex distribution. In the study that showed that singers have a lower SSS compared with controls,42 the findings were adjusted for age and BMI. The sex ratio was comparable between the singer group (20:32, men to women) and nonsinger group (23:32, men to women). In the RCT in which didgeridoo players were found to have lower AHI, daytime sleepiness, and partners’ rating for sleep disturbance compared with controls, findings were adjusted for weight change during the study.39 In 1 of the 2 studies in which double-reed instrument players

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**Table 4**—Meta-analysis for Epworth Sleepiness Scale, high risk of OSA, diagnosis of OSA, and risk factors age, BMI, and male sex.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Included Studies</th>
<th>Outcome Parameters</th>
<th>DiffM</th>
<th>Risk Ratio</th>
<th>Test for Overall</th>
<th>Test for Heterogeneity</th>
<th>Forest Plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind instrument vs. control</td>
<td>Puhan et al39; Ward et al40 (4 subgroups); Wardrop et al41</td>
<td>ESS</td>
<td>−0.16</td>
<td>−0.65, 0.33</td>
<td>.52</td>
<td>0</td>
<td>1.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BMI</td>
<td>0.65</td>
<td>−0.65, 1.91</td>
<td>.32</td>
<td>80%</td>
<td>1.92, 24.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td>0.10</td>
<td>−1.37, 1.57</td>
<td>.90</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male sex</td>
<td>1.14</td>
<td>0.90, 1.45</td>
<td>.27</td>
<td>82%</td>
<td>0.07, 28.13</td>
</tr>
<tr>
<td>Wind instrument vs. control</td>
<td>Brown et al42; Subramanian et al43; Ward et al40 (4 subgroups)</td>
<td>High risk of OSA (BQ)</td>
<td>0.85</td>
<td>0.58, 1.24</td>
<td>.39</td>
<td>81%</td>
<td>0.17, 26.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diagnosis of OSA (by a physician)</td>
<td>1.25</td>
<td>0.85, 1.87</td>
<td>.24</td>
<td>0%</td>
<td>2.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BMI</td>
<td>0.94</td>
<td>−0.37, 2.24</td>
<td>.16</td>
<td>85%</td>
<td>1.83, 25.86</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td>0.06</td>
<td>−1.11, 1.23</td>
<td>.92</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male sex</td>
<td>1.18</td>
<td>0.93, 1.49</td>
<td>.18</td>
<td>87%</td>
<td>0.06, 30.27</td>
</tr>
</tbody>
</table>

*BMI = body mass index, CI = confidence interval, DiffM = difference of means, ESS = Epworth Sleepiness Scale.

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**Table 5**—Sensitivity analysis for Epworth Sleepiness Scale and risk factors age, BMI, and male sex.

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Included Studies</th>
<th>Outcome Parameter</th>
<th>DiffM</th>
<th>Risk Ratio</th>
<th>Test for Overall</th>
<th>Test for Heterogeneity</th>
<th>Forest Plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind instrument vs. control</td>
<td>Puhan et al39; Ward et al40 (only single-reed instrument and flute players)</td>
<td>ESS</td>
<td>−0.50</td>
<td>−1.39, 0.39</td>
<td>.27</td>
<td>0%</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BMI</td>
<td>−0.10</td>
<td>−1.19, 0.99</td>
<td>.86</td>
<td>0%</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Age</td>
<td>1.87</td>
<td>−1.03, 4.77</td>
<td>.21</td>
<td>0%</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male sex</td>
<td>0.99</td>
<td>0.82, 1.19</td>
<td>.90</td>
<td>0%</td>
<td>0.16</td>
</tr>
</tbody>
</table>

*BMI = body mass index, CI = confidence interval, DiffM = difference of means, ESS = Epworth Sleepiness Scale.

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**Table 6**—Rating the certainty of the evidence (GRADE).31,32

<table>
<thead>
<tr>
<th>Determinants of Quality</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Study design</td>
<td>Cross-sectional, RCT</td>
</tr>
<tr>
<td>Number of studies</td>
<td>6</td>
</tr>
<tr>
<td>Risk of bias</td>
<td>Low to high</td>
</tr>
<tr>
<td>Consistency</td>
<td>Rather consistent</td>
</tr>
<tr>
<td>Directness</td>
<td>Limited generalizability</td>
</tr>
<tr>
<td>Precision</td>
<td>Rather precise</td>
</tr>
<tr>
<td>Reporting bias</td>
<td>Cannot be ruled out</td>
</tr>
<tr>
<td>Magnitude of the effect</td>
<td>Zero to small</td>
</tr>
<tr>
<td>Strength of the propositions emerging from this review</td>
<td>Low</td>
</tr>
<tr>
<td>Overall recommendation</td>
<td>Considered advising patients who snore or have (risk of developing) obstructive sleep apnea to practice singing or to play the didgeridoo or a double-reed instrument. However, the degree of certainty surrounding the expected effect is low.</td>
</tr>
</tbody>
</table>

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showed a lower risk of OSA, the double-reed group was majority women. However, the covariate-adjusted regression model indicated that the observed effect was not the result of sex distribution differences. The other study that found that wind instrument players (70% double-reed) had a lower risk of OSA did not report on the age, BMI, or sex of the participants. However, this was the only study taking into account smoking as a potential risk factor. There was a trend toward a higher number of smokers in the wind instrument group compared with the control group ($P = .06$). Whether smoking is a risk factor for OSA remains a matter of debate. A study containing 3,509 patients who were treated in a university hospital sleep clinic revealed that heavy smokers (> 30 pack-year) had almost twice the risk of having an AHI > 50 events/h compared with non-smokers. However, after adjusting for age, BMI, and sex, this difference was no longer significant. On the other hand, a recent study of 660 participants observed that there is an increased risk of OSA in heavy smokers.

Different types of wind instruments and circular breathing

Strayer, an orthodontist and professional bassoonist, established a classification of 4 groups of wind instrument players with different embouchure techniques: brass, single-reed, double-reed, and flute (Figure 1). In the included studies, the data were not analyzed in accordance with this classification. Wardrop et al considered all wind instrument players as one group and did not report on the different types of wind instruments. Subramanian et al examined players of three types of wind instruments (nadaswaram, trumpet, and clarinet), but pooled them all together in their analysis. Brown et al made a distinction between woodwind and brass instrument players and also performed a subgroup analysis. However, that study did not consider different types of woodwind instruments. Ward et al distinguished between high brass, low brass, and double-reed instruments, but considered players of a single-reed instrument and flute as one group.

One wind instrument that cannot be assigned to any of the 4 groups defined by Strayer is the didgeridoo, an instrument developed by Indigenous Australians. Playing the didgeridoo requires the use of circular breathing. This is a technique used to produce a continuous tone without break, achieved by using the cheeks as a reservoir of air that is expelled to continue the note while the player breathes in through the nose. The results of one of the included studies suggest that practicing the didgeridoo/circular breathing may train airway muscles, leading to less collapse of oropharyngeal tissues during sleep, which results in a beneficial effect on OSA. However, another included study compared players of wind instrument who used circular breathing with all other wind instrument players. The use of circular breathing was not found to be related to either the risk of OSA or OSA diagnosis. One explanation might be that didgeridoo players use the technique much more consistently and thus may achieve a greater level of oropharyngeal muscle training.

Players of double-reed instruments are found to have a lower risk of OSA compared with controls, although no such
association was found for the other groups of wind instruments. The mechanism behind this selective difference might be the different types of embouchure, i.e., different patterns of muscle activation used in various types of orchestral wind instruments (Figure 1). Another explanation might be the difference in air pressure required to make a sound. Goss56 provided an overview of intraoral pressure ranges in wind instruments and subglottal pressure of singing based on his own data and a survey of the literature (Figure 3). At the top is the trumpet (maximum of 150 mbar), followed by the oboe (110 mbar), euphonium (100 mbar), singing (85 mbar), bassoon and French horn (70 mbar), saxophone (55 mbar), clarinet (50 mbar), and flute (20 mbar). This clearly marks that brass and double-reed instruments (in particular the trumpet and oboe), together with singing, are associated with the highest maximum pressures. This could also explain the association between singing and a lower SSS.42 The included studies, however, do not show an association between brass instrument playing and lower risk of OSA, whereas such an association was observed for double-reed instruments. This could be explained by the fact that oboe players need to generate higher minimum pressure to start a note than brass players (Figure 3).

Compliance and practice time
Playing a wind instrument or singing to train the oropharyngeal musculature is an attractive approach to reducing OSA, because these recreational activities are potentially enjoyable in their own right.41 However, these treatments are not effective unless they are practiced consistently.40 In one of the studies analyzed for the present review, participants had to practice the didgeridoo at home for at least 20 minutes at least 5 days a week.39 This might be an achievable schedule. Conventional orchestral instruments might have greater appeal and relevance to western patients.41 However, another study showed that among double-reed instrument players, the number of hours per week the instrumentalist played was a significant predictor of the level of OSA risk. Double-reed instrumentalists at low risk for OSA played on average 16.5 hours per week, while those at a higher risk played on average 9.1 hours per week.40 Practicing 16.5 hours per week is likely far too much for amateur musicians with OSA. Additionally, proper double-reed instrument playing is not something that can be learned easily.40 Singing, however, might be very accessible. In a third study included in this review, semiprofessional singers were included, all of whom had received formal training in singing. The fewest number of years of choir singing was 5.42 The question is whether amateur singing has the same positive effect as semiprofessional singing.

Comparison with studies not included in this systematic review
One study was excluded from this systematic review because of the lack of a control group.37 In that study, 20 people who were chronic snorers received instruction in singing technique and singing exercises that they were instructed to practice for 20 minutes a day for 3 months. The duration of snoring was recorded by a voice-activated tape recorder for 7 nights, both before and after treatment. Snoring was, on average, reduced, especially in those who performed the exercises accurately and consistently, were not overweight, had no nasal problems, and began snoring only in middle age.

Four potentially interesting paper titles were identified in the initial search, but only the abstracts for these papers were retrievable.33–36 In the study by Turk et al,36 10 patients with OSA received didgeridoo lessons and practiced for 4 months. Strong associations were found between didgeridoo playing and a decrease in AHI (polysomnography) and in volume of parapharyngeal fat pads. Only a moderate association was found with decrease in daytime sleepiness. This in itself is not surprising because clinical symptoms such as daytime sleepiness correlate poorly with OSA severity as measured by AHI.57,58 In the study by Kim et al,35 19 Korean patients with OSA received didgeridoo lessons and practiced for 16 weeks. A significant improvement in snoring was found, but not in the AHI index. Bader et al33 collected completed questionnaires of 213 professional and 318 amateur musicians, of which 50% were singers, 34% wind instrument players, and 16% controls. A marked difference between sexes, but no significant difference between the groups, was found for SSS, ESS, and score and diagnosis of OSA. Antoniadou et al44 observed a low risk of OSA (BQ) among 25 players of wind instruments and 5 singers; however there was no control group in this study. The findings reported in these abstracts are comparable with the results of the studies included in the present systematic review.

Limitations
Following the search and selection, only 1 RCT could be included.38 This was the only study that provided direct data on the sleep of the participants. However, this study also contributed to clinical and methodological heterogeneity, which may negatively impact the representativeness of the results.

Because of the cross-sectional design of 4 of the 5 studies included in this review, conclusions were drawn on associations and not on causal relationships. Furthermore, the results of these 4 studies are based on questionnaires. Therefore, OSA was not diagnosed according to the gold standard, polysomnography. However, all studies used validated scales. The response rate varied per study from 10–30% by email to up to 70–90% by direct solicitation.40,41,44 Respondents may have been more likely than nonrespondents to be interested in OSA or snoring.

While the sample sizes of the studies by Brown et al44 (n = 1,105) and Ward et al89 (n = 906) are large, the sample size of the study by Puhan et al49 is very small (n = 25). Consequently, this small sample size may have a negative impact on generalizability and on study power.

The control group of the RCT performed by Puhan et al49 was generated randomly with stratification from OSA severity. The cross-sectional study among singers had a control group consisting of healthy volunteers.42 This is less than ideal compared with a control group consisting of nonwind instrument players (i.e., string, percussion, keyboard), which was used in the 3 cross-sectional studies among orchestra members.40,41,44 Fellow orchestral musicians are likely to have similar lifestyles and work patterns to the participants, which should therefore reduce
the effect of any confounding variables. Subramanian et al43 did not specify the background characteristics of their control group. However, this was the only study examining players of wind instrument that properly excluded singers in the control group.

The study by Puhan et al19 showed a clinically significant improvement in ESS score (mean change score in the didgeridoo group was 4.4 and the difference between the intervention and control groups was 3.0). In the study by Pai et al,42 however, SSS values were low in both the singer and nonsinger groups, and it is possible that many participants in this study were unlikely to have problems with snoring anyway. Although there is a statistically significant difference between the 2 groups in SSS values (singers 2.5 vs. nonsingers 3.6 on a scale of 0 to 9), the magnitude of this difference is small, and it is not possible to determine whether or not it is clinically relevant. The Snore Outcomes Survey Score and ESS scores in the study by Wardrop et al41 and the ESS scores in the study by Ward et al40 were also low for all groups.

Didgeridoo playing appeared to be the most promising musical intervention for positively affecting sleep-breathing disorders. A survey among patients with OSA demonstrated that two-thirds of respondents expressed interest in participating in a didgeridoo program.59 More and larger studies are needed to assess the generalizability, long-term compliance, and implementation of didgeridoo playing as alternative for current OSA treatments.

CONCLUSIONS

Playing a wind instrument and singing may have a positive but small effect on sleep disorders. Considering the practicability and investment of (rehearsal) time, didgeridoo and singing are the most promising interventions to reduce OSA and snoring, respectively. However, the results of this review are based on few studies and the synthesis of the evidence is graded to have low certainty.

ABBREVIATIONS

AHI, apnea-hypopnoea index
BMI, body mass index
BQ, Berlin Questionnaire
ESS, Epworth Sleepiness Score
GRADE, Grading of Recommendations Assessment, Development and Evaluation
OSA, obstructive sleep apnea
PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT, Randomized Controlled Trial
SSS, Snoring Scale Score

REFERENCES

Do musicians sleep well?


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DISCLOSURE STATEMENT

All authors gave their final approval and agreed to be held accountable for all aspects of the work, ensuring integrity and accuracy. The authors report no conflicts of interest.

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