**Background**

Although common in many Middle Eastern countries, water-pipe tobacco smoking, commonly known as water-pipe smoking (WPS), is increasingly popular in Western cultures. The primary objective of this study was to systematically review the effects of WPS on lung function. The secondary objective was to compare the effects of WPS and cigarette smoking on lung function.

**Methods**

We conducted a systematic review using the approach of the Cochrane Collaboration to search for, select, and abstract studies. We conducted two separate meta-analyses comparing water-pipe smokers with nonsmokers, and water-pipe smokers with cigarette smokers for each of three spirometric measurements (FEV₁, FVC, and FEV₁/FVC). We used the standardized mean difference (SMD) to pool the results.

**Results**
Six cross-sectional studies were eligible for this review. Compared with no smoking, WPS was associated with a statistically significant reduction in FEV1 (SMD = -0.43; 95% CI, -0.58 to -0.29; equivalent to a 4.04% lower FEV1%), a trend toward lower FVC (SMD = -0.15; 95% CI, -0.34 to 0.04; equivalent to a 1.38% reduction in FVC%), and lower FEV1/FVC (SMD = -0.46; 95% CI, -0.93 to 0.01; equivalent to a 3.08% lower FEV1/FVC). Comparing WPS with cigarette smoking, there was no statistically significant difference in FEV1, FVC, and FEV1/FVC. The six studies suffered from methodologic limitations.

Conclusions

WPS negatively affects lung function and may be as harmful as cigarette smoking. WPS, therefore, is likely to be a cause of COPD.

Abbreviations

GRADE
Grading of Recommendations Assessment, Development and Evaluation

SMD
standardized mean difference

WPS
water-pipe smoking

COPD is a preventable and treatable disease characterized by an abnormal inflammatory response of the lung to noxious particles or gases (eg, tobacco) leading to a progressive and nonreversible airflow obstruction. [1] COPD has become a leading cause of mortality and morbidity throughout the world. The Global Burden of Disease study has projected that it will become the third leading cause of death by 2020. [3] The World Health Organization classifies COPD as the fourth leading cause of mortality in the United States. [4]

The causal relationship between long-term cigarette smoking and COPD is clearly established, [5] [6] [7] with cigarette smoking being the single most important risk factor. [6] A recent systematic review showed that the prevalence of COPD is highest among male smokers who are > 40 years old. [8]

Water-pipe smoking (WPS) is a form of tobacco consumption that is increasing on a global level at a remarkable pace (see e-Appendix 1 and Fig 1 for further details on WPS). [9] The American Lung Association has described it as an “emerging deadly trend.” [10] In fact, a recent systematic review found WPS to be possibly associated with lung cancer, esophageal cancer, low birth weight, and periodontal diseases. [11]
The above-referenced systematic review identified no study assessing the association of WPS with airways diseases in general or COPD in particular. There are, however, published studies assessing the association of WPS with lung function measurements. Some of these measurements (ie, FEV1, FVC, FEV1/FVC) are considered valid surrogate measures of COPD. In the absence of data on clinical disease, data on such surrogates may be useful for both clinical and research purposes. Thus, the primary objective of this study was to systematically review the effects of WPS on lung function. The secondary objective was to compare the effects of WPS and cigarette smoking on lung function.

Materials and Methods

Eligibility Criteria

We included studies that assessed the association between water-pipe tobacco use and lung function. Eligible studies had to include a group of individuals smoking a water pipe exclusively. They also had to include at least one of the following: (1) a group of nonsmokers, (2) a group of individuals practicing exclusively cigarette smoking. Our outcomes of interest were the following three spirometric measurements: FEV1, FVC, and FEV1/FVC.

Search Strategy

In June 2008, we searched the following electronic databases starting with their dates of inception: MEDLINE, EMBASE, and ISI the Web of Science. e-Appendix 2 provides the detailed search strategies. We also reviewed the reference lists of included and other relevant papers and used the Related Articles function in PubMed and applied no language restrictions.

Selection Process

Two reviewers independently screened titles and abstracts resulting from the search using a standardized screening guide. We obtained the full text of citations considered as potentially eligible by at least one of the two reviewers. Next, the two reviewers independently screened the full texts for eligibility using a standardized and pilot tested form. Disagreements were
resolved by discussion or by a third reviewer.

**Data Abstraction**

One reviewer abstracted data from each eligible study using a standardized and pilot-tested data abstraction form. A second reviewer verified data abstraction. They resolved disagreements with the help of a third reviewer. The abstracted data included information about:

1. Study design and funding;
2. Population: setting and period, and participants' characteristics;
3. Exposure: type, measurement tool, and exposure levels of participants;
4. Outcomes: measurement tool and blinding of outcome adjudicator;
5. Methodologic features: selection method, information collection (measurement of exposure and outcome), handling of confounding, participation rate, and rate of complete data;

We collected data separately for the three different exposure groups (water-pipe smokers, cigarette smokers, nonsmokers). FEV1, FVC, and FEV1/FVC were calculated as percentages of predicted values and reported at the group level as mean and SD of these percentages.

**Data Analysis**

We calculated the $\kappa$ statistic to evaluate the agreement between the two reviewers assessing full texts for eligibility. For each of the three spirometric measurements (FEV1, FVC, and FEV1/FVC), we conducted two separate meta-analyses comparing water-pipe smokers with nonsmokers and water-pipe smokers with cigarette smokers. Because the populations and lung function measures differed across studies, we first calculated the standardized mean difference (SMD) and 95% CI for each outcome in the individual studies. The SMD expresses a measurement in standard units rather than the original units of measurement. We then pooled the SMDs across studies using a random effects model. In a sensitivity analysis, we excluded studies in which the nonsmokers were described as passive smokers. We translated the pooled SMD back into mean differences using the standard deviation for the respective spirometric outcomes derived from the National Health and Nutrition Examination Survey (NHANES) III data.[13]

We tested results for homogeneity across studies using the $I^2$ test[14] and used the following interpretation of the value of $I^2$: 0 to 50 = low, 50 to 80 = moderate and worthy of investigation, 80 to 100 = severe and worthy of understanding, 95 to 100 = aggregate with major caution (Julian Higgins, PhD, personal communication). We rated the overall quality of evidence using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.[15]

**Results**

**Description of Included Studies**

Figure 2 shows the study flow. Of 1,658 identified citations, we included six studies (Table 1) [16], [17], [18], [19], [20], [21]. One study reported results separately for men and women.[18] All studies included a group of nonsmokers, described as passive smokers in two of the studies.[19], [21] All but one study included a group of cigarette smokers.[19] All studies reported spirometric measurements. Countries in which the studies were conducted were Turkey (n = 3), Kuwait (n = 1), Saudi Arabia (n = 1), and Syria (n = 1).
Figure 2  Study flow diagram.

Table 1 -- Characteristics of Included Studies Measuring the Association Between WPS and Lung Function

<table>
<thead>
<tr>
<th>Study/Year</th>
<th>Population</th>
<th>Exposure</th>
<th>Outcome</th>
<th>Methodologic Characteristics</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>Kiter et al[17]/2000</td>
<td>Setting and period: special cafes in Izmir City (Turkey), period not reported</td>
<td>Type: water pipe, cigarette</td>
<td>Pulmonary function:</td>
<td>Selection: water-pipe smokers selected from special cafes, cigarette smokers and nonsmokers selected randomly from cafes and outside cafes</td>
<td>FEV₁, FVC, and FEV₁/FVC nonsignificantly lower in water-pipe smokers than nonsmokers</td>
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<tr>
<td>Study design: cross-sectional study</td>
<td>Participants' characteristics: 302 subjects, 100% men</td>
<td>Measurement: self-developed tool, no standardization reported; personal interview</td>
<td>Measurement tool: portable spirometer according to the standards of the American Thoracic Society; percentage predicted values calculated automatically according to the Communauté Européenne du Carbon et de</td>
<td>Information collection: objective outcome evaluation, nonstandardized exposure assessment tool</td>
<td>FEV₁ and FEV₁/FVC significantly lower in cigarette smokers than water-pipe smokers</td>
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<tr>
<td>Study/Year</td>
<td>Population</td>
<td>Exposure</td>
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<tr>
<td>Funding: not reported</td>
<td>Water-pipe smokers: 82 subjects, aged 56 ± 10 y</td>
<td>Water-pipe cumulative consumption measured as number of jurak-years = amount of jurak smoked/d × number of smoking years</td>
<td>Blinding of outcome adjudicator: not reported</td>
<td>Confounding handling: matching done for gender only</td>
<td>FVC nonsignificantly lower in cigarette smokers than water-pipe smokers</td>
</tr>
<tr>
<td>Cigarette smokers: 103 subjects, aged 46 ± 14 y</td>
<td>Cigarette cumulative consumption measured as pack-years = number of cigarette packs smoked/d × number of smoking years</td>
<td>% Participation: not reported</td>
<td>There was negative correlation of pack-years with FEV₁ in cigarette smokers, but no correlation between FEV₁ and jurak-years in water-pipe smokers</td>
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<tr>
<td>Water-pipe smokers who quit cigarette smoking: 95 subjects, aged 54 ± 12 y</td>
<td>Exposure levels of participants:</td>
<td>% Complete data: not reported</td>
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<tr>
<td>Nonsmokers: 117 subjects, aged 46 ± 16 y</td>
<td>Water-pipe smokers: 47 ± 33 jurak-years</td>
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<tr>
<td>Water-pipe smokers who quit cigarette smoking: 37 ± 42 jurak-years and 38 ± 32 pack-years</td>
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<td>Cigarette smokers: 38 ± 30 pack-years</td>
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<tr>
<td>Al-Fayez et al [18]/1988</td>
<td>Setting and period: Saudi Arabia, period not reported</td>
<td>Type: water pipe, cigarette</td>
<td>Pulmonary function:</td>
<td>Selection: volunteer recruitment</td>
<td>FEV₁, FVC, and FEV₁/FVC significantly lower in water-pipe smokers than nonsmokers</td>
</tr>
<tr>
<td>Study design: cross-sectional study</td>
<td>Participants' characteristics: 595 subjects, men aged 20–59 y and women 17–59 y. Subjects with history of asthma, chronic bronchitis, or any cardiopulmonary diseases excluded.</td>
<td>Measurement: self-developed tool, no standardization reported; personal interview</td>
<td>Measurement tool: time revolving spirometer (Vitalograph); method of calculation of percent predicted values not reported</td>
<td>Information collection: objective outcome evaluation, nonstandardized exposure assessment tool</td>
<td>FEV₁ and FVC significantly lower in men and nonsignificantly lower in women in cigarette smokers than water-pipe smokers</td>
</tr>
<tr>
<td>Funding: King AbdulAziz City for Science and</td>
<td>Water-pipe smokers: 344 subjects, 73% men</td>
<td>Exposure levels of participants: not reported</td>
<td>Blinding of outcome adjudicator: not reported</td>
<td>Confounding handling: no matching or adjustment in the</td>
<td>FEV₁/FVC significantly lower in both men and women in</td>
</tr>
<tr>
<td>Study/Year</td>
<td>Population</td>
<td>Exposure</td>
<td>Outcome</td>
<td>Methodologic Characteristics</td>
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<td>Technology</td>
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<td></td>
<td>Cigarette smokers: 251 subjects, 75% men</td>
<td>Type: water pipe, cigarette</td>
<td>Pulmonary function:</td>
<td>Analysis reported</td>
<td>Cigarette smokers than water-pipe smokers</td>
</tr>
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<td>Non-smokers: 283 subjects, 58% men</td>
<td>Measurement: self-developed tool, no standardization reported; constructed questionnaire that identifies smoking behavior of both groups, detailing rate of consumption of tobacco/d</td>
<td></td>
<td>% Participation: not reported</td>
<td>Heavy water-pipe smokers (&gt; 2 water pipe/d) exhibited a marked decline in FEV1 and FEV1/FVC compared with light smokers(1–2 water pipe/d)</td>
</tr>
<tr>
<td>Al Mutairi et al[16]/2006</td>
<td>Setting and period: local coffee shops and university students in Kuwait, period not reported</td>
<td>Type: water pipe, cigarette</td>
<td>Pulmonary function:</td>
<td>Selection: subjects selected from local coffee shops and among university students</td>
<td>FEV1 and FEV1/FVC nonsignificantly lower in water-pipe smokers than non-smokers</td>
</tr>
<tr>
<td>Study design: cross-sectional study</td>
<td>Participants’ characteristics: 168 subjects, all subjects who smoked more than one kind of tobacco, had chronic cardiopulmonary or renal diseases, or were on regular medications were excluded from the study</td>
<td>Measurement: objective outcome evaluation, nonstandardized exposure assessment tool</td>
<td></td>
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<td>FEV1, FVC, and FEV1/FVC nonsignificantly lower in water-pipe smokers than cigarette smokers</td>
</tr>
<tr>
<td>Funding: Kuwait University Research Administration Grant</td>
<td>Water-pipe smokers: 77 subjects, 90% men, aged 36.97 (34.79–39.16) y</td>
<td>Objective measurement tool: urinary cotinine and nicotine level</td>
<td>Blinding of outcome adjudicator: yes</td>
<td>Confounding handling: no matching or adjustment in the analysis reported</td>
<td>There was no significant difference in FEV1 and FEV1/FVC values in relation to duration of smoking (&lt; 10 y vs &gt; 10 y) in both cigarette and water-pipe smokers</td>
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<td></td>
<td>Cigarette smokers: 75 subjects, 93% men, aged 37.73 (35.54–39.95) y</td>
<td>Exposure levels of participants:</td>
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<td>% Participation: not reported</td>
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<td>Non-smokers: 16 subjects, 56% men, aged 33.3 (28.9–37.76) y</td>
<td>Water-pipe smokers:</td>
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<td>% Complete data: not reported</td>
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<tr>
<td>Study/Year</td>
<td>Population</td>
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<td>Outcome</td>
<td>Methodologic Characteristics</td>
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<tr>
<td>Aydin et al[19]/2004</td>
<td>Setting and period: Turkey, period not reported</td>
<td>Type: water pipe</td>
<td>Pulmonary function:</td>
<td>Selection: volunteer recruitment</td>
<td>FEV₁, FVC, and FEV₁/FVC nonsignificantly lower in water-pipe smokers than nonsmokers</td>
</tr>
<tr>
<td>Study design: cross-sectional study</td>
<td>Participants’ characteristics: 25 subjects, all subjects had no significant lung or other system disease or cigarette smoking history</td>
<td>Measurement: self-developed tool, no standardization reported; personal interview</td>
<td>Measurement tool: Sensor Media V max 22; method of calculation of percentage predicted values not reported</td>
<td>Information collection: objective outcome evaluation, nonstandardized exposure assessment tool</td>
<td></td>
</tr>
<tr>
<td>Funding: not reported</td>
<td>Water-pipe smokers: 14 subjects, 100% men, aged 53.7 ± 9.8 y</td>
<td>Exposure levels of participants:</td>
<td>Blinding of outcome adjudicator: not reported</td>
<td>Confounding handling: matching not reported but no significant difference between the mean age of the two groups</td>
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<tr>
<td>Water-pipe smokers: 23.7 ± 8.7 y</td>
<td>Passive smokers: 21.3 ± 5.2 y</td>
<td>% Participation: not reported</td>
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</table>

Age of starting smoking: 24.89 (22.61–27.17) y
Urinary nicotine = 440.48 (197.06–683.91) ng/mL
Urinary cotinine = 677.62 (458.89–896.34) ng/mL

Cigarette smokers:
Age of starting smoking: 20.36 (18.55–22.17 = 8) y
Urinary nicotine = 1487.30 (839.26–2135.37) ng/mL
Urinary cotinine = 1321.35 (1003.73–1638.98) ng/mL

Water-pipe smokers: 23.7 ± 8.7 y
Passive smokers: 21.3 ± 5.2 y

Passive smokers: defined as individuals who do not smoke but are
<table>
<thead>
<tr>
<th>Study/Year</th>
<th>Population</th>
<th>Exposure</th>
<th>Outcome</th>
<th>Methodologic Characteristics</th>
<th>Results</th>
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</thead>
<tbody>
<tr>
<td>Mohammad et al [20]/2008</td>
<td>Setting and period: Syria, first semester of 1994–1995</td>
<td>Type: water pipe, cigarette</td>
<td>Pulmonary function:</td>
<td>Selection: subjects recruited by field survey</td>
<td>FEV₁, FVC, and FEV₁/FVC significantly lower in water-pipe smokers than non-smokers</td>
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<td></td>
<td>Participants’ characteristics: 254 subjects, 100% women, no comorbidity, no respiratory symptoms related to factors other than smoking, and no exposure to other risk factors in her daily life; none of the subjects smoked both water pipe and cigarettes</td>
<td>Measurement: self-developed pilot-tested tool, no further validation reported</td>
<td>Measurement tool: automatic calibrated spirometer; percent predicted values calculated automatically according to the Communité Europeenne du Carbon e de l’Acie method</td>
<td>Information collection: objective outcome evaluation, nonstandardized exposure assessment tool</td>
<td>FEV₁, FVC, and FEV₁/FVC significantly lower in cigarette smokers than water-pipe smokers</td>
</tr>
<tr>
<td>Funding: not reported</td>
<td>Water-pipe smokers: 77 subjects, aged 40.99 ± 12.54 y</td>
<td>Water-pipe cumulative consumption calculated using: ( Q = S \times q (g) \times T (d)/1,000 )</td>
<td>Blinding of outcome adjudicator: not reported</td>
<td>Confounding handling: no matching or adjustment in the analysis reported</td>
<td>There was a negative correlation for cumulative quantity of both cigarette and WPS with FEV₁, FVC, and FEV₁/FVC.</td>
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<td></td>
<td>Cigarette smokers: 77 subjects, aged 44.84 ± 10.55 y</td>
<td>Cigarette cumulative consumption calculated using: ( Q = N (g) \times T (d)/1,000 )</td>
<td>FEV₁: considered abnormal of &gt; 80%</td>
<td>% Participation: 88</td>
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<td>Nonsmokers: 100 subjects, aged 39.13 ± 12.898 y</td>
<td>Exposure levels of participants:</td>
<td>FEV₁/FVC: considered to reflect obstruction if &lt; 70%</td>
<td>% Complete data: 96</td>
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<tr>
<td></td>
<td>Water-pipe smokers: 58 ± 3.8 kg, 60 ± 3.81 y</td>
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<tr>
<td></td>
<td>Cigarette smokers: 40 ± 3.8 kg, 38 ± 3.81 y</td>
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<tr>
<td>Köseoğlu et al [21]/2006</td>
<td>Setting and period: local coffee shops in Izmir City (Turkey),</td>
<td>Type: water pipe, cigarette</td>
<td>Pulmonary function:</td>
<td>Selection: subjects selected from local coffee shops</td>
<td>FEV₁, FVC, and FEV₁/FVC nonsignificantly</td>
</tr>
<tr>
<td>Study/Year</td>
<td>Population</td>
<td>Exposure</td>
<td>Outcome</td>
<td>Methodologic Characteristics</td>
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<td></td>
<td>period not reported</td>
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<td>lower in water-pipe smokers than nonsmokers</td>
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<tr>
<td></td>
<td>Study design: cross-sectional study</td>
<td>Participants’ characteristics: 58 subjects, all subjects who had history of systemic or pulmonary disease, COPD, lung cancer, previous lung surgery, common cold or viral respiratory disease, allergy history, history of active pulmonary infection, or taking medications that increase or decrease mucociliary clearance were excluded</td>
<td>Measurement: self-developed tool, no standardization reported; personal interview</td>
<td>Measurement tool: spirometer (Sensor Medics V-Max) according to the American Thoracic Society; percentage predicted values calculated according to Knudson and Hankinson methods</td>
<td>Information collection: objective outcome evaluation, nonstandardized exposure assessment tool</td>
</tr>
<tr>
<td>Funding: not reported</td>
<td>Objective measurement tool (urinary cotinine level)</td>
<td>Exposure levels of participants:</td>
<td>Confounding handling: matching not reported, no significant difference in ages, BMI, and pulmonary function test parameters</td>
<td>% Participation: not reported</td>
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<td></td>
<td>Water-pipe smokers:</td>
<td>Blinding of outcome adjudicator: not reported</td>
<td>% Complete data: not reported</td>
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<tr>
<td></td>
<td>Average amount of tobacco = 35.5 ± 22.8/y</td>
<td>Urinary cotinine = 838.9 ± 762.5 ng/mL</td>
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<tr>
<td></td>
<td>Cigarette smokers:</td>
<td>Urinary cotinine = 1,576 ± 974.9 ng/mL</td>
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<tr>
<td></td>
<td>Water-pipe smokers: 20 subjects, aged 56.1 ± 8.4 y</td>
<td>Average amount of tobacco = 36.2 ± 23.1 pack-years</td>
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<tr>
<td></td>
<td>Cigarette smokers: 23 subjects, aged 52.0 ± 5.7 y</td>
<td>Urinary cotinine = 1,576 ± 974.9 ng/mL</td>
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<td>Passive smokers: 15 subjects, aged 54.5 ± 19 y</td>
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</table>

Data are presented as mean ± SD unless otherwise indicated. Jurak = type of tobacco paste that contains various spices and dried fruits; N = number of cigarettes/d; Q = cumulative quantity smoked, kg; q = quantity smoked per session, g; S = number of sessions/d; T = duration of smoking, d; WPS = water-pipe smoking.

**Methodologic Quality of Included Studies**
The six included studies were cross-sectional and suffered from a number of methodologic limitations. All the studies used an objective outcome evaluation (measurement by spirometry). Authors calculated the percent predicted spirometric values using the Communité Européenne du Carbon e de l’Acier method in two studies, \[17\] , \[20\] and the Knudson and Hankinson methods in one study, \[21\]. The remaining studies did not report any method. \[16\] , \[18\] , \[19\] None of the studies reported using a standardized exposure assessment tool. Selection of subjects was either done by visiting local coffee shops, \[16\] , \[17\] , \[21\] by volunteer recruitment, \[18\] , \[19\] or by a field survey, \[20\]. Only one study reported handling confounding by matching for gender \[17\]; two other studies reported no difference between mean age for the groups involved. \[19\] , \[21\] Only one study reported blinding of outcome adjudicator, \[16\] and only one study reported the percentages of participation (88%) and complete data (96%). \[20\]

**WPS Compared With Nonsmoking**

The pooled SMD for FEV\(_1\) was \(-0.43\) (95% CI, \(-0.58\) to \(-0.29\); \(I^2 = 24\%\)) equivalent to a 4.04% lower FEV\(_1\)% value in the water-pipe group (Fig 3). In the sensitivity analysis excluding studies in which the nonsmokers were described as passive smokers, the pooled SMD remained statistically significant at \(-0.46\) (95% CI, \(-0.60\) to \(-0.31\); \(I^2 = 21\%\)). The SMD for FVC was \(-0.15\) (95% CI, \(-0.34\) to 0.04; \(I^2 = 0\%\)), equivalent to a 1.38% reduction in FVC% in the water-pipe group (Fig 4). In the sensitivity analysis, the pooled SMD was \(-0.19\) (95% CI, \(-0.40\) to 0.01; \(I^2 = 0\%\)). The SMD for FEV\(_1\)/FVC was \(-0.46\) (95% CI, \(-0.93\) to 0.01; \(I^2 = 92\%\)), suggesting a lower percent predicted value in the water-pipe group, by 3.08% (Fig 5). In the sensitivity analysis, the pooled mean difference was \(-0.51\) (95% CI, \(-1.06\) to 0.05; \(I^2 = 94\%\)). The GRADE overall quality of evidence for FEV\(_1\) was moderate; it was downgraded secondary to study limitations.

**WPS Compared With Cigarette Smoking**

The pooled SMD for FEV\(_1\) between the two groups was \(0.20\) (95% CI. \(-0.15\) to 0.55; \(I^2 = 87\%\)), which translates into a nonsignificantly lower FEV\(_1\)% by 1.88% in the cigarette smoking group (Fig 6). The SMD for FVC between the two groups was \(0.27\) (95% CI, 0.09-0.44; \(I^2 = 83\%\)), which translates into a significantly lower percentage predicted value in the
cigarette smoking group, by 2.48% (Fig 7). The SMD in FEV1/FVC between the two groups was 0.22 (95% CI, -0.29 to 0.73; I² = 94%), suggesting a nonsignificantly lower percentage predicted value (1.47%) in the water-pipe group (Fig 8). The GRADE overall quality of evidence for FEV1 was low; it was downgraded secondary to study limitations and imprecision.

Figure 6  Comparison of FEV1 in water-pipe smokers and cigarette smokers. Al Fayez 1988 A includes only the male participants; Al Fayez 1988 B includes only the female participants. See Figure 3 legend for expansion of abbreviations.

Figure 7  Comparison of FVC in water-pipe smokers and cigarette smokers. See Figure 3 legend for expansion of abbreviations.

Figure 8  Comparison of FEV1/FVC in water-pipe smokers and cigarette smokers. Al Fayez 1988 A includes only the male participants; Al Fayez 1988 B includes only the female participants. See Figure 3 legend for expansion of abbreviations.

Association Between the Duration of WPS and Lung Function

Four studies reporting on the association between the duration of WPS and lung function had mixed results. Two studies reported no correlation between the duration of WPS and the decline in FEV1. [16] , [17] The other two studies reported an association; one found a marked decline in FEV1 and FEV1/FVC when comparing heavy smokers (> 2 water pipe/d) with light smokers (1-2 water pipe/d), whereas the other reported a negative correlation for cumulative quantity of WPS with FEV1, FVC, and FEV1/FVC.

Discussion

We systematically reviewed the scientific literature for the effects of WPS on lung function. Compared with no smoking, WPS was associated with a statistically significant reduction of FEV1 and a trend toward lower FVC and FEV1/FVC. The quality of evidence is moderate (ie, further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate). [15] There were no statistically significant differences in FEV1 and FEV1/FVC between water-pipe smokers and cigarette smokers. The quality of evidence was low (ie, further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate). [15]

Our study has a number of strengths. First, we used the comprehensive approach of Cochrane Collaboration for conducting systematic reviews, including a very sensitive search strategy, a duplicate and independent selection and data abstraction processes, and a rigorous evaluation of study methodological quality. Also, by pooling results across studies we were able to obtain relatively precise estimates of the outcomes of interest. Last, this is the first meta-analysis, to our knowledge, that
assesses the association of WPS with lung function.

The study also has a number of limitations. Although the primary objective of this study was to assess the effects of WPS on lung function, the available data from cross-sectional studies provide evidence for an association but does not establish causality. Our confidence in the results of the meta-analysis is reduced by the methodologic limitations of the included individual studies. Indeed, none of the studies used a standardized tool to measure the degree of exposures of interest (e.g., in terms of smoking patterns, frequency and lengths of smoking sessions, the type and quality of tobacco used for both WPS and cigarette smoking). This is particularly problematic given the potential variability in exposure. Finally, all but two studies failed to distinguish passive smokers from nonsmokers for exposure to WPS or cigarette smoking. However, the results of sensitivity analyses excluding these two studies were consistent with the results of the main analyses.

The association between WPS and reduction in FEV1 is not only statistically significant but also of potential clinical relevance. We can assess the clinical relevance comparing the effect size to the minimal important difference, defined as “the smallest difference in score in the outcome of interest that informed patients or informed proxies perceive as important, either beneficial or harmful, and which would lead the patient or clinician to consider a change in management.” It has been suggested that the minimal important difference for FEV1 is in the range of 100 to 140 mL. The mean difference in our study was estimated to be around 4%, which approximates to 173 mL for a 40-year-old white man of 180 cm height. Therefore, the reduction of FEV1 associated with WPS is clinically relevant.

The association of WPS with a significant reduction in FEV1 suggests its implication as a risk factor for obstructive disease. This is consistent with the finding of a trend toward reduction in FVC and FEV1/FVC among water-pipe smokers. The lack of statistical significance for these reductions is likely due to the lack of statistical power. Taken together, however, these findings suggest a possible role of WPS in the development of COPD.

There is additional evidence of the implication of WPS in COPD. Two studies using questionnaires adapted from the Medical Research Council and the European Coal and Steel Community on the symptoms of chronic bronchitis identified statistically significant higher number of positive responses in water-pipe smokers than in cigarette smokers. In the first study, symptoms of chronic bronchitis were identified in 11.75% of water-pipe smokers, as compared with 9.5% of cigarette smokers, and 0% in nonsmokers. In the second study, chronic bronchitis was found to be more prevalent in water-pipe smokers than cigarette smokers for cumulative quantity and duration. Despite the limited available data, these results help add up to the evidence of the risk of development of COPD in water-pipe smokers.

Although the results of FEV1 and FEV1/FVC comparing WPS to cigarette smoking show no statistical difference, they suffered from a high level of heterogeneity. The most likely explanation for this heterogeneity is the variation of levels of exposure to the two forms of smoking. Although the effect on lung function is associated with the levels of exposure to cigarette smoking and (likely) WPS, the degree of exposure was not measured. It is also possible that the lack of observed difference between water-pipe smokers and cigarette smokers may be because of inadequate power.

Some authors have hypothesized a less important effect of WPS compared with cigarette smoking on lung function based on a number of assumptions: the inability of smoke to reach the lower airways because of the smoking pattern and because of the filtration of smoke by the water and a better healing of small airway inflammation because of intermittent nature of smoking. Our study found no statistically significant difference in FEV1 and FEV1/FVC between the two forms of smoking. Indeed, recent evidence has shown that water does not significantly filter out the nicotinic products produced by WPS. Also, water-pipe smokers have an elevation in the level of parameters of oxidation injury and a decreased total antioxidant activity. The resulting oxidative stress is believed to play an important role in the pathogenesis of COPD.

Conclusions

**Implications for Public Health Policy**

This study adds to the rapidly growing evidence of the association of WPS with deleterious health outcomes, which has very important implications for both clinical and public health practice. Spirometry performance might give the clinician an opportunity to convince smokers to quit. More importantly, our study supplies the physician with data they might use in counseling patients about the deleterious effect of WPS on lung function. As for the public health practice, this study illustrates that WPS may be as harmful as cigarette smoking in terms of lung function. Public health policy makers need to aggressively address the epidemic of WPS to raise awareness and advocate for appropriate policy changes.

**Implications for Research**

As advised by the World Health Organization, there is a need for more research related to WPS. Specifically, there is a
need for higher-quality prospective studies that could more clearly identify the causal relationship between WPS and clinical outcomes. Similarly, there is a need for exploring whether quitting smoking slows down or reverses the deterioration of lung function. Finally, researchers need to focus on standardizing the exposure measurement tools in order to reliably assess for dose-response relationships.[28]

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