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REVIEW

# Estimated prevalence of halitosis: a systematic review and meta-regression analysis

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**Abstract**
*Objective* This study aims to conduct a systematic review to determine the prevalence of halitosis in adolescents and adults.
*Methods* Electronic searches were performed using four different databases without restrictions: PubMed, Scopus, Web of Science, and SciELO. Population-based observational studies that provided data about the prevalence of halitosis in adolescents and adults were included. Additionally, meta-analyses, meta-regression, and sensitivity analyses were conducted to synthesize the evidence.
*Results* A total of 584 articles were initially found and considered for title and abstract evaluation. Thirteen articles met inclusion criteria. The combined prevalence of halitosis was found to be 31.8% (95% CI 24.6–39.0%). Methodological aspects such as the year of publication and the socioeconomic status of the country where the study was conducted seemed to influence the prevalence of halitosis.
*Conclusions* Our results demonstrated that the estimated prevalence of halitosis was 31.8%, with high heterogeneity between studies. The results suggest a worldwide trend towards a rise in halitosis prevalence.
*Clinical relevance* Given the high prevalence of halitosis and its complex etiology, dental professionals should be aware of their roles in halitosis prevention and treatment.

**Keywords** Oral malodor · Bad breath · *Foetor ex ore* · Prevalence · Meta-analysis

## Introduction

Halitosis is a general term used to define an unpleasant or offensive odor emanating from the mouth, which originates from oral or non-oral sources [1, 2]. It is also referred as bad breath, oral malodor, or *foetor ex ore*. In most individuals with persistent malodor, the odor is caused by an oral source, mainly from Gram-negative anaerobic bacterial species [3]. Those species degrade sulfur-containing substrates on different surfaces of oral cavity [2]. In this context, tongue coatings and periodontal biofilm might play an important role in halitosis establishment and perpetuation [4]. Among non-oral sources of oral malodor, it is worth emphasizing upper respiratory infection, gastrointestinal tract disturbances, and rarely diabetic ketoacidosis [3, 5].

Usually, halitosis can be defined as genuine halitosis (physiologic or pathologic), or as pseudo-halitosis, which cannot be verified objectively [6], i.e., individuals believe that they have malodor, but there is no evidence of it [3]. The three main methods for diagnosis of halitosis are self-reported halitosis, organoleptic assessment, and volatile sulfur compound (VSC) level measurement [6]. Even though the organoleptic and VSC measurement are objective methods for assessing oral

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malodor, they demand a trained examiner and specific equipment [6]. On the other hand, self-reported assessment reduces costs and time-consuming clinical examination [7].

Previous studies have revealed the negative impact of halitosis on quality of life, especially on interpersonal relationship [8]. Social and personal embarrassment are the main reasons for individuals to seek halitosis treatment by a professional [4]. Despite the social and clinical implications of halitosis, few epidemiological studies have investigated its prevalence in the general population. Available epidemiological data are based on convenience samples and on self-reported oral malodor [1]. Thus, the reported prevalence of halitosis is variable. Epidemiological studies report the prevalence rates of halitosis to range from 2.4 to 78% [9, 10]. According to the American Dental Association, about 50% of American adults suffer from oral malodor [11]. Many factors might influence the large variability between studies, such as the method used for halitosis assessment, the geographic region where the study was conducted, and the year when the study was developed. However, no previous study has estimated the worldwide prevalence of halitosis in the general population, nor has any study reported the influence of methodological characteristic on the prevalence of halitosis.

Given the aforementioned, the aim of this study is to systematically review the literature on the prevalence of halitosis to (1) calculate a worldwide pooled prevalence estimate and (2) determine factors implicated in the variability of estimates.

## Methods

### Review question

1. What is the estimated prevalence of halitosis in adolescents and adults?

### Inclusion and exclusion criteria

Original observational studies which reported the prevalence or data that allowed the calculation of prevalence of halitosis in adolescents and adults were included. The case definition for halitosis was accepted as declared by the authors. Only population-based studies with representative sample were considered. Thus, the characteristics of study population needed to be clearly described in the paper to guarantee representativeness of the sample.

Animal studies, in vitro studies, letters to the editor, reviews, studies that reported the prevalence of halitosis only in children, and studies with explicit convenience sample were excluded. Studies whose prevalence data could not be obtained were excluded. Studies in languages other than English, Spanish, French, and Portuguese were also excluded.

### Search strategy

Literature was searched to identify articles published up to June 2015 in PubMed via Medline, Web of Science, Scopus, and SciELO. An initial search was conducted on PubMed with the following MeSH and free terms: ("Halitosis" [Mesh] OR "Halitosis"[all] OR "Oral Malodor"[all] OR "Foetor Ex Ore"[all] OR "Bad Breath"[all]) AND ("Epidemiological Studies" OR "Cross-sectional Studies" OR "Cross-sectional study" OR "Studies, Cross-sectional" OR "Prevalence Studies" OR "Prevalence Study" OR "Studies, Prevalence" OR "Study, Prevalence" OR "Cohort Study" OR "Cohort Studies" OR "Studies, Cohort" OR "Study, Cohort" OR "Longitudinal Study" OR Longitudinal Studies" OR "Studies, Longitudinal" OR "Study, Longitudinal" OR "Incidence Study" OR "Studies, Incidence" OR "Study, Incidence" OR "Follow up Studies" OR "Follow-up Study" OR "Prevalence" OR "Incidence" OR "Surveys" OR "Questionnaires"). No language or date restrictions were applied within the search.

References were managed using the software Endnote X7 (Thomson Reuters, New York, NY, USA). Duplicate references were excluded. Titles and abstracts were screened based on the aforementioned criteria independently by two reviewers (MFS and LBF). Lists were compared, and in case of disagreement, a consensus was reached by discussion. Full-text assessment was performed independently by the same two reviewers. Grey literature (documents produced on all levels of government, academics, business, and organization in electronic and print formats not controlled by commercial publishing) was investigated by analyzing the first 100 hits of a Google Scholar search. In addition to the electronic search, the reviewers also performed a hand search in the reference list of all included articles. Predefined data collection worksheets were used for data extraction of each selected publication. This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statements [12].

### Critical appraisal

The critical appraisal checklist for prevalence and incidence studies recommended by the Joanna Briggs Institute was employed for the quality assessment of the studies included in the review [13]. Reviewers should answer "Yes," "No," or "Unclear" for each of the 10 items of the instrument. Studies were categorized according to quality based on an overall score calculated from the number of Yes answers. Thus, scores could range from 0 to 10. Finally, studies were categorized into the median according to their scores: high risk of bias [total sum between 0 and 5] and low risk of bias [6, 10]. The same two reviewers conducted quality assessment, and

disagreements were resolved by reaching consensus through discussion.

### Data extraction and data analysis

Relevant data were extracted from the selected articles independently by the same two reviewers: under the categories of study description (setting, sample, and design) and halitosis assessment (self-reported, organoleptic test, VSC test). Prevalence rates of halitosis were collected or calculated, if necessary. When more than one method for halitosis detection was employed; the clinical measure was preferred than the self-reported. In case two clinical measures were available, the organoleptic assessment was preferred, since it is considered the gold standard method for halitosis diagnosis [14, 15].

The estimated global prevalence of halitosis was calculated using fixed- and random-effect models. In the presence of heterogeneity ($I^2$ >50% or chi-square $p < 0.05$), the random-effect model was employed [16]. Additionally, meta-regression and subgroup analyses were performed to investigate if study characteristics influenced between-study variability. Methodological characteristics were included in a multivariable meta-regression model. Backward stepwise approach was used for variable selection. Variables with a $p < 0.20$ remained in the final model; however, only those with a $p < 0.05$ were considered significant in the final model. Additionally, subgroup analysis was performed for each methodological variable included in the final meta-regression model. We also performed meta-regression and subgroup analyses for halitosis detection method, independently of its $p$ value. Sensitivity analyses were conducted to estimate the influence of each study on the pooled results. Funnel plot and the Egger test were used to test for any potential publication bias [17]. All analyses were performed using the software Stata 13.1 (StataCorp, College Station, TX, USA).

## Results

Electronic searches revealed 940 studies. From those, 356 were duplicate and excluded. A total of 584 articles were submitted to title and abstract evaluation. Figure 1 displays the flowchart of studies selection. Twenty-three articles were included for full-text evaluation, and from those, 10 were excluded after appraisal (Table S1). Subsequently, 13 satisfied the inclusion criteria, comprising a population of 384,830 individuals. Table 1 presents the main characteristic of all included studies. Based on the quality assessment of the 13 studies included in the review, 9 presented low risk of bias; whereas, 4 presented high risk of bias (Table 1).

The estimated prevalence halitosis in the general population was 31.8% (95% CI 24.6–39.0%) (Fig. 2). Analysis revealed high between-study variability ($I^2$ 99.8%). In the final meta-regression model, year of publication ($p = 0.027$) and the socioeconomic status of the country where the study was conducted ($p = 0.021$) explained about 60% of the heterogeneity (adjusted $R^2$ 60.3%). Table 2 shows the subgroup analysis according to the variables included in the adjusted model. A greater prevalence of halitosis was noted in studies published after 2007, and in studies conducted in middle-low-income countries (Table 2). When comparing self-reported and clinical methods for halitosis detection, the method employed did not explain the variability between studies (Fig. 3). We also performed subgroup analysis comparing all three methods for halitosis detection in separate, and no relevant differences in prevalence rates were noted: organoleptic measure 30.7% (95% CI 10.7–50.6), VSC levels 28.0% (95% CI 21.4–34.6), and self-reported 33.9% (24.4–43.4). Metafunnel and Egger test ($p < 0.001$) revealed the presence of publication bias (Fig. 4). Sensitivity analysis demonstrated that the omission of any study would not significantly modify the prevalence of halitosis (Fig. S1).

## Discussion

Halitosis is a term frequently used to define unpleasant or noxious smell arising from the oral cavity. Its etiology is complex, and oral and non-oral sources are usually investigated. However, studies have attributed 80–90% of the causes of halitosis to conditions of the oral cavity [8]. Our findings revealed an estimated prevalence of halitosis in the general population of 31.8% ranging from 2.4 to 55%. Additionally, the findings from the performed sensitivity analyses reinforce the robustness of our findings. Even though previous epidemiological reports have estimated the prevalence of halitosis, their findings might suffer from methodological issues, such as convenience sample. For this reason, this review aimed to estimate the prevalence of oral malodor only in population-based studies with representative sample. To the best of the authors' knowledge, this is the first systematic review with meta-analysis informing this topic. Despite its great prevalence, information about incidence of oral malodor remains undefined.

The adjusted meta-regression analysis revealed that studies published in low-middle-income countries presented higher prevalence of halitosis ($p = 0.021$), compared to high-income countries. While in developed countries the prevalence of halitosis was 29.0% (95% CI 21.2–36.8), it was 39.8% (95% CI 21.1–54.9) in low-middle income countries (Table 2). Greater prevalence of periodontitis is noted in middle-low-income countries, as poor periodontal status is closely related to socioeconomic conditions [28]. Since periodontal disease is one of the main causes of oral malodor, we hypothesize the high prevalence of periodontitis in middle-low-income countries might have impacted on the greater

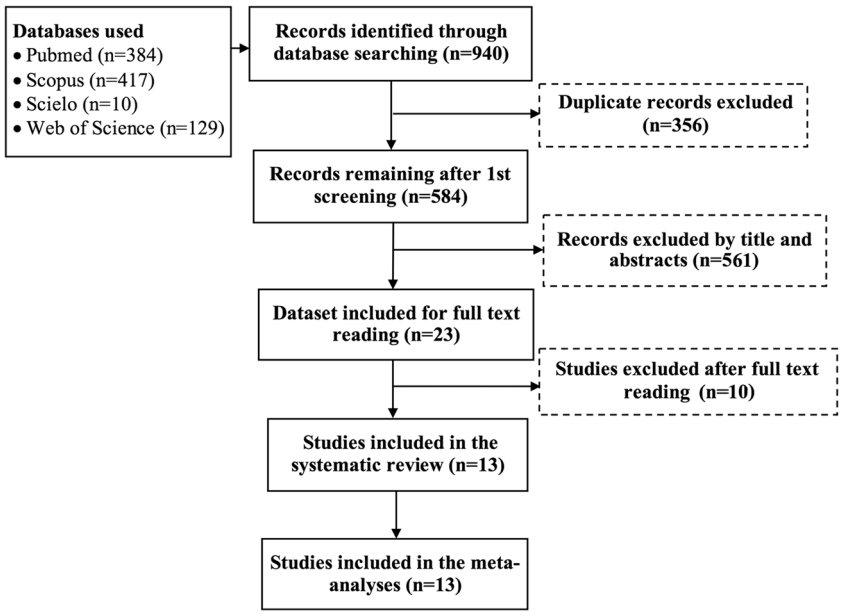


**Fig. 1** Flowchart of study selection for the systematic review according to inclusion and exclusion criteria

prevalence of halitosis [28]. It is worth emphasizing that since inequalities are quite different between these two distinct groups of countries, prevalence rates and disease distribution may vary significantly [29, 30]. Future studies should address the role played by socioeconomic status on the prevalence of halitosis.

Another methodological aspect that influenced the prevalence of halitosis was the year of the publication of the study. Studies published after 2007 presented twice the prevalence of oral malodor than studies published before then (Table 2). One possible cause is the worldwide change in dietary patterns, with an increase in the consumption of alcohol and in the use of spices as flavorings in foods since 2006 [31–33]. Volatile foods such as spices and garlic may lead to change in breath odor, and consequently halitosis [34]. These changes affect the social awareness of halitosis, e.g., a young adult may consciously avoid to consume spices and garlic before or during dates [34]. The increased prevalence of alcohol consumption may also explain partially our findings. Acetaldehyde, the first metabolite of ethanol produced by oral bacteria, may contribute to oral malodor [35]. Furthermore, the dryness of the mouth induced by alcohol plays an important role in the formation and perpetuation of halitosis [35]. An increase in the social awareness of halitosis and in the number of dry mouth cases are among the causes for the raise in mouthwash agent sold, which denotes the population raised concern about their breath smell [36, 37]. In addition, after the decline in the prevalence of the most prevalent oral diseases, oral health professionals have given closer attention to halitosis and bringing the patients' attention to the topic [38]. According to Loesche and Kazor (2002), halitosis is one of the main causes for individuals to seek for oral health professionals [39].

Another fact is that, historically, most epidemiological studies about periodontal diseases have been conducted in high-income countries. Conversely, surveys on the impact of social aspects in periodontal health have been conducted in low-middle-income countries only more recently, which may be a connection to the findings observed in the meta-regression analysis [28]. Given the aforementioned aspects, it is not surprising that higher prevalence of halitosis is observed in studies published more recently.

Organoleptic and VSC level measurements are considered valid instruments for halitosis detection [6]. The organoleptic test relies on clinical evaluation performed by a trained and calibrated clinician, who might previously avoid the use of odorific substances and foods which interfere with the test. Basically, the examiner sniffs the air exhaled from the mouth and nose and subjectively defines the presence or absence of oral malodor [40]. Despite its subjective nature, organoleptic test remains as the "gold standard" method [41]. The VSC level measurement is an objective method of recording odor compounds whenever possible [4]. However, studies have demonstrated that the measurement of VSC levels presents high specificity, but low sensitivity, and recommend the test as an adjunct instead of a substitute to the organoleptic assessment [42]. Studies comparing both methods have demonstrated non-significant correlation [43]. However, both methods demand specific equipment as well as a trained examiner to perform the examination. Thus, clinical examinations are costly and time-consuming, especially for large epidemiological studies. Alternatively, self-reported oral health status could be a useful instrument for assessing prevalence of oral conditions especially in population-based epidemiological studies [44]. Nevertheless, it has been suggested that self-reported halitosis tends to underestimate the prevalence of this condition,

**Table 1** Main findings of the studies included in the systematic review

| Author and year | Country | Study design | Sample | Method of halitosis assessment | Cases of halitosis | Total sample | Prevalence (%) | Risk of bias |
|---|---|---|---|---|---|---|---|---|
| Aimetti et al. 2015 [1] | Italy | Cross-sectional | Individuals from Turin aged 20–75 years old | Organoleptic test<br>Self-reported | 412 individuals<br>179 individuals | 744 individuals | 55.38%[a]<br>24.06% | Low |
| Al-Ansari et al. 2006 [18] | Kuwait | Cross-sectional | Individuals aged 14–74 years old | Self-reported | 361 individuals | 1551 individuals | 23.30% | Low |
| Bornstein et al. 2009 [19] | Switzerland | Cross-sectional | Individuals from Bern aged 18 years old or more | Organoleptic test<br>VSC measurement<br>Self-reported | 132 individuals<br>117 individuals<br>114 individuals | 419 individuals | 31.5%[a]<br>28%<br>27.2% | Low |
| de Jongh et al. 2016 [20] | Holland | Cross-sectional | Individuals from Holland aged 16 years old or more | Self-reported | 473 individuals | 1083 individuals | 43.70% | Low |
| Frexinos et al. 1998 [21] | France | Cross-sectional | Individuals aged 15 years old or more | Self-reported | 1059 individuals | 4815 individuals | 22.00% | Low |
| Kim et al. 2015 [22] | Korea | Cross-sectional | Individuals aged 12–18 years old | Self-reported | 84,959 individuals | 359,263 individuals | 23.60% | Low |
| Liu et al. 2006 [23] | China | Cross-sectional | Individuals from Beijing aged 15–74 years old | Organoleptic test<br>VSC measurement | 550 individuals<br>708 individuals | 2000 individuals | 27.5%[a]<br>35.40% | Low |
| Miyazaki et al. 1995 [24] | Japan | Cross-sectional | Individuals aged 18–74 years old | VSC measurement | 614 individuals | 2672 individuals | 23% | High |
| Nwhator et al. 2015 [25] | Nigeria | Cross-sectional | Individuals aged 18–65 years old | Self-reported | 440 individuals | 804 individuals | 54.70% | High |
| Soder et al. 2000 [9] | Sweden | Cross-sectional | Individuals aged 30–40 years old | Organoleptic test | 40 individuals | 1681 individuals | 2.40% | High |
| Struch et al. 2008 [5] | Germany | Cross-sectional | Individuals aged 20–81 years old | Self-reported | 603 individuals | 3005 individuals | 20.00% | Low |
| Ueno et al. 2007 [26] | Japan | Cross-sectional | Individuals from Yokote aged 40–75 years old | Organoleptic test | 785 individuals | 2141 individuals | 36.70% | High |
| Vali et al. 2015 [27] | Iran | Cross-sectional | Individuals from Isfahan aged 19–70 years old | Self-reported | 2458 individuals | 4652 individuals | 52.80% | Low |

[a] Data included in the meta-analysis

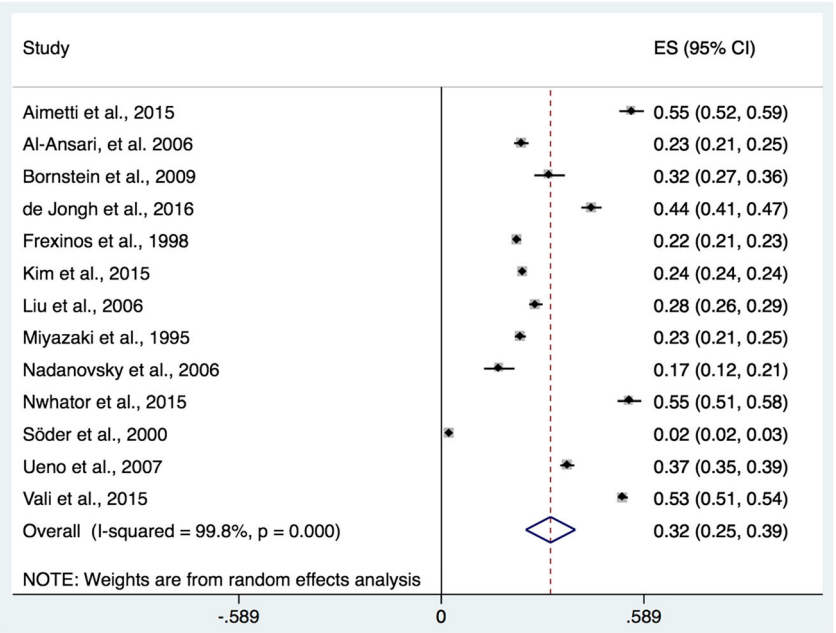


**Fig. 2** Pooled prevalence of halitosis. Data are presented as prevalence for each study (*boxes*), 95% CIs (*horizontal lines*), and summary as prevalence with 95% CI (*diamond*)

mainly because individuals are not able to detect their own odor or they are embarrassed to report it in interviews [19]. However, weak but statistically significant correlations have been found between self-reported oral malodor assessment and organoleptic method [43]. In our study, the meta-regression analysis demonstrated that the method used for halitosis assessment seemed not to influence the heterogeneity between studies (Fig. 3). Thus, self-reported assessment may be a useful instrument for estimating the prevalence of halitosis, mostly in large epidemiological studies when it is not possible to employ organoleptic measurements.

Our findings should be considered in the context of some limitations. First, few reports met the inclusion criteria, since many studies analyzed a convenience sample. Second, even though the socioeconomic status of the country brings information about the country's development as a whole, it does not provide specific information regarding social inequality. It has been demonstrated that social inequality has greater impact on health conditions than economic development [45]. In addition, only one measure from studies reporting more than one method for halitosis assessment could be included in the meta-estimate. This methodological choice was based on previous articles, which recommend the inclusion of the most reliable measure [15]. For this reason, in studies presenting both self-reported and clinical assessment, only the clinical estimate was included in the pooled analysis, since the inclusion of both measures could duplicate individuals in the analysis.

Regardless of the limitations, several strengths of our study should be highlighted. First, the inclusion of population-based studies only decreased the chance of biased prevalence rates of halitosis. Additionally, the analytical approach used to combine estimates across studies provided a worldwide prevalence of halitosis in adolescents and adults. Moreover, the variables included in the meta-regression analysis explained to a great extent the variability found between studies.

**Table 2** Meta-regression and subgroup analysis according to methodological variables

| Methodological covariates | Number | Prevalence % (95% CI) | *p* value[a] |
|---|---|---|---|
| Socioeconomic status[b] | | | 0.021 |
| High income | 10 | 29.0 (21.2–36.8) | |
| Middle-low income | 6 | 39.8 (21.1–54.9) | |
| Year of publication | | | 0.027 |
| 2007–2016 | 8 | 42.6 (29.5–46.3) | |
| 1995–2006 | 5 | 19.2 (8.8–29.5) | |
| Heterogeneity explained ($R^2$): 60.3% | | | |

[a] *p* value of the variable in the final meta-regression model

[b] According to the World Bank List of Economies (2016)

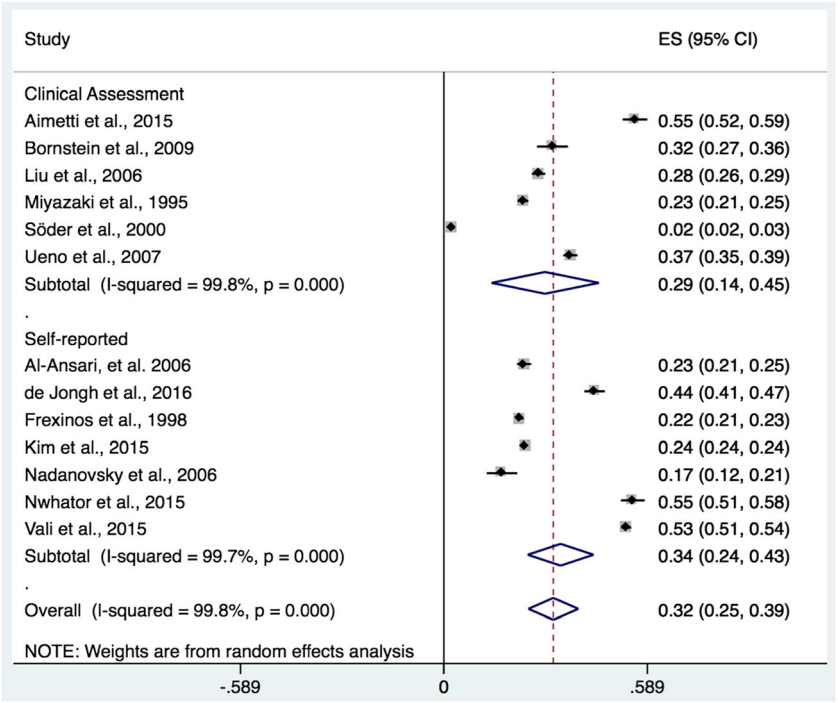


**Fig. 3** Pooled prevalence of halitosis according to the method for halitosis assessment. Data are presented as prevalence for each study (*boxes*), 95% CIs (*horizontal lines*), and summary as prevalence with 95% CI (*diamond*)

Furthermore, subgroup analysis according to the variables included in the final meta-regression model clarified how these methodological characteristics influenced the prevalence of halitosis. Finally, the large sample enrolled in the meta-analyses reinforce the robustness of our findings.

The results of our systematic review and meta-analysis provide a worldwide prevalence of halitosis in adolescents and adults. We also found a great variability in the prevalence rates among studies. We found that the method used for halitosis assessment does not impact on its prevalence. However, the year of publication and the socioeconomic status of the country where the study was conducted seemed to influence this variability. Given the high prevalence of halitosis, its complex etiology, and its impact on the individuals' social life, dental professionals should be aware of their role in halitosis prevention and treatment since halitosis prevalence tends to increase in the upcoming years.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no competing interests.

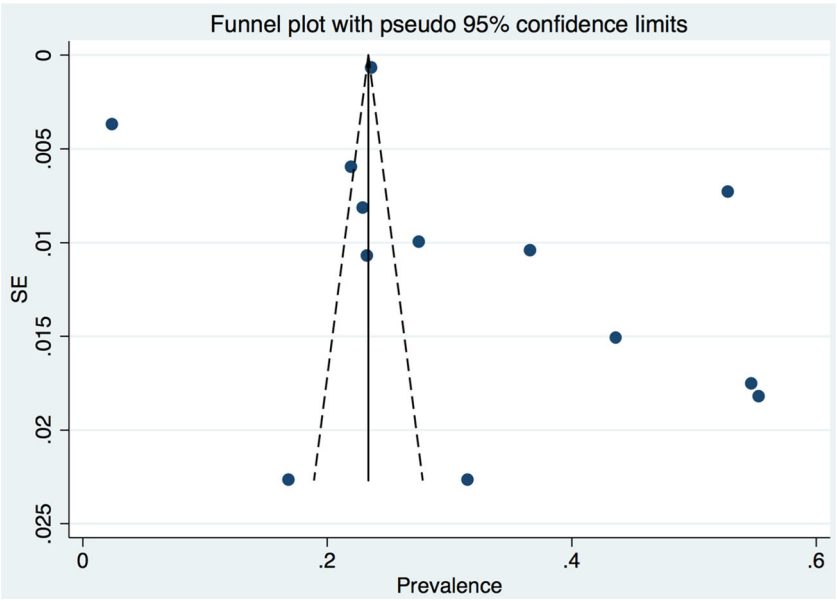


**Fig. 4** Funnel plot evidencing prevalence of halitosis (standard error (SE))

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**Ethical approval** This article does not contain any studies with human participants or animals performed by any of the authors.

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

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