Meta-Analysis of Observational Studies in Epidemiology

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# Inhaler device feature preferences among patients with obstructive lung diseases

## A systematic review and meta-analysis

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**Abstract**

**Background:** Bronchodilators administered through inhalation devices are the mainstay treatment for patients with obstructive lung diseases. Patients do not view devices as interchangeable. This systematic review and meta-analysis examined device feature preferences among patients with obstructive lung diseases treated with handheld inhalers.

**Study Appraisal and Synthesis Methods:** PubMed, EMBASE, PsycINFO, Cochrane, and Google Scholar were searched to identify publications between 2010 and 2019 that met the following criteria:

(1) English language;

(2) studied adults with chronic obstructive pulmonary disease, bronchitis, or emphysema; and

(3) reported patients' device feature preferences specific to metered-dose inhalers, dry powder inhalers, and soft mist inhalers.

A manual search extended the study period from 2001 to 2019. Random-effects models were used to generate pooled mean effect sizes and 95% confidence intervals (CIs) for preferred device features. Heterogeneity was measured by the $I^2$ statistic.

**Results:** Nineteen studies (n = 11,256) were included in this meta-analysis. Average age ranged from 50.4 to 74.3 years. The majority of patients were male (57%) and had chronic obstructive pulmonary disease (92%).

Patients preferred the following device features:

(1) small size (71.7%, 95% CI: 46.3, 97.1; n = 604, 3 studies);

(2) rapid medication administration (64.9%, 95% CI: 36.5, 93.4; n = 745, 3 studies);

(3) durability (62.1%, 95% CI: 39.7, 84.4; n = 4,500, 4 studies);

(4) a dose counter (52.3%, 95% CI: 20.7, 83.9; n = 4,536, 4 studies);

(5) portability (51.8%, 95% CI: 29.1, 74.5; n = 4,975, 7 studies);

(6) perceived ease of use (51.2%, 95% CI: 35.6, 66.7; n = 5,878, 10 studies); and

(7) perceived ease of dose preparation (50.1%, 95% CI: 26.2, 73.9; n = 4,003, 4 studies).

**Conclusions and Implications of Key Findings:** Adults with obstructive lung diseases preferred small inhaler devices that were portable, durable, perceived as easy to use, and fast in medication administration. Healthcare providers should give due consideration to the patient's device feature preferences when developing a treatment plan that prescribes an inhalation device.

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*All data generated or analyzed during this study are included in this published article [and its supplementary information files];*

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**Abbreviations:** CIs = confidence intervals, COPD = chronic obstructive pulmonary disease, DPIs = dry powder inhalers, GOLD = Global Initiative for Chronic Obstructive Pulmonary Disease, MDIs = pressurized metered-dose inhalers, SMIs = soft mist inhalers.

**Keywords:** chronic obstructive pulmonary disease, device feature preferences, handheld inhaler, meta-analysis, obstructive lung disease, systematic review

## 1. Introduction

Chronic obstructive pulmonary disease (COPD) is 1 of the most prevalent obstructive lung conditions worldwide.[1] According to the Global Burden of Disease Study, there are an estimated 251 million diagnosed cases of COPD globally and millions more have the disease without knowing it.[2] The economic burden of COPD is substantial, ranging from about $680 per patient annually in countries outside of the United States to more than $6,200 per patient per year within the United States.[3]

The clinical management of COPD relies primarily on pharmacotherapies that aim to relieve symptoms through sustained bronchodilation.[4] A variety of inhalation devices are available to deliver bronchodilator treatment including pressurized metered-dose inhalers (MDIs), dry powder inhalers (DPIs), soft mist inhalers (SMIs), and nebulizers. Each of these devices has particular features designed to facilitate use by the patient and to make medication delivery to the lungs an efficient process.[5] Patients do not see devices as being interchangeable.[6] In recognition of the importance of considering patients' preferences when prescribing bronchodilator therapy, the Global Initiative for COPD (GOLD) strategies emphasize that "the choice of inhaler device has to be individually tailored and will depend on access, cost, prescriber, and most importantly, patient's ability and preference."[4]

Despite the GOLD report recommendations, studies have shown that treating physicians may not consider patients' preferences when selecting inhalation devices.[7–9] A recent study found that only 37% of health care providers considered device type to be important when prescribing a bronchodilator treatment to their patients.[9] Other studies have shown that inhalation device characteristics are more likely to impact the prescribing physician's decision in only select patient populations, such as elderly patients with multiple comorbidities or patients with greater disease severity.[7] In addition, health care providers often prioritize medication type over device features, and tend to underestimate the degree to which their patients value certain device features.[8–11]

Considering patients' preferences when developing treatment plans for respiratory care is important for several reasons. First, patients' preferences for inhaler devices have been associated with improved medication adherence.[12] This observation is particularly relevant in COPD patients among whom poor adherence is common. Indeed, past research has shown that more than 50% of patients with COPD do not take their inhaled therapy as prescribed or instructed.[13,14] Second, achieving better adherence to treatment by prescribing the patients' preferred inhaler has been shown to improve outcomes in COPD patients.[15] Third, patients who are prescribed their preferred inhalation device have higher treatment satisfaction, fewer device use errors, and lower health resource utilization and costs.[16–19] Taken together, the literature reinforces the importance of practitioners incorporating the patients' inhalation device preferences when developing treatment plans.

To date, a limited number of systematic reviews have been published on inhaler device feature preferences by patients.[6,20] However, there is no meta-analysis study on this topic in the literature. To address this knowledge gap, a systematic review and meta-analysis was conducted to examine device feature preferences among patients with obstructive lung diseases treated with handheld devices including MDIs, DPIs, and SMIs.

## 2. Materials and methods

### 2.1. Search strategy

Following the Preferred Reporting Item for Systematic Reviews and Meta-Analyses guidelines,[21] a systematic literature search was conducted using PubMed, EMBASE, PsycINFO, Cochrane, and Google Scholar. Articles published between January 1, 2010 to February 15, 2019 that met the following inclusion criteria were identified:

(1) English language;
(2) studied adults with COPD, bronchitis, or emphysema; and
(3) reported patients' inhalation device feature preferences.

To be more comprehensive and balanced in the search strategy, all references within the articles identified from electronic searches were manually reviewed for relevance, thereby extending the search period from January 1, 2001 to February 15, 2019.

A total of 123 publications met the initial screening criteria (Fig. 1). An additional 12 publications were identified through the manual search process. After removing duplicate studies (n = 23), 112 abstracts were further examined for relevance. After excluding 73 non-relevant records, 39 full-text articles remained for review. Among these articles, 20 did not provide sufficient information on inhalation device feature preferences, resulting in 19 publications which were included in this meta-analysis.[7,9,10,16,17,22–35] Approval from an ethics committee or an institutional review board was not necessary for this study since all data were evaluated in aggregate from publicly available studies published in the literature.

### 2.2. Data extraction and quality assessment

The following data were extracted from the identified publications:

(1) study design;
(2) patients' sociodemographic characteristics (eg, age, sex);
(3) primary diagnosis;
(4) COPD severity as measured by the GOLD classification of airflow limitation rating of mild (GOLD I), moderate (GOLD II), severe (GOLD III), and very severe (GOLD IV)[4];
(5) type and brand of inhaler device;
(6) inhaler device use training;
(7) inhaler device features including perceived ease of dose preparation; perceived ease of use; availability of a dose counter; durability of device defined as sturdy, not easily

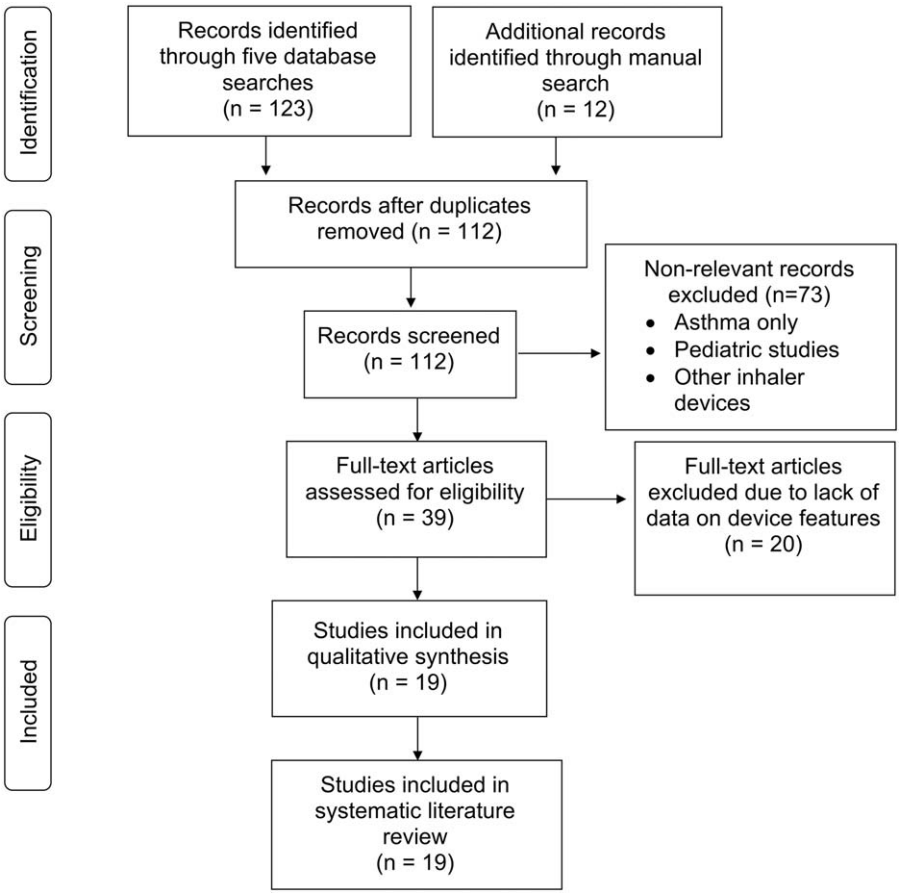



**Figure 1.** PRISMA Flow Diagram.

breakable, or built to last; dose frequency; size; portability; and speed of medication administration; and

(8) the patients' reported preferences for each inhaler device feature.

Study quality was graded by 3 trained independent reviewers. For randomized controlled trials, quality was assessed using criteria published by the Cochrane Collaborative.[36] For cross-sectional and cohort studies, quality was assessed using relevant scales by Newcastle and Ottawa.[37] Publications that met the following criteria were classified as being low quality for the purposes of our study and excluded:

(1) if data were reported for fewer than 5 patients, or
(2) if no quantifiable data were provided (ie, qualitative studies, perspectives, and opinion cases).

### 2.3. Statistical analyses

Descriptive statistics including frequencies, means, medians, standard deviations, and proportions were computed for variables of interest and compared across the studies. Inhaler device feature preferences were examined using 2 approaches:

(1) the proportion of studies that reported patients' preferences for individual device features was analyzed using binary coding (yes/no), and
(2) meta-analysis was performed if studies reported the percentage of patients who considered a particular device feature important and/or were satisfied with the use of that feature.

Information specific to patients' preferences for inhaler device features was gathered in accordance with the recommendations outlined in the Meta-analysis of Observational Studies in Epidemiology guidelines.[38] Pooled effect size estimates (weighted proportions) and 95% confidence intervals (CIs) were computed using the approximation of a binomial distribution. Data were graphically examined using forest plots to determine the extent to which effect size estimates reported in each study distributed around the pooled effect size estimates.[39] The $I^2$ statistic was used to assess heterogeneity.[40,41] $I^2$ values of 0% to 25%, 25% to 50%, 50% to 75%, and 75% to 100% were interpreted to represent little/negligible, moderate, considerable, and substantial/large degree of heterogeneity, respectively.[40,41] Sensitivity analyses were performed using the leave-one-out cross-validation technique by removing 1 study each time to check if an individual study influenced the pooled results.[36,42–45] Funnel plot techniques, Begg and Mazumdar's rank correlation test, and Egger regression test were used when appropriate to examine possible publication bias, with $P < .05$ denoting statistical significance. Given that relatively few studies reported on individual device features, considerable between-studies variability was expected.[42] Thus, all meta-analyses were

**Table 1**

**Characteristics of Studies and Patients.**

| Study | Study Design* | Patients (N) | Mean Age, yr (± SD/Range) | Sex N (%) | Diagnosis† (N) | COPD Severity‡ N (%) | Inhaler Training N (%) |
|---|---|---|---|---|---|---|---|
| Schurmann et al, 2005[23] | RCT | 245 | 55.3 (±14.9) | Male: 135 (55)<br>Female: 110 (45) | COPD (103)<br>Asthma (95)<br>Other (47 | – | 245 (100) |
| Ferguson et al, 2013[24] | RCT | 157 | 63 (>40) | Male: 92 (59)<br>Female: 65 (41) | COPD | GOLD II: 157 (100)§ | 157 (100) |
| Price et al, 2013[25] | Cohort | 2,138 | 70.4 (35–98) | Male: 1,158 (54)<br>Female: 980 (46) | COPD | GOLD I: 806 (38)<br>GOLD II: 405 (19)<br>GOLD III: 81 (49)<br>Missing: 846 (39) | – |
| Chorao et al, 2014[16] | CS | 301 | 53 (± 17) | Male: 120 (40)<br>Female: 181 (60) | COPD (107)<br>Asthma (194) | – | 301 (100) |
| Chrystyn et al, 2014[19] | CS | 1,443 | 65.2 (40–90) | Male: 1,035 (72)<br>Female: 408 (28) | COPD | GOLD I: 305 (21)<br>GOLD II: 658 (46)<br>GOLD III: 328 (23)<br>GOLD IV: 81 (6)<br>Missing: 26 (2) | – |
| Hanada et al, 2015[26] | Cohort | 57 | 73.6 (±7.1) | Male: 52 (91)<br>Female: 5 (9) | COPD | GOLD I: 5 (10)<br>GOLD II: 25 (44)<br>GOLD III: 21 (37)<br>GOLD IV: 5 (10) | – |
| Juvelekian et al, 2015[27] | Cohort | 271 | 57.6 (±12.29) | Male: 218 (80)<br>Female: 53 (20) | COPD | GOLD I: 7 (3)<br>GOLD II: 231 (85)<br>GOLD III: 27 (10)<br>GOLD IV: 6 (2) | – |
| Molimard and Colthorpe, 2015[10] | CS | 245 | 60.7 | – | COPD | GOLD I: 29 (12)<br>GOLD II: 103 (42)<br>GOLD III: 74 (30)<br>GOLD IV: 15 (6) | – |
| Dal Negro and Povero, 2016[28] | CS | 333 | 55.2 (± 18.3) | Male: 155 (47)<br>Female: 178 (53) | COPD (158)<br>Asthma (176) | – | 202 (61) |
| Miravitlles et al, 2016[29] | CS | 77 | 69.7 (± 10) | Male: 69 (90)<br>Female: 8 (10) | COPD | GOLD II: 77 (100)§ | 73 (95) |
| Ohbayashi et al, 2017[30] | RCT | 54 | 74.3 (± 10.1) | Male: 52 (96)<br>Female: 2 (4) | COPD | GOLD I: 10 (19)<br>GOLD II: 25 (46)<br>GOLD III: 12 (22)<br>GOLD IV: 7 (13) | 54 (100) |
| Davis et al, 2017[31] | CS | 503 | (40–75) | Male: 215 (43)<br>Female: 288 (57) | COPD (236)<br>Asthma (110)<br>Other (157) | – | – |
| Bournival et al, 2018[32] | CS | 67 | 69.8 (± 8.3) | Male: 36 (54)<br>Female: 31 (46) | COPD‖ | GOLD I: 3 (4)<br>GOLD II: 24 (36)<br>GOLD III: 10 (15)<br>GOLD IV: 6 (9)<br>Missing: 24 (36) | 67 (100) |
| Ding et al, 2018[7] | CS | 3,569 | (>40) | – | COPD‖ | – | – |
| Hanania et al, 2018[9] | CS | 499 | (55–75) | Male: 215 (43)<br>Female: 284 (57) | COPD | – | 379 (100) |
| O'Hagan et al, 2018[33] | Cohort | 240 | (40–75) | Male: 107 (45)<br>Female: 133 (55) | COPD (63)<br>Other (177) | – | 240 (100) |
| Oliveira et al, 2018[17] | RCT | 140 | 63.5 (± 8.2) | Male: 78 (56)<br>Female: 62 (44) | COPD | – | 140 (100) |
| Price et al, 201834 | CS | 764 | 56 (± 9.8) | Male: 390 (51)<br>Female: 374 (49) | COPD | GOLD I: 198 (26)<br>GOLD II: 420 (55)<br>GOLD III: 115 (15)<br>GOLD IV: 31 (4) | 535 (70) |
| Chouaid et al, 2019[35] | CS | 153 | 50.4 (40–70) | Male: 103 (67)<br>Female: 50 (33) | COPD | GOLD II: 70 (46)<br>GOLD III: 63 (41)<br>GOLD IV: 3 (2)<br>Missing: 17 (11) | 135 (88)¶ |

(*continued*)

**Table 1**
**(continued).**

| Study | Study Design* | Patients (N) | Mean Age, yr (± SD/Range) | Sex N (%) | Diagnosis† (N) | COPD Severity‡ N (%) | Inhaler Training N (%) |
|---|---|---|---|---|---|---|---|
| Total | 11 CS<br>4 Cohort<br>4 RCT | 11,256 | – | Male: 4,229 (38)<br>Female: 3,213 (29)<br>Missing: 3,814 (34) | COPD: 10,301 (92)<br>Asthma: 576 (5)<br>Other: 381 (3) | GOLD I: 1,409 (14)<br>GOLD II: 2,195 (21)<br>GOLD III: 730 (7)<br>GOLD IV: 154 (2)<br>Missing: 5,813 (56) | Yes: 2559 (23)<br>No: 502 (4)<br>Missing: 8,195 (73) |

* CS = cross-sectional, RCT = randomized controlled trial.
† COPD = chronic obstructive pulmonary disease.
‡ GOLD, Global Initiative for Chronic Obstructive Pulmonary Disease, 2019.
§ GOLD stage was inferred based on mean $FEV_1$, % predicted.
|| Patients diagnosed with COPD and asthma.
¶ Inhaler training included both in-person and video training;–, data unavailable.

performed using restricted maximum likelihood random-effects models with JASP 9.2 software.[42]

## 3. Results

### 3.1. Patient characteristics

Nineteen studies (n = 11,256) were included in this meta-analysis (Table 1). Of these studies, 11 were cross-sectional, 4 were randomized controlled trials, and 4 were cohort studies. The patients' average age ranged from 50.4 to 74.3 years and the majority were male (57%). Overall, 92% of patients had COPD, with the remaining 8% diagnosed with asthma or another obstructive lung disease. Of the patients with COPD for whom disease severity was reported (n = 4,488), nearly 69% were classified as having moderate to very severe COPD (GOLD spirometric stages II to IV).

### 3.2. Inhalation device feature preferences

All studies examined device feature preferences among patients using different types of handheld inhalers including MDIs, DPIs, and SMIs. The most frequently reported device features were perceived ease of use, selected physical characteristics (eg, shape, color), portability, and availability of a dose counter (Fig. 2). About one third of the studies also reported on features related to size, perceived ease of dose preparation, durability, and speed of medication administration.

Aggregate findings across the studies revealed that patients preferred the following device features:

(1) small size (71.7%; 95% CI: 46.3, 97.1; n = 604, 3 studies; $I^2 = 92.9$, 95% CI: 73.6, 99.2) (Fig. 3A);
(2) rapid medication administration (64.9%; 95% CI: 36.5, 93.4; n = 745, 3 studies; $I^2 = 92.7$, 95% CI: 67.0, 99.2) (Fig. 3B);
(3) durability (62.1%; 95% CI: 39.7, 84.4; n = 4,500, 4 studies; $I^2 = 97.7$, 95% CI: 92.6, 99.8) (Fig. 3C);
(4) a dose counter (52.3%; 95% CI: 20.7, 83.9; n = 4,536, 4 studies; $I^2 = 99.1$, 95% CI: 97.6, 99.9) (Fig. 3D);
(5) portability (51.8%; 95% CI: 29.1, 74.5; n = 4,975, 7 studies; $I^2 = 99.5$, 95% CI: 98.7, 99.9) (Fig. 3E);
(6) perceived ease of use (51.2%; 95% CI: 35.6, 66.7; n = 5,878, 10 studies; $I^2 = 98.8$, 95% CI: 97.3, 99.6) (Fig. 3F); and
(7) perceived ease of dose preparation (50.1%; 95% CI: 26.2, 73.9; n = 4,003, 4 studies; $I^2 = 96.7$, 95% CI: 89.0, 99.7) (Fig. 3G).

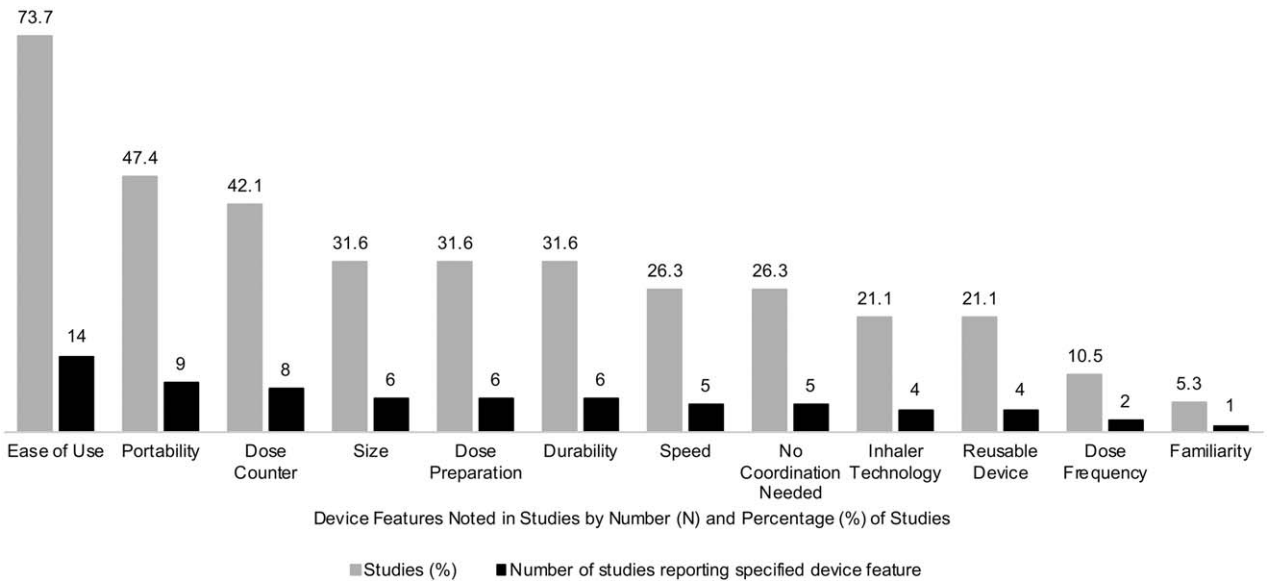
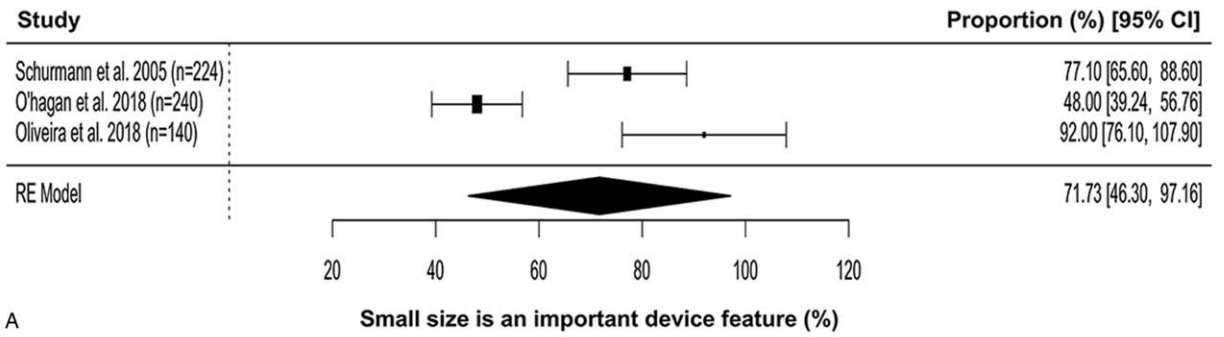
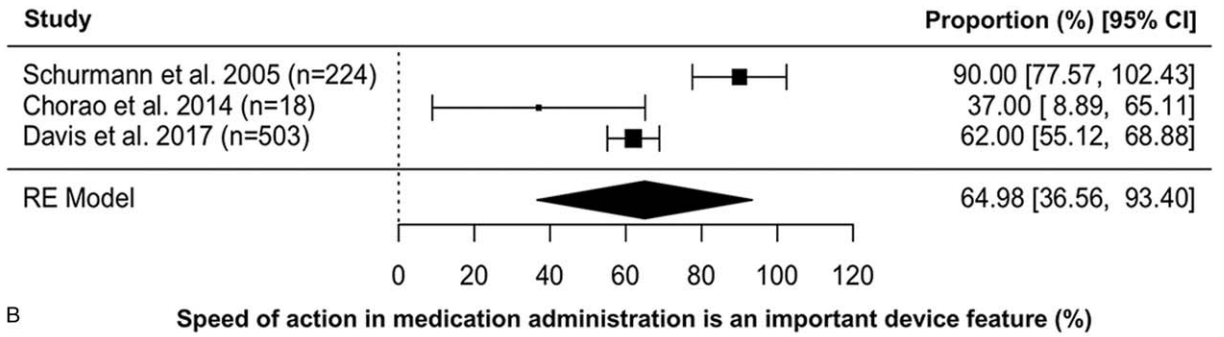



**Figure 2.** Prevalence of studies reporting on inhaler device feature preferences.




A

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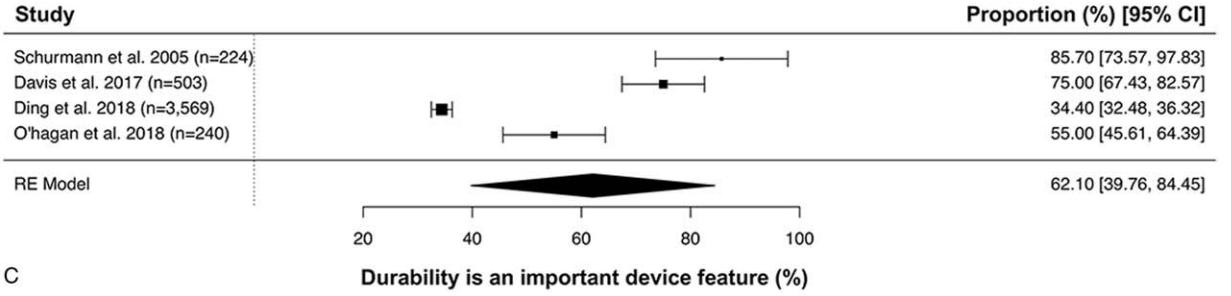


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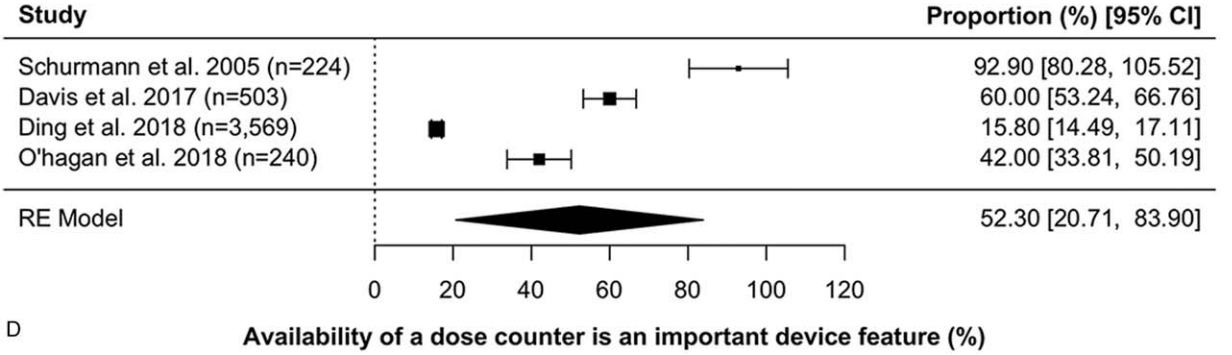
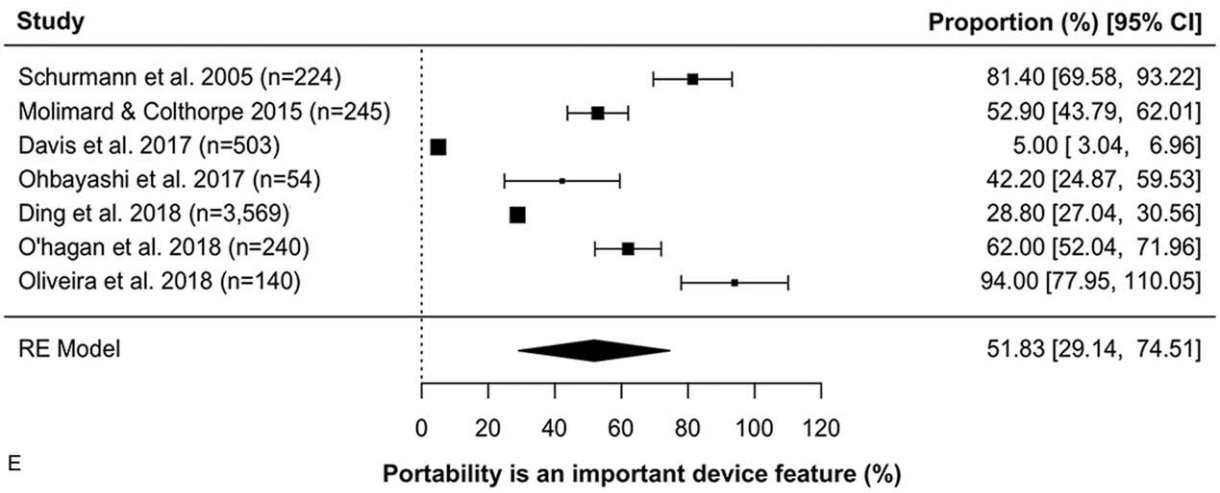
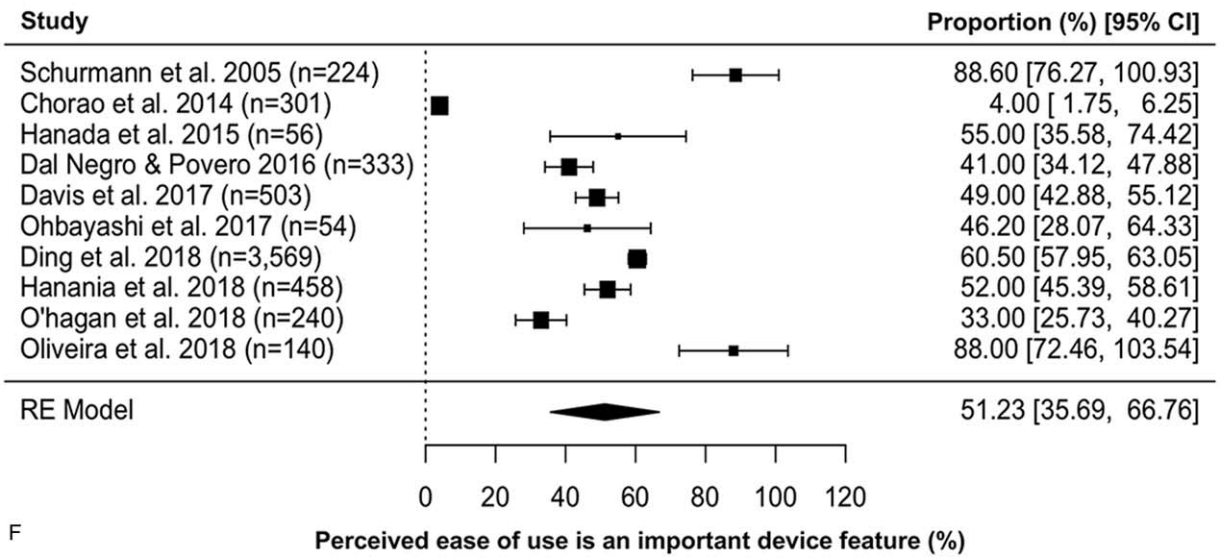



D

**Figure 3.** A. Meta-analyses of device feature preferences: Inhaler size. Note: $I^2$: 92.91% (95% CI 73.62, 99.24); Test for heterogeneity: Q (df = 2): 30, $P < .001$. Figure 3B. Meta-analyses of device feature preferences: Speed of action in medication administration. Note: $I^2$: 92.69% (95% CI 66.95, 99.22); Test for heterogeneity: Q(df = 2): 20, $P < .001$. Figure 3C. Meta-analyses of device feature preferences: Inhaler durability. Note: $I^2$: 97.68% (95% CI 92.62, 99.76); Test for heterogeneity: Q (df = 3): 177, $P < .001$. Figure 3D. Meta-analyses of device feature preferences: Availability of a dose counter. Note: $I^2$: 99.08% (95% CI 97.6, 99.91); Test for heterogeneity: Q(df =): 326, $P < .001$. Figure 3E. Meta-analyses of device feature preferences: Portability. Note: $I^2$: 99.5% (95% CI 98.74, 99.9); Test for heterogeneity: Q(df = 6): 629, $P < .001$. Figure 3F. Meta-analyses of device feature preferences: Perceived ease of use. Note: $I^2$: 98.77% (95% CI 97.29, 99.64); Test for heterogeneity: Q (df = 9): 1279.35, $P < .001$. Figure 3G. Meta-analyses of device feature preferences: Perceived ease of dose preparation. Note: $I^2$: 96.69% (95% CI 88.95, 99.66); Test for heterogeneity: Q (df = 3): 80, $P < .001$.



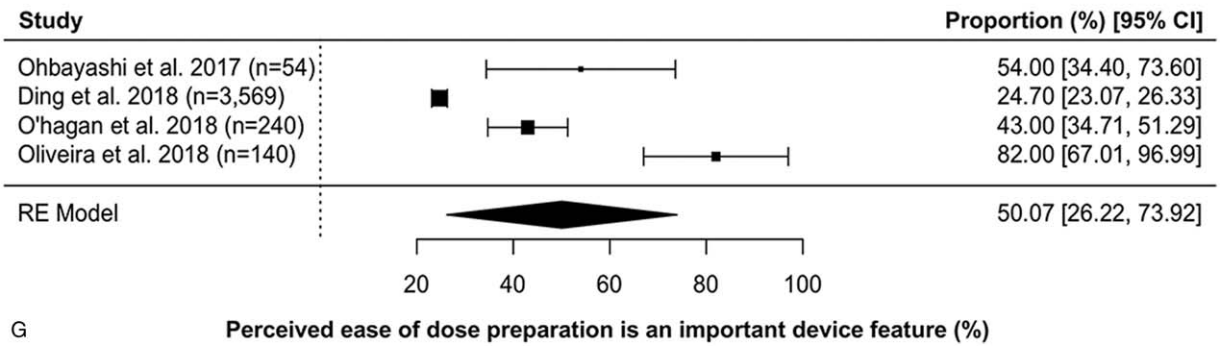




Figure 3. (Continued)

### 3.3. Heterogeneity and sensitivity analyses

Considerable heterogeneity was observed across the studies for each device feature. Sensitivity analyses revealed minor to moderate variations in the pooled effect size for each device feature depending on the removal of particular studies when employing the leave-one-out cross-validation technique (Table 2). The resulting ranges for the pooled effect sizes were as follows: 62.3% to 83.5% of patients preferred small size inhalers, 53.3% to 75.5% of patients preferred inhalers with rapid medication administration, 54.5% to 71.6% of patients preferred durable inhalers, 39.0% to 64.6% of patients preferred inhalers with a dose counter, 45.0% to 59.7% of patients preferred portable inhalers, 47.0% to 56.5% of patients preferred inhalers that they perceived as easy to use, and 38.6% to 59.2% of patients

**Table 2**

**Sensitivity analyses results by patients' device feature preferences.**

| Handheld Inhaler Device Feature | OR (95% CI)* | Model |
|---|---|---|
| Small size | 71.7 (46.3, 97.1) | All studies included (n = 3) |
| | 69.4 (26.3, 112.5) | Schurmann et al removed |
| | 62.3 (33.7, 90.8) | Oliveira et al removed |
| | 83.5 (69.0, 97.9) | O'hagan et al removed |
| Rapid medication administration | 64.9 (36.5, 93.4) | All studies included (n = 3) |
| | 53.3 (30.0, 76.6) | Schurmann et al removed |
| | 75.5 (48.0, 102.9) | Chorao et al removed |
| | 65.0 (13.2, 116.9) | Davis et al removed |
| Durability | 62.1 (39.7, 84.4) | All studies included (n = 4) |
| | 64.6 (33.7, 95.4) | O'hagan et al removed |
| | 54.5 (31.3, 77.8) | Schurmann et al removed |
| | 57.8 (28.7, 87.0) | Davis et al removed |
| | 71.6 (54.2, 89.0) | Ding et al removed |
| A dose counter | 52.3 (20.7, 83.9) | All studies included (n = 4) |
| | 39.0 (13.7, 64.4) | Schurmann et al removed |
| | 49.8 (5.6, 94.0) | Davis et al removed |
| | 64.6 (35.7, 93.4) | Ding et al removed |
| | 55.8 (12.1, 99.6) | O'hagan et al removed |
| Portability | 51.8 (29.1, 74.5) | All studies included (n = 7) |
| | 46.9 (22.7, 71.1) | Schurmann et al removed |
| | 51.7 (24.8, 78.6) | Molimard et al removed |
| | 59.7 (40.3, 79.1) | Davis et al removed |
| | 53.4 (27.0, 79.8) | Ohbayashi et al removed |
| | 50.2 (23.6, 76.7) | O'hagan et al removed |
| | 55.8 (30.4, 81.2) | Ding et al removed |
| | 45.0 (23.3, 66.6) | Oliveira et al removed |
| Perceived ease of use | 51.2 (35.6, 66.7) | All studies included (n = 10) |
| | 47.0 (32.2, 61.8) | Schurmann et al removed |
| | 56.5 (44.0, 69.1) | Chorao et al removed |
| | 50.9 (33.7, 68.0) | Hanada et al removed |
| | 52.4 (35.2, 69.8) | Dal Negro et al removed |
| | 51.5 (34.1, 68.9) | Davis et al removed |
| | 51.8 (34.6, 68.9) | Ohbayashi et al removed |
| | 50.2 (32.9, 67.4) | Ding et al removed |
| | 51.2 (33.7, 68.6) | Hanania et al removed |
| | 53.3 (36.5, 70.1) | O'hagan et al removed |
| | 47.2 (32.2, 62.3) | Oliveira et al removed |
| Perceived ease of dose preparation | 50.1 (26.2, 73.9) | All studies included (n = 4) |
| | 44.7 (36.8, 52.6) | Ding et al and Oliveira et al removed |
| | 52.8 (−3.3, 108.9) | Ohbayashi et al and O'hagan et al removed |
| | 49.2 (16.5, 81.9) | Ohbayashi et al removed |
| | 59.2 (35.8, 82.6) | Ding et al removed |
| | 52.8 (19.5, 86.1) | O'hagan et al removed |
| | 38.6 (22.0, 55.2) | Oliveira et al removed |

CI = confidence interval.
* OR = odds ratio

preferred inhalers that required little to no dose preparation (i.e., ease of dose preparation). Overall, the sensitivity analyses showed the least degree of variation in effect size for 2 device features, portability and perceived ease of use, both of which were reported across the largest number of studies.

A close examination of funnel plots for each of the device features revealed no asymmetry. Due to an inadequate number of studies ($n < 5$) required to properly evaluate potential publication bias, this assessment was limited to only 2 device features, portability (n = 7 studies) and perceived ease of use (n = 10 studies). Begg and Mazumdar's rank correlation test revealed no publication bias for either device feature. However, results from the Egger's test indicated possible publication bias across the studies that reported on portability as a preferred device feature ($P = .01$).

## 4. Discussion

To our knowledge, this is the first systematic review and meta-analysis to examine inhaler device feature preferences in adults with obstructive lung diseases treated with bronchodilators. We found that patients prefer inhaler devices that are small in size, durable, portable, have a dose counter, are perceived as easy to use, and administer medications rapidly. These results suggest that patients find device features related to convenience (eg, small size and portability), utility (eg, ease of use), and feedback/assurance (eg, availability of a dose counter and rapid medication administration) to be important.

Nearly 72% of patients preferred a small inhaler device and 52% said device portability was important to them. These features provide the added convenience of allowing patients ready access to prescribed medications without restricting lifestyles.[46] Having convenient access to an inhalation device maybe valued by patients for a multitude of reasons including allowing greater independence and the ability to maintain a more active lifestyle, factors that have been associated with improving medication adherence.[47]

More than half of the patients rated perceived ease of inhaler use and ease of medication dose preparation as important device features. Past studies on inhaler device utility have shown that patients associate ease of use with having to perform fewer inhalation steps that require hand-breath coordination and priming of the inhaler in order to deliver the medication into the lungs.[34,48,49] Moreover, research on inhaler use and health outcomes has found that perceived ease of inhaler use leads to lower device use errors, higher medication adherence rates, and higher levels of patient satisfaction with prescribed therapies.[19,49,50]

Having some form of feedback or assurance that the medication was being delivered to the lungs was another device feature preferred by patients. One such feature included the availability of a dose counter that provided patients with confirmation that the medication had been released from the inhaler. Dose counters also informed patients about the number of medication doses remaining in the inhaler. Speed of medication administration was another preferred device feature that appeared to be related to the need for feedback and assurance. Clearly, optimal drug delivery is critical to symptom management among patients with respiratory care needs. Indeed, since nearly all patients with impaired lung function experience respiratory distress at some point in their lifetime, it is understandable that any device feature that could offer feedback on the medication administration process would be valued by patients.

In real-world settings, many factors affect treatment success when an inhalation device is prescribed including the patients' and practitioners' device preferences, the patients' physical and cognitive abilities that influence proper device use, and economic considerations that impact access to needed devices. Weighing patients' preferences against the features of a prescribed inhalation device should be an important consideration for health care providers when developing treatment plans. Today, the commercial availability of different types of inhalation

devices with varying features can facilitate health care providers' ability to match the right device to the right patient in order to optimize clinical outcomes.[4,20,51] Many handheld inhalers and nebulizer devices offer the features preferred by patients including small size, portability, rapid medication administration, and ease of use.[4,5,50,52] Since patients' satisfaction levels with prescribed inhalation devices are associated with improved health outcomes[9,10,16,17,19], giving due consideration to patients' preferences during the device selection process would be prudent and consistent with recommended treatment strategies.[4]

Our findings should be viewed in light of certain limitations inherent to systematic reviews and meta-analysis studies. First, due to the lack of data, factors that may have influenced heterogeneity across the studies could not be evaluated nor was it possible to examine device feature preferences by demographic or clinical characteristics (eg, disease severity and comorbidities). Third, the studies included in this meta-analysis were limited to handheld inhaler devices, thus device feature preferences among patients using nebulizers were not assessed. Fourth, specific information on the definitional attributes of certain device features, such as inhaler size or perceived ease of dose preparation, were not provided in the original studies. Therefore, the consistency of meaning for those device features could not be examined in our meta-analysis. Another limitation was our inability to fully assess possible publication bias across all of the device features. Lastly, our meta-analysis was limited to studies published in English. Thus, the patient populations included in our study may not be representative of the broader group of patients with obstructive lung diseases which could limit our study's generalizability. To address some of these limitations, future studies should explore device feature preferences in a more comprehensive manner across various groups of patients based on disease severity and overall burden of illness inclusive of comorbid conditions. In addition, research is warranted on device feature preferences among patients treated with other types of inhalation devices, such as nebulizers.

Despite its limitations, our study provides added insights that can help guide patient-centered care for adults with obstructive lung diseases. By considering patients' inhalation device preferences, health care providers can optimize treatment plans to better meet the respiratory needs of their patients.

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## Author contributions

**Conceptualization:** MN, CD, SC, and BRC.
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**Funding acquisition:** MN.
**Methodology and data acquisition:** MN, SC, and KY.
**Statistical analysis:** MN and SC.
**Writing – original draft preparation:** MN, CD, and BRC.
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