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EDUCATION

A systematic review of instruments aimed at evaluating metered-dose inhaler administration technique in children

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ABSTRACT

Objective. The objective of the present study was to perform a systematic review of instruments aimed at evaluating pressurized metered-dose inhaler (pMDI) administration technique in children and evaluating the measurement properties of these instruments. **Methods.** A systematic search of the literature was performed in order to identify studies in which an instrument (scale, checklist, or questionnaire) for evaluating pMDI administration technique in children was described. Instruments were evaluated based on their reliability, validity, utility, endorsement frequency, restrictions in range, comprehension, lack of ambiguity, and lack of value-laden or offensive content. **Results.** A total of 24 instruments were identified. The age of the children ranged from 1 month to 18 years, the number of steps or items included in the instruments ranged from 3 to 21, and nearly half of the instruments distinguished between essential and non-essential steps or items. In only 7 of the 24 instruments was there a report of their measurement properties, mainly reliability and utility. Taking into consideration the information contained in the instruments, as well as their measurement properties, we determined four instruments to be the best of the available ones. **Conclusions.** Among the 24 instruments for the assessment of pMDI administration technique in children that were identified and systematically examined, four were considered to be the best ones available. However, additional evaluation of their measurement properties should be done before using them in clinical practice and for research purposes.

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Introduction

Asthma and other obstructive airway diseases have been widely recognized as the most common chronic diseases of childhood and as major public health problems in many countries around the world [1]. Inhalation has become the preferred route of administration of medications in the management of asthma and other obstructive airway diseases, mainly because of its direct delivery to the airways, thus producing a more rapid onset of action and fewer systemic side effects, with smaller doses than would be required with other routes of administration [2]. Among the different types of inhalation devices, pressurized metered-dose inhalers (pMDIs) are the most commonly recommended and most widely used devices for pediatric patients because of their efficacy, portability, and general acceptance by asthmatic children and their caregivers [3].

However, an appropriate technique for the administration of an inhaler is critical to achieve an optimal

therapeutic effect. There is compelling evidence showing that an inadequate inhaler technique is associated with decreased lung deposition, suboptimal therapeutic effect, and an increase in the side effects of inhaled medications. Specifically, it has been reported that misuse of pMDIs decreases the lung deposition of bronchodilators from 20% to 7% [4], produces a significant loss of potential efficacy of bronchodilators due to decreased bronchodilation (30%) [5], and is associated with poorer asthma control in inhaled corticosteroid-treated asthmatics [6].

The use of pMDIs in conjunction with valved holding chambers or spacers with an appropriate mouthpiece or a well-fitted face mask is strongly recommended for reducing problems associated with the coordination and inhalation of medications in pediatric patients [3]. Depending on the child's cognitive ability, a number of skills are considered critical for an effective delivery of inhaled medications to the conducting airways. These skills usually comprise shaking of the canister prior to

actuation; the correct assembly of the spacer device and the pMDIs; the form, mechanism, and actuation moment of the canister; holding the breath during a phase of the breathing cycle (inhalation/exhalation) or before, during, or after canister actuation (when using chamber with mouthpiece); and the closing of the mouth around the mouthpiece or good face-mask fitting [7–9].

The majority of these skills have been grouped in a number of instruments (scales, checklists, or questionnaires) that have been used mainly for research purposes. However, to the best of our knowledge, no previous studies have performed a systematic review of all available instruments intended to evaluate pMDI administration technique among children with asthma and other RADs, and no studies have evaluated the measurement properties of these instruments. This systematic review is important because choosing the most effective instruments for the evaluation of pMDI administration technique is critical, not only for research, but also for clinical purposes. Identifying the most appropriate instrument for evaluating pMDI administration for a specific patient may personalize teaching based on individual skills. This tailored intervention may notably improve pMDI technique and ultimately have a great impact on clinically important outcomes such as asthma control.

The overall goal of the present study was to perform a systematic review of instruments aimed at evaluating pMDI administration technique among children with asthma and other obstructive airway diseases and evaluating the individual measurement properties of all the available instruments.

Methods

Search strategy

A systematic search of the literature was performed by two independent reviewers of the electronic databases PubMed and Embase from the inception of the database to December 2015 in order to identify studies in which an instrument (scale, checklist, or questionnaire) was described for evaluating pMDI administration technique among children with asthma and other obstructive airway diseases.

For this search strategy, the following mesh terms and free text words were used to search the PubMed database: (inhal* OR spacer* OR inhal* device OR metered-dose inhaler) AND (skill* OR inhal* skill OR utilization OR technique OR use OR evaluation OR administration technique OR application OR inhal* technique OR inhal* treatment) AND (scale OR instrument OR checklist) AND (childhood asthma OR asthma outcome OR asthma

education OR control of asthma OR asthma control). For the purpose of including additional studies, we examined the references of the identified articles, and we contacted experts in the field. Any disagreements were resolved by discussion, and if necessary a third reviewer was involved. We considered studies published in any language.

Inclusion and exclusion criteria

Studies of instruments were included if they evaluated inhaler administration technique among children with asthma and other obstructive airway diseases, whether or not they assessed the measurement properties of the instruments. Articles reporting on instruments that exclusively evaluated dry powder inhaler administration technique were not included.

Data extraction

From the included studies, we extracted descriptive data (author, year, setting, age range of the children, and disease characteristics) and the key features and measurement properties of the selected instruments (source of instrument, construct, number of items/domains, response options, interpretation, validity, and reliability).

Assessment of the measurement properties of the selected instruments

For the purpose of evaluating the measurement properties of identified and selected instruments, we used the checklist for assessing the usefulness of rating scales proposed by Streiner [10]. This checklist consists of 5 domains, each dealing with one of the following measurement properties: where the instrument's items originated (previous scales, clinical observation, expert opinion, patients' reports, research findings, or theory); assessment of the instrument's items for endorsement frequency (percentage of participants who selected each of the response options), restrictions in range, and comprehension; reliability (internal consistency, test-retest reliability, and inter-rater agreement); validity (face validity, content validity, criterion validity, and construct validity, this latter understood as the degree to which the measurement corresponds to other variables and measures that are not identical to the construct of an appropriate technique for the administration of an inhaler, but to which the construct of an appropriate technique for the administration of an inhaler should be related); and utility (completion time, training time, and scoring). Each domain of this checklist contains 3 to 6 items on relevant aspects of domain appraisals (Table 1). Studies were not rejected

Table 1. Principal findings for instruments aimed at evaluating metered-dose inhaler administration technique among children with asthma and other reactive airway diseases.

Instrument	Study	Study design	Mode of pMDI administration	Age range of the children	Disease characteristics	Number of items/steps	Scoring	Where the instrument's items originated	Reliability	Validity	Utility
A standardized MDI-spacer checklist	Aziz NA, 2006 [24]	Uncontrolled before- and after study	MDI with a holding chamber (with facemask); Aerochamber	1–12 years	Physician-diagnosed asthma. $n = 85$	8 steps not discriminated between essential and non-essential steps. Five additional steps for assessing the technique of cleaning the spacer	Score (0–8 or 13) based on the number of correct steps.	Not stated	Not assessed	Not assessed	Not assessed
MDI checklist b	Boccuti L, 1996 [8]	Cross-sectional study	MDI with a spacer (with mouthpiece)	7–17 years	Moderate to severe asthma. $n = 100$	10–11 steps; 6–7 essential, depending on the spacer used (Optihaler, Azmacort, or InspirEase).	Score (0–5) based on the number of correct steps. Zero points for failing to perform any one of the essential skills	Previous scale, existing literature and a multidisciplinary team	Internal consistency: coefficient alpha = 0.90 Interrater agreement = 100%	Not assessed	Four trials were required for training in use the checklist
Behavioral criteria to determine accurate MDI technique	Burkhardt PV, 2005 [30]	Uncontrolled before- and after study	MDI with a spacer (with facemask)	7–11 years	Persistent asthma. $n = 36$	6 criteria, not discriminated between essential and non-essential criteria	"good," "fair," or "poor," MDI technique, depending on the number of criteria that were present	Previous scale	Not assessed	Not assessed	Not assessed
Steps of inhaler device use	Capanoglu M, 2015 [25]	Analytical cross-sectional study	MDI with a spacer (with facemask)	1–18 years	Patients with asthma who were using inhaled corticosteroids treatment for at least 6 months. $n = 171$	7 steps, all of them considered essential	"Using inhaler devices correctly": Patients who did not make a mistake in any step.	Literature review	Not assessed	Not assessed	Not assessed
Inhaler technique steps for a MDI with and without a spacer	Carpenter DM, 2015 [14]	Randomized controlled trial	MDI with a spacer (with mouthpiece) and MDI without a spacer	7–17 years	Mild, moderate or severe persistent asthma. $n = 91$	8 steps for MDI with a spacer and 8 steps for MDI without a spacer, not discriminated between essential and non-essential steps	"Using inhaler devices incorrectly": Patients who made at least one mistake MDI technique was measured as the number of steps that the child performed correctly	Not stated	Not assessed	Not assessed	For training purposes, the study research assistant viewed a DVD that had examples of optimal MDI technique until she could accurately identify all omissions in technique.

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Table 1. (Continued)

Instrument	Study	Study design	Mode of pMDI administration	Age range of the children	Disease characteristics	Number of items/steps	Scoring	Where the instrument's items originated	Reliability	Validity	Utility
The standardized inhaler checklist	Chen SH, 2002 [13]	Analytical cross-sectional study	MDI with a spacer (with mouthpiece)	8–13 years	Persistent asthmatic patients. $n = 132$	8 steps, not discriminated between essential and non-essential steps	Each item was rated as successfully demonstrated (giving a score of one) or incorrect (giving a score of zero)	Recommendations of the National Institute of Health's review committee for the treatment of asthma	Authors used an internal test for reliability, initially choosing 20 students who regularly used inhaler therapy for their asthma control. Tested in this fashion, the checklist revealed adequate internal consistency and reliability (alpha coefficient = 0.73).	For the content validity of the study, nine experts were invited to evaluate the relative appropriateness of the check-list to the study intent. Authors applied the suggestions of this group to improve the checklist and to make it more easily understood.	Not assessed
MDI standardized checklist.	Deerojanawong J, 2009 [17]	Analytical cross-sectional study	MDI alone and MDI with a spacer (with facemask or mouthpiece)	3–14 years	Pediatric pulmonologist diagnosed asthma. $n = 93$	8 steps; 6 essential and 2 non-essential steps	The inhalation technique was considered correct when all essential steps were properly performed.	Recommendations of the National Institute of Health (NIH) and revision by project staff	Not assessed	Not assessed	Not assessed
Criteria to rate performance of metered aerosol technique	Hughes DM, 1991 [35]	Randomized controlled trial	MDI with a spacer (with facemask or mouthpiece)	6–16 years	Physician-diagnosed asthma. $n = 89$	5 steps, not discriminated between essential and non-essential steps	Performance of metered aerosol technique was rated as good, fair, or poor, depending on the criteria neglected	Not stated	Not assessed	Not assessed	Not assessed

Standardized checklists for assessing MDI plus spacer use b	Kamps AW, 2000 [15]	Prospective cohort study	MDI with a spacer (with facemask or mouthpiece)	1–14 years	Patients with asthma diagnosis given by general practitioners or by pharmacy assistants referred to a pediatric pulmonology outpatient clinic. $n = 95$	7 steps; 5 essential and 2 non-essential steps	Each essential step was rated as successfully demonstrated or incorrect	Previous scale	Not assessed	Not assessed	As a reference group, a research fellow instructed and evaluated the inhalation technique of a group of 29 patients at least twice over a 4-week period
Essential steps to ensure correct inhalation technique with a MDI/s device	Kamps AW, 2002 [33]	Prospective cohort study	MDI with a spacer (with facemask or mouthpiece)	Mean age: 4.1 ± 2.6 years	Patients with physician-diagnosed asthma attending an outpatient asthma clinic. $n = 108$	5 steps, all of them considered essential	Correct inhalation technique operationally defined as performance of all the essential steps correctly.	Previous scale	Not assessed	Not assessed	Not assessed
The observation checklist of all the steps of the using MDI with spacer	Kumar A, 2013 [26]	Uncontrolled before-and-after study	MDI with a spacer (with mouthpiece)	5–16 years	The instrument was designed for evaluating skills in using MDI amongst school teachers of children aged 5–16 years. $n = 91$	20 steps not discriminated between essential and non-essential steps	Score 1 was given for every correct step and score 0 for every wrong or missed step.	Not stated	Not assessed	Not assessed	Not assessed

(Continued on the next page)

Table 1. (Continued)

Instrument	Study	Study design	Mode of pMDI administration	Age range of the children	Disease characteristics	Number of items/steps	Scoring	Where the instrument's items originated	Reliability	Validity	Utility
Steps to assess MDI with spacer device technique	Machira EPM, 2001 [18]	Descriptive cross-sectional study	MDI with a spacer (with facemask or mouthpiece)	6 months - 12 years	Patients with physician-diagnosed asthma attending a pediatric chest clinic and a pediatric emergency unit. $n = 82$	7 steps; 5 essential and 2 non-essential steps	Correct technique was judged to be the performance of all the essential steps, while incorrect technique was considered to be any missed or wrongly performed steps.	Not stated	Not assessed	Not assessed	Not assessed
Questionnaire of MDI use	Malot L, 2007 [27]	Descriptive cross-sectional study	MDI without a spacer	5-18 years	Physician-diagnosed asthma. $n = 59$	7 steps; 3 essential and 4 non-essential steps	Each step was rated as successfully demonstrated or incorrect	Not stated	Not assessed	Not assessed	Not assessed
Assessment of skills in MDI use checklist	Marguet C, 2001 [23]	Analytical cross-sectional study	MDI with a holding chamber (with facemask)	1 month-5 years	Patients attending the pulmonology clinic for recurrent symptoms. $n = 94$	9 steps not discriminated between essential and non-essential steps	Each step was rated as successfully demonstrated or incorrect	Instruction booklet provided with each of the devices studied (Babyhaler and Nebuchamber)	Not assessed	Not assessed	Not assessed
Steps to demonstrate correct MDI technique	Minai BA, 2004 [32]	Uncontrolled before-and-after study	MDI without a spacer	Mean age: 11.6 ± 2.8 years	Physician-diagnosed asthma. $n = 45$	8 steps, not discriminated between essential and non-essential steps	The patient's MDI score was the percentage of steps performed correctly	Instrument based on based on the National Institute of Health's Expert Panel Report 2 Guidelines for the Diagnosis and Management of Asthma	Not assessed	Not assessed	Not assessed

Standardized MDI with spacer checklist	Oskaya E, 2010 [16]	Randomized controlled trial	MDI with a spacer. Not specified if facemask or mouthpiece was used	7–11 years	Mild-to-moderate asthma. $n = 66$	10 steps: 5 essential and 5 non-essential steps	Score (0–5) based on the number of correct steps. Zero points for failing to perform any one of the essential skills	Previous scale	Not assessed	There was no significant correlation between asthma outcome measures and MDI spacer checklist scores	Not assessed
MDI-spacer device technique checklist	Reznik M, 2014 [7]	Analytical cross-sectional study	MDI with a spacer (with facemask)	2–9 years	Physician-diagnosed asthma. $n = 169$	10 steps: 5 essential and 5 non-essential steps	Score (0–10) based on the number of correct steps. Correct users: score ≥ 7	Literature review and clinical practice	Eight of the ten steps on the checklist demonstrated perfect or almost perfect agreement between different raters.	Not assessed	Five trials were required to achieve 100% agreement on all items between two raters.
National Institutes of Health, National Heart, Lung, and Blood Institute steps to optimize medication delivery via MDIs	Scarfone RJ, 2002 [9]	Analytical cross-sectional study	MDI alone and MDI with a holding chamber and face mask	2–18 years	Patients with acute asthma exacerbations in the emergency department. $n = 208$	6 steps for MDI users and 7 steps for MDI with a holding chamber and face mask users	Score (0–6 or 7) based on the number of correct steps.	Literature review and expert opinion	Not assessed	Not assessed	Not assessed

(Continued on the next page)

Table 1. (Continued)

Instrument	Study	Study design	Mode of pMDI administration	Age range of the children	Disease characteristics	Number of items/steps	Scoring	Where the instrument's items originated	Reliability	Validity	Utility
Steps to assess metered dose inhaler device technique b	Sleath B, 2011 [11]	Analytical cross-sectional study	MDI alone and MDI with a spacer (with mouthpiece)	8–16 years	Patients with mild, moderate, or severe persistent asthma. $n = 270$	8 steps for MDI with a spacer and 8 steps for MDI without a spacer; not discriminated between essential and non-essential steps	Each step was rated as successfully demonstrated or incorrect	Literature review and clinical experience	All of the medical visit audiotapes were transcribed verbatim. A detailed coding tool was developed and two research assistants coded 20 of the same transcripts throughout the study period to assess inter-coder reliability	Not assessed	For training purposes, the study research assistants viewed a DVD that had examples of optimal MDI technique until they could accurately identify all errors and omissions in technique.
Inhalation technique questionnaire items	Uijen JH, 2009 [28]	Descriptive cross-sectional study	MDI with a spacer (with facemask) and MDI without a spacer	0–12 years	Patients who had been prescribed inhalation medication in the last three months. $n = 46$	8 items; 3 related to essential mistakes	Each item was rated as successfully demonstrated or incorrect	Adapted from previous scale	Not assessed	Not assessed	Not assessed
Steps for assessment of use of spacer devices for inhaled drug delivery	Vella C, 2005 [34]	Descriptive cross-sectional study	MDI alone and MDI with a spacer (with facemask or mouthpiece)	2–14 years	Patients with a known diagnosis of chronic bronchial asthma attending for routine follow-up at a general children's outpatients' clinic. $n = 200$	3 steps, not discriminated between essential and non-essential steps	Failure to agitate the MDI or a poor inspiratory effort constituted an overall poor technique. The use of a spacer device with a face mask beyond the age of 4 yr was considered to be inappropriate.	Not stated	Not assessed	Not assessed	Not assessed

Steps used in the assessment of inhaler technique	Vodoff MV, 2001 [31]	Descriptive cross-sectional study	MDI with a spacer (with facemask)	6–48 months	Physician-diagnosed asthma. $n = 60$	12 steps, not discriminated between essential and non-essential steps	Score 1 was given for every correct step and score 0 for every wrong or missed step.	Literature review	Not assessed	Not assessed	Not assessed
Steps to assess MDI with holding chamber technique	Walia M, 2006 [29]	Analytical cross-sectional study	MDI with a holding chamber (with facemask or mouthpiece)	5 months - 18 years	Children with asthma attending an outpatient pediatric chest clinic. $n = 213$	5 steps; 4 essential and 1 non-essential step	The inhalation technique was considered correct when all essential steps were performed correctly	Not stated	Not assessed	Not assessed	Not assessed
The standardized educational MDI checklist ^b	Welch MJ, 2010 [12]	Uncontrolled before-and-after study	MDI with a spacer (with facemask or mouthpiece)	1–6 years	Children who were being prescribed 1 of the 2 pre-identified inhaler devices for the first time. $n = 110$	21 steps (13 major steps), some of which were applicable only to patients using mouthpiece, other to those using facemask, and other to those using valved spacers	Each step was rated as successfully demonstrated or incorrect. A Performance Mastery Score was defined as the proportion of major steps correctly performed out of all major steps possible.	Review of product information, the medical literature, and asthma guidelines.	Inter-rater agreement: Kappa statistic = 0.64 ($p < 0.001$)	Not assessed	Not assessed

^a MDI: Metered dose inhaler; ^b Instruments selected as the best available ones, based on what the instruments measures and how well they have been validated.

on the basis of these measurement properties; rather, the results were synthesized in order to facilitate the selection of the best available instrument. All measurement properties were scored independently by two researchers (CERM, GN) before reaching a consensus.

Selection of the best available instruments

When deciding on the best available instruments we considered the following criteria: First, we took into account that the choice of devices for children is critically affected by the child's cognitive ability: it is recommended that children up to 3 years of age be treated with pMDIs with a valved holding chamber and a facemask. However, as soon as the child is able to use a mouthpiece (at about three to four years of age), this should be encouraged, since mouthpiece breathing increases lung deposition compared with facemask breathing [3].

Furthermore, the recommended technique when inhaling from a pMDI and a spacer with mask in young children is through a normal, quiet breathing. However, it is recommended that children > 6 years of age use a "single-breath" technique, because this technique is associated with greater lung deposition compared to the normal, quiet breathing technique [3]. Second, we considered the form of scoring for the instrument. Ideally the instrument should yield a number that can be manipulated statistically and that is based on a functional analysis of each of the skills contributing to drug delivery (assigning different weights to different items and giving higher value to items considered critical for effective delivery of medication to the conducting airways) [10]. Finally, we took into account the individual measurement properties of all the available instruments.

Results

Results of the search

The study selection process is shown in Figure 1. The systematic search of databases retrieved 91 studies. Among those, 81 were excluded. Eighteen additional potentially relevant studies were identified from reference lists, of which 14 finally met the inclusion criteria. Finally, 24 studies using these same instruments for assessing pMDI administration technique among children with asthma and other obstructive airway diseases were included in the review.

Content and properties of the instruments

Table 1 describes characteristics of each of the 24 included studies. Out of the total of 24 instruments

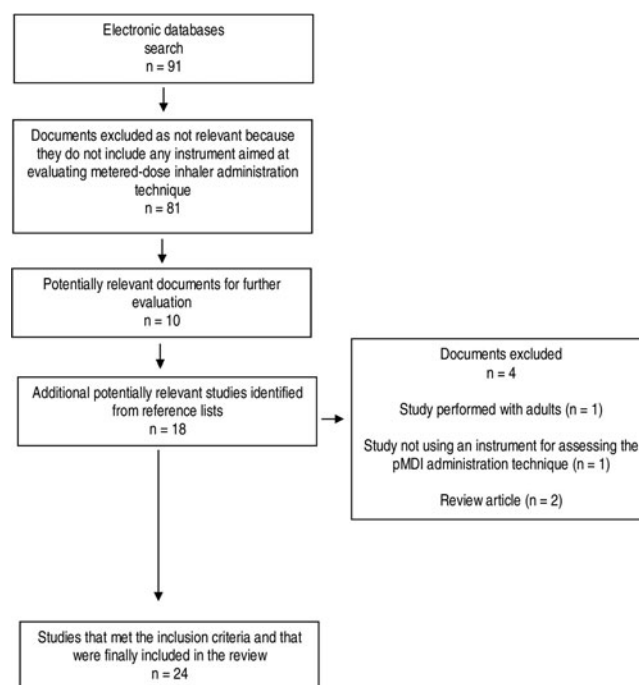


Figure 1. Study flow diagram for studies reporting instruments aimed at evaluating pMDI administration technique among children with asthma and other reactive airway diseases. *pMDI: pressurized metered-dose inhaler.

included, 20 (83.3%) were designed for assessing pMDI administration technique among asthmatic children and the remaining 4 (16.7%) for assessing pMDI administration technique among children with other types of obstructive airway diseases, not necessarily asthma [12,23,26,28]. The sample size of the studies that included the instruments ranged from 36 to 270 children. Although most of the instruments assessed the administration of pMDI with a spacer (with facemask and/or mouthpiece), a few assessed the administration of pMDI alone [27,32].

The age of the children ranged from 1 month to 18 years, with some instruments not distinguishing between the use of a mouthpiece and the use of a spacer with a facemask for assessing the administration of pMDI in patients within a wide range of age. The number of steps or items included in the instruments ranged from 3 to 21, with nearly half of the instruments distinguishing between essential and non-essential steps or items. With respect to the scoring of the instruments, the majority of instruments rated each step or item as successfully demonstrated or incorrect, instead of giving a scoring based on a functional analysis of each of the skills contributing to drug delivery. Most instruments contained steps or items that were derived from previous scales, a review of the literature, clinical experience, and recommendations given by biomedical research agencies such as the National Institutes of Health. However, in 8

instruments (33.3%), it was not stated where the steps or items originated [14,18,24,26,27,29,34,35].

Measurement properties of the instruments

In only a minority of the instruments (8/24) was there a report of their measurement properties [7,8,11–16]. The two measurement properties most frequently assessed and reported were reliability and utility. With respect to the former, the measurement properties most often used as a measure of reliability were internal consistency and inter-rater agreement. In three of the instruments, inter-rater agreement was determined using the kappa statistic, with levels of agreement ranging from moderate to almost perfect [8,11,12]. In two of the instruments, internal consistency was determined using Cronbach's alpha coefficient, with levels of internal consistency ranging from acceptable to excellent [8,13].

With respect to utility, 5 of the studies reported the methodology or the time necessary for training researchers in the use of the instruments [7,8,11,14,15]. Regarding validity, only two of the studies reported data on the validity of the instruments, with one of them reporting on construct validity [16] and the other reporting on content validity [13]. No instrument reported information regarding endorsement frequency, restrictions in range, or comprehension of the items or steps contained in the instruments.

Results of the selection of the best available instruments

When considering what the instruments measure and how well they have been validated, we determined that the best available instruments are those used by Boccuti [8], Sleath [11], Welch [12], and Kamps [15], because these instruments met a greater number of the above-mentioned criteria.

Discussion

The present study shows that a total of 24 instruments devoted to the evaluation of pMDI administration technique among children with asthma and other RADs have been reported in the literature. The majority of these instruments were designed for assessing the technique of the administration of the pMDI with a spacer among asthmatic children within a wide range of age, rating each step or item as successfully demonstrated or incorrect. They contained steps or items that came from previous scales, a review of the literature, clinical experience, and recommendations given by biomedical research agencies. However, in only a minority of the instruments was there a

specific report on their measurement properties, including reliability, utility, and validity.

As far as we know, no previous studies have systematically evaluated the measurement properties of all available instruments intended to assess pMDI administration among children with asthma and other obstructive airway diseases. Deciding which is the best available instrument for daily clinical practice and for research purposes is essential, not only for ensuring valid information, but also for taking appropriate corrective actions in case of the detection of an inadequate inhaler technique. In addition, through the identification of pitfalls in all the available instruments for the evaluation of pMDI administration among children with asthma and other obstructive airway diseases, the present study could provide critical new information that will be helpful in the design of future instruments intended for evaluating this technique of administration.

We found that age range was a feature consistently reported in the tools used to assess pMDI technique in children. Some instruments are aimed toward age-specific ranges, while others are designed to be used more broadly. As mentioned above, we determined that the best available instruments are those used by Boccuti [8], Sleath [11], Welch [12], and Kamps [15]. However, none of these instruments is perfect. For example, the instrument used by Boccuti [8] assessed the technique of pMDI administration using a mouthpiece and performing a "single-breath technique" (which is correct for the age group evaluated), weighted items differently according to their contribution to the total score, and assessed some aspects of reliability and utility, but failed to assess validity, other aspects of reliability (test-retest reliability), and other aspects of utility (completion time and scoring), as well as additional aspects (endorsement frequency, restrictions in range, and comprehension). Additionally, this instrument is not intended for use in children less than seven years of age.

Likewise, the instrument used by Welch [12] assessed the technique of administration of pMDI in a correct manner according to the age group, weighted items differently according to their contribution to the total score, and calculated and reported the inter-rater agreement. However, it only assessed children aged 1 to 6 years old, and it failed to assess validity, utility, other aspects of reliability (internal consistency and test-retest reliability), and the additional aspects mentioned above. Similarly, the instrument used by Kamps [15] evaluated children within a wider age range (1–14 years) and assessed some aspects of utility but did not report other measurement properties, and the scoring system consisted of rating each essential step as successfully demonstrated or incorrect. Other non-selected instruments included children within a wide

range of age, assessed the technique of administration of pMDI in a correct manner according to the age group, and discriminated between essential and non-essential steps but did not report any measurement property [17, 18].

Our results are in overall agreement with previous studies that have performed systematic reviews of instruments aimed at evaluating a wide range of health care topics in children, including physical activity [19], developmental co-ordination disorder [20], and cerebral palsy [21]. All of these reviews concluded that current studies do not provide enough information regarding the psychometric properties of available instruments, and that future studies should include additional psychometric properties in order to ensure valid and reliable measures.

We are aware that our research may have three limitations. First, the methodology used to evaluate the available instruments is more appropriate for evaluating scales than checklists [10]. However, scales, checklists, questionnaires, and other instruments have in common that they are attempting to quantify the amount of some attribute. Accordingly, a systematic evaluation of these instruments needs to ensure the quality and validity of the information obtained and that they measure the attribute with minimal error [10]. Second, the Consensus-based Standards for the selection of health Measurement INstruments (COSMIN) initiative developed a checklist aimed at evaluating the methodological quality of studies on measurement properties, and it has been widely used for this purpose [22].

However, our main objective was to identify all available instruments that evaluate pMDI administration technique among children with asthma and other obstructive airway diseases, rather than performing a systematic review of the measurement properties of these instruments. For this reason, and because we anticipated a significant number of studies not primarily aimed at examining the measurement properties of the instruments and because we lacked information on the majority of these measurement properties, we decided not to use the COSMIN checklist in our study. Finally, the literature search may have been incomplete because we did not include grey literature, unpublished work, and dissertations.

Conclusions/Key findings

For the assessment of pMDI administration technique among children with asthma and other obstructive airway diseases, 24 instruments were identified and systematically examined. However, only 7 out of the 24 measurement instruments included a report of their measurement properties, including reliability, utility, and validity. Selecting an instrument intended to evaluate pMDI administration technique among children with

asthma and other obstructive airway diseases requires taking into consideration what the instrument measures and how well it has been validated. Based on these criteria, we selected four instruments as the best of the available ones. Nonetheless, none of the four instruments is perfect, and before making a decision regarding the adoption of any of these instruments in clinical practice or for research purposes, additional evaluation of their individual measurement properties should be done in order to ensure appropriate validity and reliability within the specific context in which the instrument will be used.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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