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A systematic review of methods of scoring inhaler technique

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ABSTRACT

Many inhaler devices are currently used in clinical practice to deliver medication, with each inhaler device offering different benefits to overcome technique issues. Inhaler technique remains poor, contributing to reduced airway drug deposition and consequently poor disease control. Scoring inhaler technique has been used within research as an outcome measure of inhaler technique assessment, and this systematic review collates and evaluates these scoring methods. The review protocol was prospectively registered in PROSPERO (CRD42020218869). A total of 172 articles were screened with 77 included, and the results presented using narrative synthesis due to the heterogeneity of the study design and data. The most frequently used scoring method awarded one point per step in the inhaler technique checklist and was included in 59/77 (77%) of articles; however limited and varied guidance was provided for score interpretation. Other inhaler technique scoring methods included grading the final inhaler technique score, expressing the total score as a percentage/ratio, deducting points from the final score when errors were made, and weighting steps within the checklist depending on how crucial the step was. Vast heterogeneity in the number of steps and content in the inhaler technique checklists was observed across all device types (range 5–19 steps). Only 4/77 (5%) of the inhaler technique measures had undertaken fundamental steps required in the scale development process for use in real world practice. This review demonstrates the demand for a tool that measures inhaler technique and highlights the current unmet need for one that has undergone validation.

1. Introduction

Inhaled medications are the cornerstone of the pharmaceutical treatment of airway diseases such as asthma and chronic obstructive pulmonary disease (COPD) [1]. However, since the introduction of inhaled medication over 50 years ago as a treatment for airways diseases, there has been increased recognition that inhaler technique has been getting worse [2] which is recognised as a contributing factor of poorly controlled airways disease [3]. When using an inhaler, a high level of cognitive ability is required to complete the device-specific steps needed for a correct inhaler technique, as well as praxis to use the device, good visuospatial ability, and good inhalation coordination for correct device handling [4].

Scoring systems are employed widely in medicine and scoring inhaler technique has been used within research studies as an objective outcome measure of inhaler technique. Clinical decisions and management plans are often based on medical scores as they support clinical diagnostic accuracy, stratify risk, and forecast outcomes [5]. To date, there are no known scoring systems to assess and quantify inhaler technique routinely used within clinical practice across the UK. Such a scoring system would allow healthcare professionals to highlight poor inhaler technique, which can then be optimised promptly. It would ideally comprise a validated inhaler technique checklist providing a series of steps to be followed to achieve an optimised inhaler technique, combined with a scoring method to produce a final, meaningful score upon which decisions regarding inhaler technique optimisation can be made and assure the clinician the device is being used correctly. Currently, however, there remains a distinct lack of consensus between

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researchers and within the literature regarding the standardisation of the steps that should be included and assessed in inhaler technique checklists [6], which not only makes it difficult to identify which steps have the highest rate of misuse, but also those that are the most difficult to achieve [7]. This variation was identified in a review of literature for scoring systems used in Turbohaler and Diskus devices, which highlights significant heterogeneity between checklists even for the same device, and emphasises the need for a universal inhaler technique scoring system to allow for accurate comparisons between studies and subsequent meta-analysis [8].

This systematic review collates and evaluates methods of scoring inhaler technique used in research literature to date (part 1), along with the content and source of the checklists used in the scores (part 2) which aims to highlight significant issues with ambiguity and a lack of consistency regarding which items are included or indeed excluded in an inhaler technique assessment checklist.

2. Methods

The systematic review protocol was written outlining the study procedures and objectives and prospectively registered with PROSPERO (CRD42020218869). Both study design and data heterogeneity between the articles made meta-analysis impossible, so the results were analysed descriptively and are presented in a narrative format according to the synthesis without meta-analysis (SWiM) in systematic reviews reporting guideline [9], an extension of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis statement (PRISMA; http://www.prisma-statement.org). All articles using a score as an outcome measure of inhaler technique were included in this narrative review. There were no restrictions regarding publication date, but non-English language articles, conference abstracts, poster presentations and periodicals were excluded.

An extensive literature search was conducted on the December 13, 2020 of EMBASE, EMCARE, MEDLINE, Cumulative Index of Nursing and Allied Health Literature (CINAHL), PubMed, and the British Nursing Index (BNI) for published studies using Medical Subject Headings (MeSH) and free text words in titles and abstracts (Table 1). Search terms included keywords combined using Boolean AND/OR in search strings plus truncation. Additional articles were identified by searching the citation list of the identified articles and through Google Scholar. The search was centred around asthma and COPD as these are the two most common respiratory diseases worldwide for which inhalers would be used and did not specify literature specific to adults or children.

Titles and abstracts (n = 172) were uploaded and screened in Covidence, a web-based platform which uses software to manage and streamline systematic reviews (available at www.covidence.org). Two reviewers (RDV and AH) independently screened the titles and abstracts for the eligibility criteria. In cases of disagreement, a consensus was reached following discussion; if necessary, a third researcher's opinion was obtained (AJC).

For completeness, to ensure the manuscript reports on literature up to the point of publication, the database searches and subsequent systematic review methodology were repeated to identify additional articles published from the initial database search date until June 30, 2023. This search identified an additional 16 articles which encompass a score to quantify inhaler technique, and although not included in this narrative synthesis, reflect the findings discussed in this review [10–23].

Methods of scoring inhaler technique were characterised and grouped to facilitate the synthesis reporting. From these articles, data were also extracted regarding which inhaler(s) were used in each study, the number of steps involved in the inhaler technique checklist and the source(s) of the inhaler technique checklist.

Table 1
Database search terms.

1	scor* OR tool OR instrument OR rating scale
2	technique* OR ability OR correct* OR poor
3	error* OR incorrect* OR correct* or poor
4	Asthma OR COPD OR "chronic obstructive pulmonary disease" OR respiratory
5	1 AND 2 AND 3 AND 4
6	Inhaler* OR inhalation device
7	5 AND 6

3. Results

Database searching identified 141 records, with an additional 31 records extracted following forward citation review. Subsequent abstract screening excluded 74 articles not meeting inclusion criteria and following a full-text review of the remaining 98 articles, a further 21 were excluded. A total of 77 articles meeting the criteria were included in this systematic review (see Fig. 1).

In each article reviewed, the inhaler technique score was used as an outcome measure to assess the inhaler technique and was predominantly used by healthcare professionals with patients in a clinical environment. However, in 15/77 (19%) papers, scores were used to measure healthcare professionals ability to demonstrate inhaler technique [25–39].

Articles were categorised and grouped according to the method of scoring inhaler technique included in the study and although some overlap was noted between scoring methods, six overarching themes were identified; awarding one point per step achieved in the inhaler technique checklist to give an overall score (n = 59); presenting the final score as a grade (n = 9); expressing the total score as a percentage or ratio (n = 2); weighting steps within the checklist depending on how crucial the step is considered (n = 2); scoring systems deducting points from the final score (n = 3) and scoring systems that have undertaken steps towards achieving instrument validation and include theoretical and psychometric analysis (n = 4) (Table 2). Every inhaler technique measurement in the review yielded a score following the assessment of the ability to complete a series of steps observed in the inhaler technique checklist.

3.1. Part 1: inhaler technique scoring methods

The most frequently observed method of scoring inhaler technique was awarding one point for performing each step in the inhaler technique checklist correctly and a score of zero if the step was omitted or performed inadequately/incorrectly, with the final score expressed as a total sum of points achieved. Of the literature reviewed, 59/77 (77%) of articles opted for this method of scoring inhaler technique, with more steps in the checklist completed reflecting a greater skill in using the inhaler device. All steps in the inhaler technique checklist were allocated equal weighting. However, it was recognised that some steps in the inhaler technique checklist were more important in drug delivery but scored equally [31].

Although simple to quantify and allocate a final score, the method of awarding one point per step in the checklist highlights difficulties in interpreting the results of the scores. There is currently no consensus concerning the most appropriate threshold for defining correct versus incorrect use of inhalers in a checklist [72]. Almost two thirds (40/59) of articles assigning one point per step do not discuss any criteria to interpret the final score. Of the 19 articles that guide score interpretation, instructions are heterogeneous and ambiguous. Of these articles, two consider the technique to be 'optimal/perfect' when every step in the checklist is performed appropriately [32,69], others define the technique as 'incorrect/failed' if there is an error in a single step [28,45,51,61,66] and one advised that scores in between the minimum and maximum achievable suggested some degree of proper technique as indicated by the number of steps performed correctly [63]. Furthermore, two articles consider technique improper if <75% of steps are completed [53,72], or unsatisfactory if <80% completed [96] and the addition of it being mandatory to complete the steps in chronological sequence is also included [73].

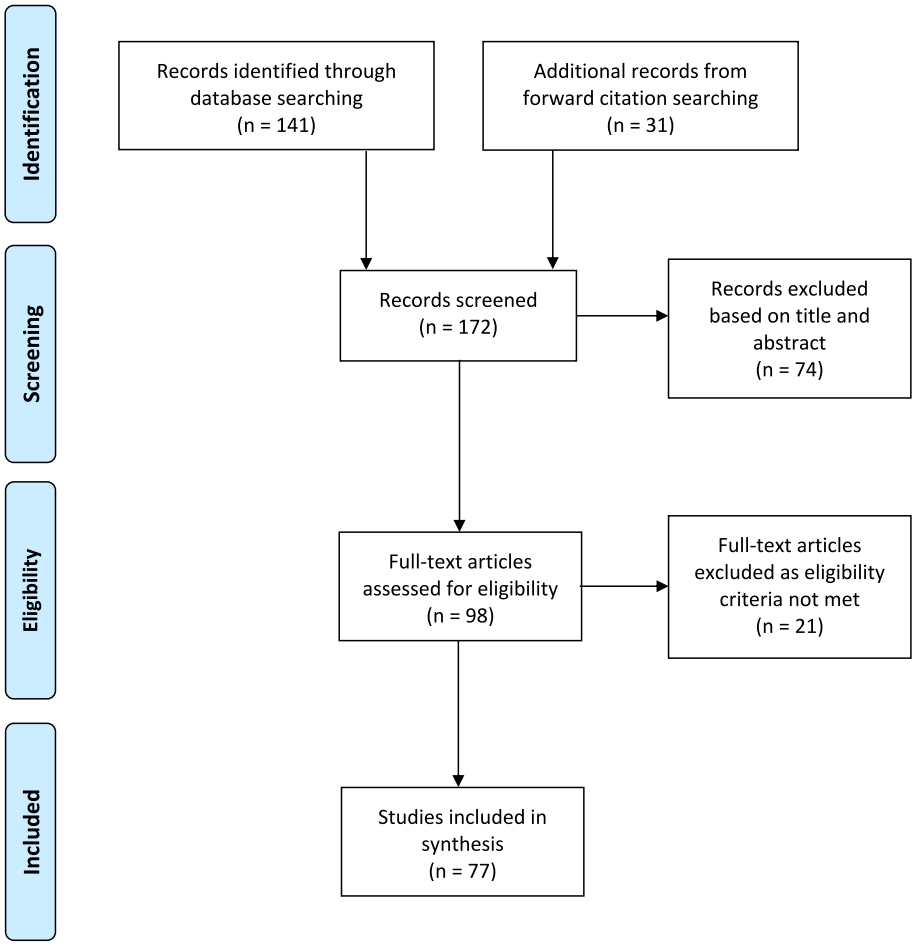

Fig. 1. PRISMA flow diagram. Study identification, screening, and study selection process [24].

Table 2
Studies included in each inhaler technique scoring method category with the source of the inhaler technique checklist used in the study[O].

Scoring systems awarding one point per step completed in the checklist	Al-Hassan et al. [40] (a)	Basheti et al. [49] (l)	Gregoriano et al. [58] (b)	Micallef et al. [65] (a)	Serra-Battles et al. [76] (a)
	Ali et al. [25] (c)	Beatty et al. [50] (l)	Hanania et al. [37] (a)	Mulhall et al. [66] (b)	Shah & Gupta [77] (a)
	Alsaffar et al. [41] (a)	Belachew et al. [33] (c)	Jolly et al. [59] (c)	Nelson et al. [67] (b)	Siri & Loomba [78] (c)
	Alsomali et al. [42] (l)	Bosnic-Anticevich [51] (l)	Kakkanattu et al. [60] (d)	Nguyen et al. [28] (g,j,l)	Spaggiari et al. [29] (d,k,l)
	Amirav et al. [26] (a)	Bryant et al. [52] (h)	Kamps et al. [61] (e)	Nonhlanhla et al. [68] (a)	Steier et al. [79] (a)
	Aziz et al. [43] (a)	Cain et al. [34] (a)	Kesten et al. [38] (a)	Paasche-Orlow et al. [69] (c,l)	Turkeli et al. [80] (a)
	Bartolo et al. [44] (f)	Chogtu et al. [53] (a)	Khan & Azhar [39] (c)	Perez et al. [70] (a)	Valarmathi & Parajulee [30] (c)
	Basheti et al. [32] (l)	Chopra et al. [35] (a)	Kiser et al. [6] (b,l)	Poudel et al. [71] (d)	Van der Palen et al. [81] (e)
	Basheti et al. [45] (d,l)	Dahl et al. [54] (a)	Kishore et al. [27] (c)	Press et al. [72] (l)	Van Der Palen et al. [82] (a)
	Basheti et al. [46] (l)	Davis et al. [55] (l)	Li et al. [62] (l)	Quinet et al. [73] (a)	Verver et al. [31] (e)
	Basheti et al. [47] (l)	Duarte-De-Araujo et al. [56] (b,l)	Lurslurchachai et al. [63] (l)	Rootmensen et al. [74] (l)	Zhang et al. [83] (b,l)
	Basheti et al. [48] (a)	Epstein et al. [57] (l)	Madkour & Galal [64] (d,l)	Rydman et al. [75] (l)	Welch et al. [91] (b)
Scoring systems with graded outcome measures	Allen & Prior [84] (l)	Diggory et al. [86] (a)	Jones et al. [88] (a)	Rönmark et al. [90] (a)	
	Allen et al. [85] (l)	Hämmerlein et al. [87] (a)	Lenney et al. [89] (a)	Sadowski et al. [4] (l)	
Scoring systems expressing outcome as a percentage/ratio	Mehuys et al. [92] (a)	Tommelein et al. [93] (l)			
Scoring systems with weighted steps	Boccuti et al. [94] (l)	Shammer & Baay [95] (i			
Scoring systems deducting points from the final score	de Oliveira Santos et al. [96] (l)	Gemicioglu et al. [36] (b)	Zambelli-Simoes et al. [97] (l)		
Scoring systems undertaking validation processes	Boccuti et al. [94] (l)	Davies et al. [98] (l)	Manzella et al. [99] (a)	Zambelli-Simoes et al. [97] (l)	

Source of inhaler technique checklist:a-No reference given, b-Package inserts/manufacturer's guidelines, c-NAEPP, d-GINA, e-Dutch Asthma Foundation, f-ATS, g-GOLD, h-Australian Respiratory guidelines, i-National Asthma Council Australia, j-Ministry of Health for Vietnam, k-ERS/ISAM, l-Other References.

In contrast, an alternative inhaler technique scoring method awarded points for deficiencies with a score of zero reflecting a perfect technique [86]. The two articles presenting their final sum score as a percentage/ratio of correct steps also do not discuss a desirable score but if major inhalation errors were observed, their final score was also assigned as zero [92,93].

A further method of scoring inhaler technique used in three articles was deducting points from the final score if pre-defined errors were observed. This point deduction ranged from −1 to −8 points depending on the severity of the given error, which also varied between the articles [36,96,97].

Nine studies present a more descriptive method of awarding an inhaler technique score and describe a series of 'grades' to assess inhaler technique. These scores have been tabulated to demonstrate the complexity of score interpretations (Table 3).

3.1.1. Scale validation

Of the articles included in this review, only four undertook the series of essential steps required in the instrument development and validation process, which determines if a measurement tool generates outcomes that clinicians can use to make clinical decisions with confidence [94,97–99]. Additional articles were identified that had undertaken rudimentary reliability testing, such as establishing intra- and inter-rater reliability, however did not undertake any additional validity testing considered best practice in scale development [6,29,72,74,91]. Finally, further claims of inhaler technique checklist validation were also made throughout the literature; however, on closer tracking of the citations made within these articles, no validation processes were identified [47,63].

The first article to present validation data for a scoring instrument was developed by Manzella et al. [99]. Given the moniker 'the Inhaler-Use Checklist' (IUC), it was developed to demonstrate patients' ability to use metered dose inhalers (MDI) and reports being able to quantify the results of skill-enhancing interventions. Interestingly, despite being one of the first inhaler technique scoring systems to include validation processes, it is only referenced once across the literature reviewed. The IUC scoring tool developed by Manzella was subsequently used as the basis of a further scoring system, the MDI checklist developed by Boccuti et al. [94]. It was used to measure the MDI technique with three different spacer devices in children and, of the four tools developed to score inhaler technique which included validation, documented the fewest validation processes. The third article presenting validation data for their 'Inhaler Device Assessment Tool' (IDAT) was by Davies et al. [98]. The authors reviewed the previously developed MDI checklist developed by Boccuti et al., but instead chose to base their score on a non-referenced generic tool rendering the subsequent development process less robust. Although the IDAT is presented in a user-friendly guide demonstrating the basic validation processes and outcome data, the full details of the instrument validation process are contained within a conference submission with limited details making a full assessment of the validation processes challenging. Another scoring method, developed by Zambelli-Simoes [97], assesses MDI and dry powder inhaler (DPI) technique in asthma with the resultant score used to devise specific education targeting the errors made by patients. The authors highlight that no gold standard scoring system for inhaler technique currently exists acknowledging that such a system would be useful in assessing patients' difficulties when using inhaled medications.

Table 3
Guidance on graded inhaler technique score interpretation.

Allen & Prior [84]	Steps required in a competent technique are determined, and anything short of this is scored as 'incompetent'.
Lenney [89]	Inhaler technique is graded by determining criteria required to achieve each grade: • 'Grade A' - optimal inhaler technique, indicating good drug delivery. •'Grade B' - some delivery, reflecting poorer technique and reflects partial delivery of the drug. •'Grade C' - reported as very poor technique with little or no drug delivery.
Allen [85]	This study uses an analogue score of 0–10, with 0 being the worst possible technique and 10 the perfect technique, with the threshold between 5 and 6 separating bare competence from incompetence.
Sadowski [4]	Essential steps are noted in their checklist that must be completed to achieve an 'effective dose', a 'mostly effective dose', a 'slightly less effective dose' and a 'poor dose'. When this was applied in the study, a scale from 0 to 5 was created where 0 = no dose (none of the essential steps was followed); 1 = poor dose; 2 = slightly less effective dose; 3 = mostly effective dose and 4 = completely effective dose.
Hammerlein [87]	A 21-item checklist was generated in their scoring method, and each step was graded simply as having been performed correctly or incorrectly.
Jones et al. [88] Ronmark et al. [90]	For each aspect considered in the checklist, 0 points were awarded for poor/incorrect technique, 1 for those achieving moderate/not completely correct technique, and 2 for good/correct technique.
Diggory [86]	Each of the 5 aspects in the checklist was graded between 0 and 2 by awarding points for deficiencies, with a score of 0 reflecting perfect technique.
Welch [91]	Each step in the checklist was graded as 'yes' if completed, 'partial' if correct but not complete, or 'no' if missing or incorrect. An individual inhaler technique "performance mastery score" was defined as the proportion of major steps correctly performed out of all the major steps possible.

Instrument development requires detailed, evidence-based assessment profiles across several psychometric dimensions. These validation processes can be divided into three phases: item generation, theoretical analysis or 'scale construction' and psychometric analysis or 'scale evaluation' [100,101].

The preliminary step in instrument development and validation is that of item generation which collates evidence surrounding the area the instrument will measure [101]. In the development of an inhaler technique measurement tool, this phase would provide a clear definition and justification for the inclusion and indeed exclusion of items in the inhaler technique checklist, ensure sound subsequent theoretical definition and psychometric analysis, and ultimately ensure construct validity using empirical techniques such as calculating the content validity ratio and the content validity index [102,103]. None of the validated scores in this review exhaustively completed this pivotal first phase in scale development, relying upon unreferenced sources or opinion, thereby threatening subsequent validation claims.

Phase two of scale validation establishes a theoretical analysis of scale construction. It typically involves the scale developer engaging the opinion of subject matter experts to ensure the construct to ensure all relevant aspects are encompassed in the construct. All four validated scores involved experts in developing their measurement tool and described the iterative processes of pilot and feasibility testing of the first drafts, with revisions and modifications to the tool made following discussions with the panel. Although healthcare professionals would typically use an inhaler technique assessment tool, it is also important to ensure that the population the instrument is being developed for are represented [104] and it was a notable absence that experts by experience were not used in any of the articles.

The final phase of scale validation is scale evaluation which involves analysis to ensure reliability and consistency using a range of measures including test-retest, inter-rater, internal consistency and parallel-forms reliability [105]. Within the papers reviewed, internal consistency was established statistically using Cronbachs alpha coefficient by Manzella (0.70) [106], Boccuti (0.90) [94] and Zambelli-Simoes (0.97) [97], whereas inter-rater reliability was obtained using Kappa statistic by Davies (0.82) [98].

Construct validity is essential for the practical implementation of the construct and ensures the items and dimensions are accurately measured and operationalised [107]. Although none of the four validated scores fully completed the item generation phase involved in content

validation, selective elements of construct validity were established in each. Manzella [106] presented preliminary evidence of convergent and discriminant validity, whereas Zambelli-Simoes [97] also presented discriminant validity and presented data on criterion validity.

Despite presenting these selective aspects of validation, each of the four inhaler technique scoring systems have limited applicability for use in clinical practice in the UK. They either have not been validated for use in this country, are validated for spacer devices not used in the UK and the final scoring instrument is only visible and accessible within the articles by Davies [98] and Zambelli-Simoes [97]. This observation highlights again the urgent unmet need for a validated inhaler technique scoring tool.

3.2. Part 2: additional data synthesis

3.2.1. Inhaler technique checklist steps

Across the 77 articles in the review, 18 different inhaler device types were included, with articles often including checklists for more than one inhaler device type. The most common device included in the literature was the MDI, with 51/77 (66%) articles including this device type. This was followed by the Turbohaler device included in 29/77 (38%) articles; the Accuhaler/Diskus device in 25/77 (32%) articles followed by the MDI plus spacer, which was included in 22/77 (29%) articles.

The review also collated the number of steps included in each inhaler technique checklist in each article, revealing vast heterogeneity across all devices (range 5–19 steps). It emphasises the current problem of lack of consistency as to which steps should be included in an inhaler technique checklist leading to the disparate content in literature (Fig. 2). This evidence is supported by a systematic literature review and meta-analysis of device errors which found that error rates were higher in inhaler technique assessments comprising a larger number of steps, although there was no discernible trend in this, and highlighted the importance of the development of standardised checklists [108].

3.2.2. Inhaler technique checklist source

Data extraction included identifying the reference source for each checklist (indicated in brackets after each reference in Table 2). This detailed assessment highlighted the disparity and diversity in source material used to create the inhaler technique checklists in each of the 77 studies included in this systematic review. Of these articles, 28/77 (36%) did not offer a reference for the source of their inhaler technique checklist, which was developed by the authors of the study. Unfortunately, this issue recurs throughout the literature, which undoubtedly contributes to the demonstrably disparate content of inhaler technique checklists, thus rendering it impossible to compare data between studies or perform meta-analyses.

One of the referenced sources was the inhaler package insert which provides instructions on inhaler use created by manufacturers. However, this was only referenced in 7/77 (9%) of articles [6,36,58,66,67,83,109]. In addition, national and international guidelines on inhaler technique have been published by panels of experts over the years; however, only 22/77 (29%) of papers referenced a national or international guideline, including National Asthma Education and Prevention Programme (NAEPP) [25,27,30,33,39,59,69,78], Global Initiative for Asthma (GINA) [29,45,60,64,71], Dutch Asthma Foundation [31,61,81], American Thoracic Society (ATS) [44], Global Initiative for Chronic Obstructive Lung Disease (GOLD) [28], Australian Respiratory guidelines [52], National Asthma Council of Australia [95], Ministry of Health for Vietnam [28] and European Respiratory Society/International Society of Aerosol Medicine (ERS/ISAM) [29]. The remainder of the articles chose a variety of other sources on which to base their checklist, with 20 articles referencing a total of 56 sources which were also often unreferenced.

4. Discussion

The use of device specific checklists are the most efficient and practical method of evaluating inhaler technique in clinical practice. They capture the elements of the technique being observed and can also be used to guide optimisation using methods such as the 'teach-to-goal' intervention, where inhaler users repeatedly demonstrate their technique following re-education until mastery is attained [72]. Checklists have also been used to assess and record inhaler technique via video-based platforms which are becoming a more popular method of service delivery, and their reliability has been shown to reduce inter-observer variability [77,110–112]. The lack of standardisation in

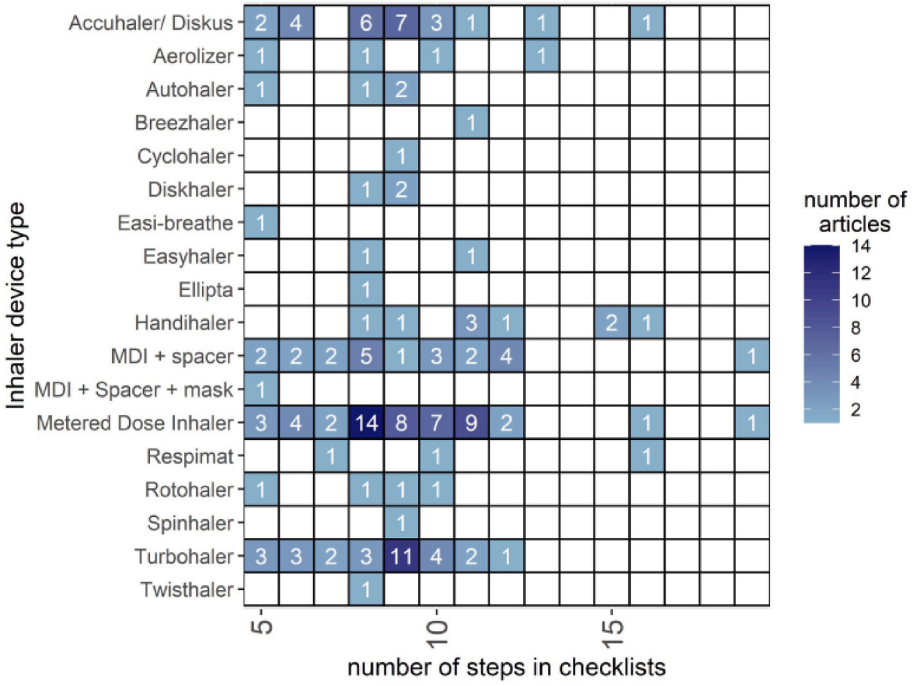

Fig. 2. Heatmap demonstrating the variance in the number of steps in published inhaler technique checklists.

inhaler technique checklists repeatedly demonstrated throughout this review highlights the importance of the development of both generic and specific inhaler technique checklists which can be used by healthcare professionals worldwide to ensure inhaler technique education is consistent, and strengthen the validity and interpretation of data collected in future studies to support global best practice. Although device specific checklists capture the nuances associated with each inhaler device, generic checklists are able to incorporate steps observed across inhaler devices [113,114]. The development of generic checklists applicable to all inhaler devices will also ensure they are 'future-proofed' from developing technologies including the use of digital and smart technology, along with inhaler device innovations developed and introduced by pharmaceutical companies.

The use of a scoring system to assess and quantify inhaler technique has been observed in recent publications and demonstrates that scoring inhaler technique can be used in conjunction with digital health technologies and 'smart' inhalers to assess outcomes [115]. Digital health technology promotes collaborative care between clinicians and patients, and offers the chance to enhance and personalise self-management of respiratory conditions; though how this is integrated into clinical care and which outcomes should be measured to establish successful interventions needs to be fully established [116,117]. Smart inhalers use assistive technology to capture data from inhaler users typically via an attachment which fits onto an inhaler device known as an electronic inhaler monitoring device [118]. This data is uploaded to a digital platform and provides information to healthcare professionals regarding medication adherence and also feedback on inhaler technique by measuring inspiratory flow via inbuilt acoustic detection, and has been shown to improve both adherence and disease control [119,120].

This systematic review was undertaken primarily to identify and establish methods of scoring inhaler technique published in research studies. Although scoring inhaler technique has frequently been documented in the literature, only a handful of these measures have presented with any scientific rigour the plethora of processes required in scale development and validation to produce a meaningful score upon which clinical decisions can be made, a point which was also concluded in a systematic review of instruments aimed at evaluating MDI administration in children [121]. The review repeatedly highlights the unmet need for such a validated score to be developed.

The first step in measurement development is establishing the construct to be measured. Inhaler technique is a latent construct unmeasurable as a stand-alone concept. Instead, it is informed by a series of steps, known as indicators or items in scale development, which are functions of the construct. This review highlights significant issues with ambiguity and a lack of consistency regarding which steps should be included, or indeed excluded, in an inhaler technique checklist to ensure sound psychometric analysis of the content. To clarify this, further work must be undertaken to mirror the processes involved in developing other measurement tools [122–125] and include inductive and deductive methods of scale development.

A range of options for scoring inhaler technique is presented in this review. Although the one-point-per-step scoring method was most frequently applied, it was highlighted that this method may not reflect the importance of certain steps in a checklist which may be more critical in delivering inhaled medication to the lungs. In the articles presenting graded inhaler technique scores, a variety of methods of score interpretation was described which were generally subjective and frequently ambiguous. This could be perceived as cumbersome and pose a barrier to implementation in clinical practice. To the less experienced assessor of inhaler technique, these methods of grading inhaler technique are more complex and are likely to be more time-consuming to use in an already 'time-pressured' environment than the simple summation presented in the one-point-per-step method.

Acknowledgement was made in the graded scoring methods regarding steps considered more important in delivering drugs to the lungs, which is the aim of an inhaler device. Several other articles also consider some steps in an inhaler technique checklist more important to complete correctly, and these steps are weighted or double-scored to reflect this [86,95–97]. However, not only does this weighting process vary considerably between studies, but there is also a lack of consistency between which of the steps are considered 'important'. These essential steps originate from many sources, including being designated by the researchers [52,83], based on guidelines including the NAEPP [25,33] and the Dutch Asthma Foundation [61,74] or in accordance with literature [45]. Although the essential steps commonly refer to device preparation and drug delivery during inhalation, there is marked heterogeneity across the studies regarding which steps are considered essential, even in the same device, along with the number of steps considered essential (range 3–7 steps). Interestingly, none of the designated essential steps reference drug deposition or outcome measure studies, which could provide a more robust argument behind the requirement of each step as it recognised that errors in certain steps in inhaler technique are linked to uncontrolled symptoms and increased exacerbation rate [126–128]. Errors in essential steps, typically referred to in literature as critical errors, are recognised as an action or omission that has a detrimental impact on delivery of the drug to the lungs, subsequently leading to suboptimal disease control [3]. Due to the connotation of immediate threat to life evoked by the term 'critical', the term 'clinically important' error is suggested as an alternative term as it more accurately links steps to clinical outcomes. As previously discussed in this review, there is a need for the standardisation of checklists which capture and highlight clinically important errors to healthcare professionals involved in technique optimisation, which will ultimately positively impact disease control.

Assigning a score in a measurement tool is not a simple process and requires careful consideration, however none of the articles in this review fully address the complexities of score application. Whilst weighting steps considered more important in an inhaler technique checklist seems superficially a logical concept, this approach runs the risk of a cancellation effect when domains are combined so that a high score in one area compensates for a low score in another so the overall result is therefore obscured, or steps requiring re-education in an inhaler technique not clearly highlighted [97,129]. Simple summation of the total score when steps are aggregated also runs the risk of the important information about each step being lost [130].

Another salient point noted in the articles including more comprehensive validation processes [94,97,98,106] is that the subject matter experts used in scale development were part of the same 'in-house' team. Using experts from a range of external healthcare establishments reduces the risk of bias created by nuances in inhaler practice within an individual institution. In addition, the inclusion of experts by experience, in this case patients using an inhaler device is also recommended but this was not the case for any of the articles reviewed.

5. Conclusion

There is currently no commonly used guidance on how inhaler technique should be taught, which is demonstrated by the heterogeneity in inhaler technique content revealed in this review. Several national and international bodies such as Asthma and Lung UK (ALUK), the United Kingdom Inhaler Group (UKIG), the European Respiratory Society (ERS), Global Initiative for Asthma (GINA), Global Initiative for Chronic Obstructive Lung Disease (GOLD) and the Aerosol Drug Management Improvement Team (ADMIT) have developed guidance on teaching correct inhaler techniques, yet despite this, the distinct lack of inclusion of these bodies of work referenced in the literature in this review demonstrates this guidance has not been widely acknowledged. A good inhaler technique is crucial in ensuring optimal inhaled drug delivery to the lungs, which can improve symptom control by more effectively treating the underlying lung disease. Inhaler technique should be checked, and errors rectified at every opportunity to improve inhaler technique globally. The availability of a measurement tool that

can be used in conjunction with modern methods of assessing inhaler technique using digital and smart technology which highlights areas requiring correction in particular clinically important errors, would facilitate the inhaler technique assessment and optimisation process and would be an asset in clinical practice. An inhaler technique measurement tool should be applicable across all inhaler device types, yield a score reflective of the inhaler technique combining the values of the measured indicators, be simple and easy-to-use, and demonstrate the totality of processes required to robustly establish reliability and validity to draw sound inferences from the score.

Declaration of competing interest

There is no conflict of interest.

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