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What can be done to impact respiratory inhaler misuse: exploring the problem, reasons, and solutions

Anna Volerman[1], **Delesha Carpenter**[2], **Valerie G Press**[*,1]

[1]University of Chicago Biological Sciences Division, Departments of Medicine and Pediatrics, 5841 S Maryland Ave, MC 2007, Chicago, IL 60637, USA

[2]University of North Carolina Eshelman School of Pharmacy, Division of Pharmaceutical Outcomes and Policy, 1 University Heights, CPO 2125, Asheville, NC 28804, USA

Abstract

Introduction: Respiratory inhalers, when used correctly, provide critical treatments for managing pulmonary conditions. However, many patients misuse inhalers, negatively affecting disease control, quality of life, healthcare utilization, and costs. Numerous factors are associated with misuse and are nested within four levels of influence: individual, interpersonal, organizational/institutional, and policy.

Areas covered: This review analyzed published literature and identified the most salient factors at each level of this socio-ecological framework. English language articles from any year were identified from PubMed, Google Scholar, and Embase databases. Misuse exists across clinical settings, patient populations, and device types. Several potential solutions are highlighted. Published interventions to improve inhaler technique have utilized handouts, in-person, virtual, and biofeedback approaches both inside and outside of healthcare settings with varied effectiveness. However, some interventions have superior effectiveness for improving technique and reducing acute care utilization.

Expert opinion: To robustly address inhaler misuse, future solutions should focus on multi-level approaches to account for the myriad of factors contributing to inhaler misuse. Solutions should also streamline inhaler equipment, identify innovative technology-based solutions, support collaborations across healthcare and non-healthcare settings, and ensure reimbursement to healthcare professionals for inhaler education. Rigorous research studies must be funded and supported to identify and disseminate solutions.

[*]Corresponding author: Valerie G Press, University of Chicago Biological Sciences Division, Departments of Medicine and Pediatrics, 5841 S Maryland Ave, MC 2007, Chicago, IL 60637, Phone: 773 702 5170, Fax: 773 834 2238, vpress@bsd.uchicago.edu.

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1. Introduction

Respiratory inhalers are critical to the management of various pulmonary conditions, including asthma and chronic obstructive lung disease (COPD) [1–2]. They are designed to deliver the medication to the respiratory system, thereby acting directly on the lungs and also minimizing systemic effects of the drugs. Effective inhaler use is necessary for the medicine to reach the lungs and reverse the pathophysiology associated with the disease, for example inflammation or bronchoconstriction. However, when inhalers are used incorrectly, termed inhaler misuse, their positive effects cannot be realized.

Inhaler misuse has broad implications for both patients and the healthcare system. Consequences include worse disease control and quality of life, increased healthcare utilization in hospitals and emergency departments, as well as higher healthcare costs [3–5] .The cost of inhaler misuse is estimated to be $7–15 billion annually; a substantial portion of the total of $50 billion spent on inhalers for respiratory conditions [6]. In addition to these overall inhaler estimates, cost-related nonadherence (CRNA) is reported in more than half of adult patients and over a third of children with asthma in Australia [7]. In a systematic review of CRNA among patients with COPD, the evidence showed an association between adherence and economic outcomes [8].

Given the significant consequences of inhaler misuse, this review's goal is to comprehensively describe the problem of and promising solutions to inhaler misuse. This paper first describes the issue of improper inhaler use and then applies the socio-ecological framework to examine reasons for and solutions to inhaler misuse. Relevant English language articles from any year were identified from PubMed, Google Scholar, and Embase databases using key word searches for "inhaler technique", "inhaler competence", "inhaler misuse", "diskus technique", "metered dose inhaler technique", and "inhaler education." Additionally, relevant articles' references were reviewed for additional papers.

2. The Problem

Respiratory inhaler misuse is well-described in the literature for various pulmonary conditions. For asthma and COPD, studies show that the majority of patients are unable to use their inhaler correctly, ranging from half to more than 80% [9]. It is important to note that inhaler misuse extends beyond patients as studies show that the majority of healthcare professionals (67–90%) cannot describe or demonstrate the steps necessary for correct inhaler use [10].

Notably, identification of inhaler misuse has not been limited to particular medication types/devices, care settings, or populations. Misuse has been most studied with metered dose inhalers (MDI), however high rates of misuse have been described across different types of

inhalers [11–12]. Studies across both inpatient and outpatient settings also support high prevalence of inhaler misuse [11,13]. Further, data from research in adults and children demonstrate that inhaler misuse is prevalent across the age spectrum [11,14–15]. Finally, studies show that disparities exist in asthma and COPD with minority, low-income patients disproportionately affected, which may also be present in terms of inhaler misuse [16]. Research also suggests certain factors may predispose individuals to high rates of misuse, for example older age, female gender, use of multiple devices, lack of prior inhaler education, very poor to average self-assessment f inhaler technique, use of home oxygen, and bronchodilator responsiveness [17–21].

Despite these high rates of inhaler misuse, no significant changes to the rates of inhaler misuse have been observed over the past several decades, indicating that this problem has not diminished [12,22]. Because this issue of inhaler misuse is pervasive, it is critical to examine the reasons for and solutions to misuse among diverse populations and settings.

3. Reasons for inhaler misuse: Socio-ecological framework

Decades of research have identified numerous factors that are associated with inhaler misuse. In this review, we focus on the factors that directly lead to inhaler misuse and do not focus on those with indirect effects. It is important to note that any factor that negatively impacts medication adherence may also contribute to poor inhaler technique.

Ecological models can be used to organize the factors directly associated with inhaler misuse into spheres of influence. The spheres of influence range from individual level to environmental or population level, with the individual nested at the center (Figure 1). Ecological models show how individuals and their health behaviors are influenced by each level as well as the complex interplay between levels. Using this ecological perspective, four levels of influence seem especially relevant to inhaler misuse: individual (or patient), interpersonal, organizational/institutional, and policy (Figure 1). Factors from these different levels can interact with each other to affect patient inhaler technique. This section focuses on defining and describing each factor (Table 1); future sections describe current and potential solutions.

3.1 Individual

Because most patients self-administer their inhaled medications, several individual or patient-level factors can contribute to inhaler misuse, including knowledge, skill, attitudes, self-efficacy, and health literacy.

3.1.1 Knowledge is essential for correct technique and is defined as the patient knowing the steps for proper technique for each of their prescribed inhaler devices. There are several reasons why patients may lack adequate inhaler technique knowledge. First, they may have never received inhaler technique education. For example, more than 95% of physicians did not assess child inhaler technique or demonstrate proper use of MDIs during audiotaped pediatric asthma visits [23]. This lack of assessment and demonstration occurs even though national guidelines recommend that such inhaler technique assessments should be conducted at each asthma visit [1]. Second, patients may have received inaccurate inhaler technique

education. A systematic review found that up to 90% of healthcare professionals were not able to perform correct inhaler technique [10]. If clinicians cannot demonstrate correct inhaler technique themselves, then it is unlikely that they could teach patients proper technique. Further, children and parents may receive education from various medical and non-medical individuals who have varied knowledge about correct inhaler technique; this varied education may result in conflicting information [24]. Third, patients' knowledge of correct technique tends to deteriorate over time [25–29]. For example, although patients demonstrate improvements in asthma inhaler technique after receiving training, improvements in technique are only maintained with booster training [4,30–32]. More specifically, children who receive repeated technique instruction are 8.2 times more likely to demonstrate correct technique than children who do not receive repeated instruction [33].

3.1.2 Skill, defined as the ability to physically perform all inhaler technique steps correctly, is another factor that is essential for correct technique. Physical conditions, such as arthritis or other conditions that make it difficult to use one's hands and fingers can make it difficult for patients to manipulate their inhaler devices, even when they have adequate technique knowledge [34]. Vision problems have also been associated with worse technique [35] Poor coordination is another physical issue that can compromise a patient's inhaler technique and may be particularly relevant for younger children and the elderly [11,36]. Additionally, patients with cognitive issues, such as learning disabilities or difficulty concentrating, may find it more difficult to remember and enact the multiple steps required for correct technique [37–38].

3.1.3 Attitudes, or an individual's beliefs about inhalers and inhaler technique, may indirectly contribute to inhaler misuse. Studies that examine the effect of negative attitudes on technique are lacking, but patients who believe their inhaled medications are unnecessary or inconvenient may be less likely to use them [39, 40]. Regular use can reinforce proper technique through maintenance of skills; thus, negative attitudes that lead people to use inhalers inconsistently may also contribute to inhaler misuse [18].

3.1.4 Self-efficacy refers to people's confidence that they can overcome barriers to perform correct inhaler technique. Overall, only a quarter of pediatric asthma patients and 22% of COPD patients are completely confident that they use their inhalers correctly [41–43]. Greater self-efficacy has been associated with better technique. Specifically, a longitudinal study found that children with greater inhaler technique self-efficacy were more likely to perform more Diskus steps correctly [23]. However, self-efficacy does not always accurately reflect an individual's skill level. For example, children commonly made multiple technique errors even though they and their parents were highly confident that their child was using their inhalers correctly [44–46].

3.1.5 Health literacy, defined as an individual's ability to understand inhaler technique information, could also contribute to inhaler misuse. Poorly designed or text-heavy inhaler technique educational materials, such as pamphlet inserts, may be especially difficult to comprehend for individuals with lower levels of health literacy. Limited health literacy has been associated with worse inhaler technique in multiple studies with adults [47,48].

3.2 Interpersonal

The interpersonal level is the next level of influence in the ecological model. This level includes important others in the patient's social network, including clinicians and other healthcare professionals, family members, and friends. Within this level, we focus on three factors: patient-provider communication, social support, and conflicting information.

3.2.1 Patient-provider communication refers to lack of communication or inaccurate communication about inhaler technique between the clinician and the patient. In one longitudinal study, children with asthma whose providers asked them to demonstrate MDI technique (i.e., an important type of technique communication) during medical visits were significantly more likely to perform more MDI steps correctly one month later [23]. Also, children whose providers discussed a written action plan (e.g. a written form of communication) performed significantly more Diskus steps correctly [23]. Despite the positive effects of communication, one study published in 2014 found that only 13% of providers assessed MDI and spacer technique at every visit, indicating that lack of technique assessments and demonstrations persist [49]. In addition to infrequent technique communication, inaccurate communication about technique can contribute to inhaler misuse. A systematic review found that approximately 85% of providers are unable to accurately identify patient technique errors and that providers' technique skills have actually worsened in recent years [10]. As noted earlier, inadequate inhaler technique knowledge can compromise providers' ability to effectively communicate and educate about patient technique errors.

3.2.2 Social support is defined as inhaler technique aid and assistance offered by an individual's social network members. Network members may include family, friends, peers, health coaches, and health care professionals such as clinicians and school nurses. A recent study applying social network theory highlights how medical and non-medical individuals co-influence the information and support that parents receive and thus affect how children with asthma use their medicines [24]. Inhaler technique aid and assistance from network members could come in various forms, including emotional support (e.g., providing encouragement and praise for correct technique) and informational support (e.g., providing information and advice about how to use inhalers correctly). Studies specifically investigating the effect of social support on inhaler technique are limited, though there is strong evidence linking social support with better medication adherence [50]. A recent study found that an intervention that trained lay health coaches to assess the inhaler technique of COPD patients over a 9-month period resulted in patients performing significantly more inhaler steps correctly when compared with usual care [51]. Additionally, with training, patients' caregivers could provide practical support for inhaler technique by assessing technique at home [49].

3.2.3 Conflicting information, or receipt of conflicting information about correct technique from multiple sources, may negatively impact inhaler technique. Because patients may obtain inhaler technique information from multiple sources, including primary care physicians, specialists, written materials, online videos, and family and friends, it is possible that technique information from these sources may be inconsistent or conflicting. Although there is a paucity of studies about conflicting technique information, one study found that

many YouTube videos showing Respimat Soft Mist inhaler technique omitted at least one step [52]. When patients encounter conflicting information about inhaler technique, they may enact specific strategies to deal with the conflicting information, including deferring to their most trusted source, seeking additional information, or using the source that was easiest to understand [53]. These reactions may not result in patients selecting a source that has accurate technique information.

3.3 Organizational/Institutional

Organizations and institutions may also influence inhaler misuse. Due to a lack of empirical studies examining the relationship between organizational/institutional factors and inhaler technique, the nature and magnitude of the effect of these factors on inhaler misuse is unknown. The most influential organizations and institutions for inhaler technique are those where inhaler technique education is delivered, such as healthcare practices and clinics, pharmacies, and hospitals. However, places where individuals use their inhalers, such as schools and workplaces, may also influence technique. Below we highlight three institutional-level factors that may be of greatest relevance to inhaler misuse: length of medical appointment, availability of training devices, and school inhaler policies.

3.3.1 Length of appointment refers to the total amount of time a provider has for a standard office visit. One study found that the average length of time for a primary care office visit was 15.7 minutes, during which a median of six topics were covered [54]. In addition to conducting a physical exam, clinicians commonly discuss lifestyle behaviors (e.g., diet, exercise, smoking), vaccinations, and co-morbid conditions. With competing topics to address during a 15-minute visit, assessing and educating about inhaler technique, which can take several minutes to complete depending on the number of technique errors that need to be addressed, may be given less priority by clinicians.

3.3.2 Availability of training devices refers to the presence of placebo training devices to assess inhaler technique at clinical practices and other healthcare settings. Clinicians have reported that they do not have training devices on-site [49], limiting their ability to engage in inhaler technique training. In addition to placebo devices, there are several electronic inhaler technique training devices that provide visual feedback when patients use their inhalers correctly. While this technology offers a potential valuable approach to inhaler education, widespread uptake of these devices is limited as many are expensive and do not have FDA approval [55]. Specific programs, like the Practitioner Asthma Communication and Education (PACE) program, have provided general practitioners with demonstration devices and technique training [56]. Whether having training devices available influences clinicians' inhaler technique assessment and demonstration behaviors is a worthwhile area for future research.

3.3.3 School inhaler policies are those policies that are related to the ability of students to carry inhalers and self-administer inhaled medications at school. All states permit students to independently carry and administer their inhalers at school, although each state differs in their development and implementation of policies for asthma self-management at school [57]. Despite these policies, significant variability exists in terms of medication availability, carry, and use among students at schools.[44], [45] Further, 34% of adolescents with asthma

reported that it is difficult to use their asthma medications at school [58]. Additionally, school-based education programs provide variable amounts of inhaler technique education and practice, ranging from 15 to 60 minutes [59]. Taken together, this previous research indicates that there are opportunities to better support student inhaler technique education and inhaler use at schools.

3.4 Policy

Federal, state, and health insurance payer policies also have the potential to influence inhaler misuse. Below we focus on two policies: inhaler technique education reimbursement and inhaler device costs.

3.4.1 Inhaler technique education reimbursement refers to payer reimbursement to clinicians for provision of inhaler technique education. The ability of clinicians to maintain financially viable practices depends to a large extent on receiving reimbursement for the services they provide. Currently, it is not standard practice for payers to reimburse clinicians or pharmacists for delivering inhaler technique education, which may serve as a major barrier to implementing inhaler technique assessment and education in routine practice. Specifically, only two out of 47 Medicaid plans listed billings codes for inhaler technique [60].

3.4.2 Inhaler device costs, or financial costs to patients to fill inhaler and/or spacer prescriptions, can also act as a barrier to correct technique [61]. Spacers make specific MDI technique steps easier to perform so that patients do not have to coordinate MDI actuation with medication inhalation. Spacers often require a prescription and costs can vary depending on insurance coverage and spacer type. Although commercial spacers can be purchased without a prescription, prices vary widely (from $4 to more than $30), which can be too expensive for many patients [62]. Additionally, only 64% of pharmacies licensed to accept Medicaid as payment for spacers in Arkansas actually did so, with pharmacies citing corporate policies or problems with claims reimbursements as reasons for not accepting payment [63]. Policies like these can limit patient access to spacers. For patients who would benefit from multiple spacers and patients with limited financial resources, both the need for a prescription and the cost can limit access. For example, children with asthma may want to keep a spacer at school and at home so they don’t have to carry it with them, but if they only have one prescription, then they may choose to keep their spacer at home. Inhaler costs also vary greatly and may affect inhaler technique indirectly through lower medication adherence. One study of COPD patients found that individuals with high out-of-pocket inhaler costs were at higher risk of cost-related non-adherence when compared to individuals who did not use inhalers [64]. Another study of adults and children with asthma in Australia found high rates of under use, more than half of adults and more than one-third of children, related to costs [7].

In this section, we highlighted reasons for inhaler misuse based on the socio-ecological framework, however we did not discuss many factors that can indirectly lead to inhaler misuse. It is important to note that any factor that negatively impacts medication adherence may also contribute to poor inhaler technique. It is beyond the scope of this review to review all of these factors. However, interested readers should consult the WHO’s multi-

dimensional adherence framework [66]. This framework describes five interacting dimensions that affect medication adherence, including health system factors, social/economic factors, condition-related factors, therapy-related factors, and patient-level factors. As noted in our discussion of attitudes, regular use of inhalers can reinforce proper technique through maintenance of skills [18]; thus, factors that contribute to non-adherence should also be considered when attempting to reduce inhaler misuse.

4. Solutions: Existing Interventions (Table 2)

The socio-ecological model is useful for identifying the various factors that affect behavior as well as identifying solutions to facilitate optimal inhaler use. For example, if a healthcare organization wanted to focus on improving patients' inhaler technique knowledge (i.e., an individual-level factor), it may implement a multi-level solution that includes individual (e.g., provide patients with written inhaler technique materials), interpersonal (e.g., train clinicians to communicate more effectively about inhalers), and policy-level (e.g., reimburse providers to assess patient inhaler technique) interventions. While multi-level solutions are necessary to address persistent inhaler misuse, it is important to consider approaches at each level of the socio-ecological model, as well as combine solutions across levels. A range of current solutions exist to teach patients effective inhaler technique, applying a variety of approaches.

4.1 Usual care

Most commonly, current clinical practice includes no direct education or insufficient education for patients. In fact, at least a quarter of patients report never receiving inhaler education [67– 68], and most others do not receive repeated education, despite the guideline recommendations [2]. This results in patients referring to the package inserts that come with the devices and/or their own intuition [69–71]. Package inserts are difficult to read, with small font, and therefore errors in technique are common and critical errors occur in a non-trivial proportion of patients who are only provided the package inserts [70–71]. Patients who report not receiving education are more likely to demonstrate errors than those reporting some education [72]. Therefore, package inserts alone are insufficient to improve patient technique.

4.1 Handouts

Simple direct educational approaches include patient education handouts, which differ with respect to their health literacy appropriateness. Specifically, inhaler technique handouts may vary in their application of key health literacy principles, such as including sufficient white space, using large font, simple language, and incorporating pictures [71,73].

Many of these approaches are not significantly more effective than the package inserts or no education at all, with only a handful demonstrating improvement in technique [71,74]. Written instructions have been shown to be ineffective, resulting in less than 10% improvement in technique [75]. However, if written materials are used, studies suggest that using pictures may lead to better comprehension [76].

4.2 In-person education in health care settings

4.2.1 Simple verbal instructions without demonstration has been useful for some devices, such as MDIs, but not for other devices, such as the Diskus device [77,78]. Instructions with demonstration by the healthcare professional are more effective than written and/or verbal instructions [28,75,77–78]. Verbal instructions with or without demonstration have been delivered in-person [35,77–79], via video [75,80], or animation [28], and implemented by physicians [81–85], pharmacists [85–88], nurses [89,90], and respiratory care therapists with varied effectiveness [74–75, 83].

4.2.2 Demonstration of inhaler technique provides an opportunity for patients to show how they use their inhaler and receive feedback. Demonstration of inhaler technique has been found to be superior to verbal instruction alone [77–78,91]. The current gold standard educational approach is repeated rounds of assessment and education using the teach-to-goal (TTG) educational technique [35,77–79,92–95]. This approach ensures that both aspects of the guidelines, namely assessment and education, are conducted and allows the intervention to be tailored to the patient based on their direct needs. This teach-to-goal approach has traditionally been provided by in-person educators [35,77–79,95]. TTG has been studied in adults [35, 77–79,93,96–97] and pediatric populations [94] as well as among patients with asthma [35,77–79,94,97] or COPD [35,77–78,93,96–97]. TTG has been studied in the ambulatory setting [95], the hospital setting [35,77–79], in schools[94], and even through teleconferencing (see below for more information)[93,96]. In one study, this strategy has been found to decrease misuse from around 90% to nearly 10% [78]. TTG has been shown to be more effective than verbal instructions at reducing misuse and also at reducing acute care utilization among hospitalized patients [77,78]. Further, TTG has been found to be more effective than verbal education across all levels of health literacy among ambulatory patients [28]. One reason that TTG may be effective is that it can be tailored to individual patients during the educational session [79]. Educational interventions that are tailored have been suggested in the literature when initiating and monitoring patients' response and use of inhaled therapies [98]. A caveat of in-person education is that patients need repeated practice and educational sessions, usually within a month of the initial education, as the effects of the initial intervention wanes over time [78]. However, repeated in-person education may not be feasible for many patients for multiple reasons, including lack of education provided at ambulatory visits, barriers such as transportation, or cost issues related to providing education at clinical encounters and/or in home or community settings.

4.3 Virtual education

Virtual education may be a potential solution for offering patients repeated educational sessions. However, access to technology, willingness to engage in a remote visit, and ability to use the technology (eHealth literacy) may act as barriers to adoption of virtual education [99].

4.3.1 Videos allow for consistent quality education about correct inhaler technique with various devices without the need to train clinicians and ensure their ongoing skills. This type of approach overcomes the limited ability of clinicians to describe and demonstrate proper inhaler technique, as noted above. A brief video on MDI technique was found to improve

inhaler skills among children with persistent asthma but did not impact self-efficacy or asthma control; however, skills waned within a month [100]. In contrast, a video that was tailored to the specific steps that children missed during an inhaler technique assessment resulted in significant improvements in inhaler technique that were maintained at one month follow-up [53]. In a study of adults with chronic airway disease, the use of training videos improved technique immediately in the majority of participants (88%), with three-quarters (76%) maintaining technique at 1–2 months follow-up) [101].

4.3.2 Video modules combine technology-based approaches that provide consistent quality education with adaptive learning approaches based on patients' knowledge and skills. A virtual teach-to-goal (V-TTG) intervention that is patient driven using interactive learning modules tailored via adaptive learning technology has been developed. This module is located on the internet and can be accessed via a link in an email that can open on any device to make accessing the intervention quick and easy. Studies show that V-TTG is similarly efficacious to in-person interventions for reducing inhaler misuse in hospitalized adults, primarily African-American, and holds promise for further dissemination across various populations and healthcare settings [80,97,102].

4.3.3 Internet-based interventions enable patients to complete home-based education and self-management interventions on their own time and at their own pace. Various studies have evaluated such web-based platforms. In one study, a higher proportion of patients in the at-home web-based intervention group had correct MDI technique as compared to individuals in the in-office traditional care, though no significance testing was reported [103]. Another pilot study of a web-based 'tutorial' found that those in the tutorial group showed better inhaler technique than the control group, although this study included only a small group of participants (n=18 intervention; n=16 control) [104]. In another study of self-directed internet-based training versus in-person group training, both groups showed improved technique [105].

4.3.4 Telehealth allows for 'face-to-face sessions' between patients and clinicians while overcoming barriers to in-clinic visits, namely travel and time. In-person education that includes rounds of education and demonstration is the gold standard; however, not all patients can always attend an in-person visit. Thus, the use of tele-health technology to conduct "face-to-face" sessions is growing. Pharmacist-led interventions using telehealth sessions have been found to be more effective than package inserts among rural adolescents with asthma [106]. Similarly, a multi-session pharmacist-led telehealth intervention that provided teach-to-goal education to rural adult patients with COPD found improvements across symptoms, technique, and self-efficacy [93,96].

4.3.5 Gaming has received less attention as an inhaler technique intervention, even though video games have been shown to improve education and self-management outcomes [107]. One asthma intervention that was delivered by CD-ROM included a game that asked children to put pictures of someone using their inhaler in the correct order [108]. This activity was part of a larger intervention that was during a 2-hour intervention, with the inhaler technique education estimated to be 15-minutes. There were no statistically

significant differences in inhaler technique when compared with the control group, but a validated measure of inhaler technique was not used in the study.

4.4 Feedback devices

One of the limitations of self-management among individuals with asthma or COPD is that there is limited physiologic feedback to support adherence to medications and to know if their technique is sufficient. The use of devices to provide biofeedback could help support self-management and adherence [55]. Eight inhaler technique feedback devices were reviewed in 2017 [109]. These devices provide feedback about correct technique for steps that can be difficult for healthcare professionals to assess, such as whether the patient inhaled forcefully enough or coordinated inhaler actuation with inhalation. However, there were several limitations for the devices reviewed, including that none were capable of providing feedback on all essential MDI steps and only one (INCA; described below) provided feedback on all essential Diskus steps. The review also highlighted there was significant variation in costs as well as how and when feedback was provided. Although evidence about the effectiveness of these devices in reducing inhaler misuse is limited, these devices have great potential to facilitate inhaler technique assessments during office visits and at home [110].

4.4.1 The INCA device uses inhalation sounds and airflow to monitor inhaler technique [111–112]. Biofeedback using the INCA device has demonstrated effectiveness at identifying inhaler adherence among patients with COPD and also has been found to improve technique and adherence among patients with asthma [113,114]. The use of community pharmacies to teach and monitor inhaler technique and adherence using the INCA device is currently being studied in Ireland [112,115–117].

4.5 Education in Non-Healthcare Settings

Because inhaler education often requires multiple educational sessions, the utilization of resources beyond the healthcare setting can help address this care need.

4.5.1 Home setting: Interventions in the home allow patients to learn proper inhaler use with their own devices, which can be a limitation when personal devices or placebo devices are not available in clinical settings. Also, at home, patients may have family or friends present who support medication use, such as parents, adult children, or home nurses. Indeed, patients with asthma reporting relying on family and friends as important members in their health networks [118].

These individuals can also receive education to help reinforce or assist with proper inhaler use, which may not be feasible if they cannot come to an in-person education session in clinical settings. Few studies examined at-home interventions. One study of Puerto Rican youth in Chicago showed that four at-home educational sessions delivered by community health workers led to improved inhaler technique, as compared to children receiving education via four newsletters [119]. Due to the costs of delivering in-home education, delivering home-based technique education may not be feasible. Future work that evaluates the cost-effectiveness of such programs is warranted.

4.5.2 Community pharmacies: Inhaler technique education with trained community pharmacists have been evaluated, which often incorporate multiple educational sessions with patients. In one study in Australia, patients with asthma were assigned to three (one group) or four (another group) educational sessions in community pharmacies. This general approach proved feasible as pharmacists for both groups were able to recruit and deliver the interventions; however, no difference in technique was found between these two groups [120]. Of note, this intervention was not solely focused on inhaler technique. Multi-component interventions are important for providing well-rounded self-management education, but may make differentiating individual intervention effects. In another Australian study, two interventions were compared, one that included only written and verbal instructions compared to one that also incorporated demonstration [121]. Similar to the findings of interventions described earlier, the intervention that included demonstration was more effective [121]. Studies in the United States, Northern Ireland, Grenada, and Belgium also found community pharmacies were effective in providing asthma and/or COPD education and improving inhaler technique [86,122–125]. Another study examined the combination of multiple community pharmacist-led educational sessions with the addition of instructional technique labels on the inhaler devices [88]. One-community pharmacist-led study specifically evaluated whether the type of feedback provided resulted in different outcomes with cohorts split into qualitative only or qualitative plus quantitative feedback, with the latter cohort showing greater improvement [126]. Finally, the use of small-group education in pharmacies for patients with asthma has also been studied in Australia [127]. Inhaler technique improved among those receiving small group education from a community pharmacist but not from usual care from community pharmacists [127].

4.5.3 School settings: Schools can be an important setting to provide inhaler education as children spend a majority of their day in schools. Various programs deliver asthma programs to children while they are at school, although fewer focus on inhaler technique and even less measure the impact of this education on children’s technique [128]. These programs vary in length and can be delivered by nurses or lay health educators [129–130]. The evidence suggests that inhaler technique education in schools has mixed outcomes with some studies showing sustained improvements at 12 months post education [128].

4.5.4 Community centers: Community centers which could be any location open to the community, provide an opportunity to bring together patients and their families, advocates including teachers and social workers, and health educators in non-threatening and easy to access locations. One study found that educational sessions tailored to a community’s needs based on location and timing of the sessions was accessible, acceptable, and useful [131].

5. Future Directions

Traditional approaches to inhaler education have shown some promise, though future advancement in the interventions themselves and also within systems to provide technique education is needed to impact the persistent issue of inhaler misuse. Given the myriad reasons for inhaler misuse, it is critical to think across the levels of the socio-ecological model to improve inhaler technique among patients. To truly advance the effectiveness of

inhaler technique interventions, persistent barriers need to be overcome. These barriers include inhaler devices that are difficult for patients to use correctly without repeated assessment and education, as well as a healthcare system that does not support providing effective, evidence-based solutions. Comparing educational interventions across studies is made more difficult by lack of harmonization of measures; future work to standardize assessment tools could improve researchers' ability to evaluate the impact of educational interventions on inhaler technique and health outcomes [132–133]. Further, the topic of patient education is often viewed as pedestrian, which limits the ability of researchers to obtain funding to support identification of effective inhaler technique interventions that are feasible to scale, implement, and disseminate. Finally, as newer inhaler devices are developed, some show more patient-centeredness while others remain difficult for patients to intuitively use; it is critical that development of new devices is done with patient's ease of use as the key focus.

In addition to barriers, there are potential future solutions to address inhaler misuse. As our technology advances, so too does our ability to support innovative tailored simulated learning methods to improve patient technique. Sensors that detect patient movement and monitor inspiratory maneuvers could be integrated into devices to provide real-time feedback on the accuracy of patients' technique. Additionally, learning through virtual reality and other simulated environments could be used to instruct both patients and clinicians on proper technique. To incentivize development of new inhaler technique technologies, national health organizations, such as the National Science Foundation and the National Institutes of Health, could issue specific calls to fund technology development in this area. Additionally, universities and the private sector could support hack-a-thons to develop solutions to poor inhaler technique.

Although technological innovation to provide biofeedback holds promise to improve technique, policy must support the availability of these inhalers and/or devices for clinics and for patients, particularly those most affected by inhaler misuse. Organizations must support the integration of these inhalers and/or devices within healthcare and non-healthcare settings, allowing the benefits of these technologies to be realized for all patients. In addition to future innovative solutions, drug manufacturers can make all necessary tools for proper inhaler use (e.g., inhalers and spacers) available with a single prescription, rather than requiring different prescriptions. Requiring multiple prescriptions is further affected by lack of clinician training and patient education, limited availability of devices at pharmacies, and high costs. Increasing access to needed inhaler equipment for all patients can facilitate and reinforce the value of proper technique. For instance, MDIs should be used with spacers across all age groups, and masks are recommended for young children. These should come with the MDIs and not be seen as optional or be provided separately. Also, as more inhaler devices are available, healthcare professionals must know not only how to use inhalers correctly and how to teach this information to patients but also how to select what prescription drug and inhaler device are best for each patient to ensure alignment between device type and patient knowledge / skills. In addition, inhaler educational strategies can be shared across organizations to support innovation across these settings as related to educational and behavioral interventions and further ensure repeated instruction and assessment for patients. The role of the social network is significant in supporting instruction

and assessment and thus should be enhanced in educational and behavioral interventions whenever possible. Further, critically, patient-centeredness, cultural tailoring of interventions, and personalized educational strategies are needed as a solution to the individual natures of patients' barriers to self-management [16,35,53,80,94,134–135]. The growth of value-based care within the health system can help support team-based care models which are critical to support such innovation, as physicians alone cannot shoulder the responsibility of inhaler education. Reimbursement by insurers will be critical to support healthcare professionals to consistently deliver this education.

For educational interventions to be successfully disseminated and implemented across healthcare settings, they need to be scalable and feasible. One key factor is the length of the intervention. A handful of educational interventions have studied the time it takes to provide the education. In a study of two hospital-based in person interventions, an interactive, multi-round "teach-to-goal" intervention to teach two devices took about three times longer than a brief verbal-instructions only intervention (~6.3 vs. 2 minutes; $p<0.0001$) [77]. In a tele-health pharmacist delivered teach-to-goal intervention that taught multiple devices over multiple sessions, the average intervention visit took just over one-half hour (33.7 +/− 11.8 minutes) [93].

Critical to any inhaler technique educational intervention/program is the concept that multiple sessions are needed. Sufficient evidence exists to suggest that even the most successful interventions delivered one-time wane, typically within a month [18,32,78,93,96,100,136–137]. In two multi-session tele-health intervention studies, multiple educational sessions demonstrated improved overall technique as well as symptom and quality of life markers. In one study that provided more than one educational session, predictors of sustained technique included baseline technique and preventer inhaler type (DPI>MDI) [18]. Therefore, multiple sessions need to be provided. What is needed is the dosing (i.e., number of sessions) requires for patients, and whether this differs across patient population(s), setting, and type of trainers. To date, there is not conclusive evidence of the number of sessions, nor which type of trainer (e.g., pharmacist, nurse, etc) is ideal for which type of intervention. What seems most critical is that the intervention itself has built-in fidelity as the trainers themselves will likely require repeated 'quality assurance' training.

One ongoing topic of controversy among those developing and evaluating inhaler technique interventions is the topic of 'critical' steps- specifically which ones are critical, how to ensure the critical steps are taught, and whether there are differing clinical outcomes associated with certain critical steps. In a systematic review of critical inhaler errors among patients with asthma or COPD, they found a wide range of how these critical errors were defined, yet they did find that in general critical errors have been associated with important health outcomes [138]. For instance, in one study of patients with asthma, specific errors were identified with as being 'critical' and being associated with worse asthma outcomes, but mostly limited to DPIs [139]. With regards to educational interventions, in another study of adults hospitalized with asthma or COPD, misuse rates post-education did not differ when limiting the analysis to critical outcomes. [78].

6. Conclusion

In light of the significant prevalence and impact of inhaler misuse, healthcare systems and policies must support comprehensive solutions to improve inhaler technique among all populations. Investments in the study and dissemination of feasible and effective interventions are necessary to advance the study of new approaches to inhaler education as well as support the adoption and impact of proven models for improving inhaler technique. Coordination and innovation across patients, clinicians, insurers, healthcare institutions, and communities is critical to solve this persistent issue of inhaler misuse and see the improvements in disease control, healthcare utilization, and cost reductions.

7. Expert opinion

To overcome the decades-long persistence of inhaler misuse by the majority of patients with respiratory disease, it is critical to ensure patients receive regular and repeated inhaler technique assessment and education. Therefore, to support guideline-based recommendations that patients should receive inhaler technique assessment and education at every health care visit, multi-level solutions need to be implemented both within and outside traditional healthcare settings. Solutions should: 1) expand access to inhaler equipment both for educational demonstration and for clinical use, 2) train clinicians, patients, and their social network members on correct inhaler technique; 3) develop scalable, innovative technological solutions that support proper inhaler use at home and 4) make delivery of inhaler technique education economically viable for clinicians and health systems. Many current innovations may not be realistically feasible for implementation into clinical practice. For instance, time constraints and reimbursement may limit the health systems' ability to deploy high-quality effective in-person education at each visit. Therefore, technology-based solutions and/or methods to identify high-risk patients who warrant the time and effort required for in-person inhaler education must be further evaluated and ultimately harnessed. Further, it is imperative that solutions are coordinated across patients, clinicians, health systems, and communities in order to address the wide-range of factors and barriers that impact inhaler misuse. These comprehensive solutions, utilizing the best current evidence and further innovation, could ultimately lead to the real-world impact that helps patients use their inhalers properly in any setting. This impact includes improved symptom control and quality of life, fewer acute care utilization events, and decreased costs to both patients and the healthcare system. However, until the patient-level and system-level barriers are addressed, these important outcomes will not be realized for the majority of patients with ongoing inhaler misuse.

Key areas of improvement in the field of inhaler misuse include: 1) development of inhaler devices that are easier for patients to correctly use without the need for repeated assessment and education; 2) expanded resources within healthcare that supports system-wide effective and evidence-based solutions to inhaler misuse. One mechanism to support this type of innovation may be harnessing value-based care payment models that encourage holistic care approaches by providing opportunities to financially support care interventions for a population of patients, which is not supported in a traditional fee-for-service model. For instance, in value-based care models, the program can support community health worker

home visits and/or transportation to appointments for patients, while in a fee-for-service model, these types of intervention would not be feasible; 3) decreasing the cost of medications delivered via respiratory inhalers, as the cost prohibitive nature of the medications may keep patients from consistently having access to and using the devices, limiting their opportunity to maintain inhaler technique skills if taught; and 4) large-scale dissemination and implementation of feasible, scalable, effective system-based approaches to ensure patients receive their guideline-recommended inhaler technique assessment and education across and between healthcare visits.

In order to realize the advances outlined above, it is critical that rigorous research studies are funded to develop and test more user-centered inhaler devices. Additionally, future research should identify systems-level facilitators that support scalable interventions to support proper inhaler technique, such as through value-based care programs. Further, research is needed to identify interventions and implementation approaches that allow for scalable dissemination and implementation of system-based interventions. Comparative effectiveness trials to evaluate the impact of inhaler technique interventions on clinical outcomes are also warranted. Before the field of inhaler technique research can advance, we must first address the widespread fallacy that inhaler technique is pedestrian and unimportant. Unless there is stakeholder understanding, buy-in, and committed support to ensure that patients must have effective inhaler technique skills, patients will not experience the benefits of the otherwise efficacious inhaler-based medications and will continue to have poor health outcomes with high costs to patients and health systems.

It is the hope of the authors that within the next five years, significant research advances will be made to understand effective, feasible, scalable system-based advances to implementing inhaler assessment and education as a standard-of-care for all patients with obstructive lung disease. Technology will clearly have a larger role in facilitating inhaler technique assessment and education through device innovation and remote access to technical experts. Importantly, whether these advances differentially affect some patient populations will need to be monitored, so that health disparities are not widened. Further, team-based care within and beyond healthcare settings will expand access to inhaler education and help reinforce education across populations. Finally, value-based care programs will galvanize efforts to employ these guideline-based principles to allow populations of patients to receive the necessary interventions, such as inhaler technique education, required to manage and control their disease and avoid costly healthcare utilization. While inhaler technique has improve little despite forty years of research in this area, the opportunities are great for patients, clinicians, and researchers, insurers, and funders to work together to advance inhaler use and improve outcomes for individuals with obstructive lung disease.

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4. Toups MM, Press VG, Volerman A. National Analysis of State Health Policies on Students' Right to Self-Carry and Self-Administer Asthma Inhalers at School. J Sch Health. 2018;88(10):776-784. doi:10.1111/josh.12681** This policy paper is a comprehensive review of all 50 states and the District of Columbia's laws and policies for the self-carry and administration of quick-relief asthma inhalers among children in prekindergarten through 12th grade. All states permit students to carry and administer their inhalers at school, although each state differs in their development and implementation of policies for asthma self-management at school.
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6. Press VG, Arora VM, Kelly CA, Carey KA, White SR, Wan W. Effectiveness of Virtual vs In-Person Inhaler Education for Hospitalized Patients With Obstructive Lung Disease: A Randomized Clinical Trial. JAMA Netw Open. 2020;3(1):e1918205. doi:10.1001/jamanetworkopen.2019.18205* This study evaluated the use of a direct-to-patient inhaler educational intervention called "virtual teach-to-goal" compared to an in-person intervention called "teach-to-goal". The results of this non-inferiority randomized clinical trial showed that the 'virtual' teach-to-goal performed nearly as well as the in-person intervention, which may allow for wider dissemination among hospitalized patients and ultimately for patients across any setting.
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[PubMed: 29229099] * This systematic review examined school-based asthma interventions that included inhaler technique instruction. The education was most often led by nurses and differed in length. Very few interventions evaluated changes in students' inhaler technique and these studies suggest students benefit from such education, however mixed evidence exists for sustained improvement during follow-up up to 12 months.

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Article highlights

- Respiratory inhalers are designed to deliver the medication to the respiratory system, thereby acting directly on the lungs and also minimizing systemic effects of the drugs.
- Inhaler misuse is associated with worse disease control and quality of life, increased healthcare utilization at hospitals and emergency department visits, as well as higher healthcare costs.
- Inhaler misuse broadly affects all medication types/devices and is found across care settings and patient populations.
- Numerous individual, interpersonal, organizational/institutional, and policy factors are associated with inhaler misuse.
- Usual care includes no or limited education about correct inhaler use and this does not meet the clinical guideline standards.
- In-person, virtual, and biofeedback approaches have been developed within and beyond traditional healthcare settings for inhaler education with varied effectiveness.
- Approaches that utilize both assessment and education about inhaler technique are associated with greater effectiveness and are consistent with existing clinical guidelines.
- Future solutions to inhaler misuse should focus on factors at multiple levels of influence.

Figure :
Socio-ecological framework for considering reasons for and solutions to inhaler misuse

Table 1:

Reasons for inhaler misuse and solutions for inhaler misuse, based on the socio-ecological framework

Socio-ecological framework construct ***Definition***	**Reasons for inhaler misuse**	**Solutions for inhaler misuse**
Individual		
Knowledge *Knowing the steps for proper technique for each prescribed inhaler device*	· Never received inhaler technique education · Received inaccurate inhaler technique education from clinicians · Deterioration of knowledge over time	· Integrate inhaler technique education and demonstrations into clinical workflows and non-clinical settings · Educate clinicians or other healthcare professionals about how to assess and teach inhaler technique as well as enhance general awareness of difficulty of inhaler use · Provide patients with materials (written or online) about inhaler technique that can be accessed at home · Repeated inhaler technique education and demonstrations
Skill *Ability to physically perform all inhaler technique steps correctly*	· Physical issues, such as arthritis, vision problems, or inability to coordinate inspiration · Cognitive issues that make it difficult to remember or perform multiple inhaler technique steps	· Integrate inhaler technique education and demonstrations into clinic workflows · Assess skills to determine if appropriate (e.g., dexterity, etc) · Prescribe assistive devices, such as spacers/holding chambers and/or nebulizers, for individuals who are unable to demonstrate proper technique due to physical or cognitive issues · Develop new inhalers using user-centered design principles · Provide opportunities for observed practice
Attitudes *Beliefs related to inhalers and inhaler technique*	· Negative attitudes toward using inhalers (e.g., inconvenience, not as strong as nebulizers) · Beliefs that inhaled medications are unnecessary	· Provide self-management education that addresses psychological aspects of disease
Self-efficacy *Confidence in one's ability to overcome barriers to perform correct inhaler technique*	· Overconfidence in using inhaler device when technique is incorrect · Lack of confidence to use inhaler correctly	· Integrate inhaler technique education and demonstrations into clinic workflows and correct errors in technique · Periodically assess patient inhaler self-efficacy and provide additional education/ resources to those with low self-efficacy
Health literacy *An individual's ability to understand inhaler technique information*	· Poorly designed or text-heavy inhaler technique educational materials (e.g., pamphlet inserts)	· Design written, video, and online inhaler technique educational materials that can be understood by individuals with low health literacy · Design inhaler technique educational interventions that can be tailored across levels of health literacy
Interpersonal		
Patient-provider communication *Lack of communication or inaccurate communication about inhaler technique between clinician and patient*	· Patients given no or suboptimal education about how to use their inhaler devices	· Conduct periodic assessments of clinician inhaler technique communication · Provide communication training to clinicians · Create and provide question prompt lists for patients to use to trigger conversation with clinicians
Social support *Inhaler technique aid and assistance offered by an individual's social network members*	· Network members who encourage correct inhaler and/or spacer use	· Educate patients' social network members about importance of correct technique (e.g., caregiver education, school-based education for students' peers) · Train patients' social network members to assess technique
Conflicting information *Receipt of conflicting information about correct technique from multiple sources*	· Multiple sources, such as family members, peers, online sources, or written materials, provide patient with conflicting information about how to use an inhaler properly	· Assess whether patients have received conflicting information · Provide patients with high quality inhaler technique materials
Organizational / Institutional		

Socio-ecological framework construct ***Definition***	**Reasons for inhaler misuse**	**Solutions for inhaler misuse**
Length of appointment *The total amount of time a provider has for a standard office visit*	· Limited office visit time for inhaler technique assessments and education	· Develop inhaler technique assessment protocols and tools that can be integrated into pre-visit wait time and implemented by non-clinician medical office staff · Provide inhaler technique education in non-healthcare settings, such as schools, pharmacies, or other community locations · Provide inhaler technique education using telehealth
Availability of training devices *The presence of placebo training devices to teach technique at practices and clinics*	· Lack of placebo training devices at clinics and other office settings	· Make available low-cost placebo training devices that can be easily found and purchased by practices, clinics, and schools
School inhaler carry policies *Policies that are related to the ability of students to carry inhalers and self-administer inhaled medications at school*	· Policies that limit the abilities of students to carry or use their inhalers at school	· Create universal policy that allows students with asthma to carry their inhalers with them · Disseminate information about policies to school staff, parents, and children · Implement school-based education
Policy		
Reimbursement for inhaler technique education *Payer reimbursement to clinicians for provision of inhaler technique education*	· No or minimal reimbursement for providers to assess and educate about inhaler technique	· Conduct cost effectiveness studies of the impact of inhaler technique education on patient outcomes · Increase payer reimbursement for inhaler technique education
Spacer & inhaler costs *Financial costs to patients to fill inhaler and/or spacer prescriptions*	· Inhaler and/or spacer too expensive for families	· Increase insurance coverage for multiple inhalers and spacers · Make free or low-cost spacers available for patients without insurance

Table 2:

Existing interventions for inhaler misuse

Method	Intervention	Description	Evidence	Levels	References
None or insufficient	No intervention	None	≥25% of patients never receive inhaler education Most patients do not receive repeated education, despite guideline recommendations	Individual	[2, 67–68]
Written	Package inserts	Official medication instructions that comes with every prescription	Difficult to read and often with small font, leading to errors Patients who report not receiving education are more likely to demonstrate errors than those reporting some education	Individual and policy	[70–72]
Written	Handouts	Patient education handouts that vary with respect to their health literacy appropriateness (amount of white space, large font, use of simple language, use of pictures, etc)	Not significantly more effective than the package inserts or no education at all; only handful demonstrate improved technique Not very effective with <10% improvement in technique	Individual	[60–70, 73, 74–75]
Written	Handouts with pictures	Written text combined with pictures	May lead to better comprehension	Individual	[76]
In person	Brief verbal instructions (no demonstration)	Instructions are provided verbally without demonstration (e.g., read the instructions out loud)	Useful for some devices, such as metered dose inhalers, but not for other devices, such as diskus	Individual	[77–78]
In person	Brief verbal instructions with demonstration	Instructions are provided verbally along with demonstration of inhaler technique but without assessment/re-assessment of patients' technique pre/post education	Varied effectiveness when delivered in-person and via video or animation, as well as when delivered by physicians, pharmacists, nurses, and respiratory care therapists More effective than written and/or verbal instructions.	Individual	[35, 74–75, 77–91]
In person (face to face)	Teach-to-goal	In-person education provide repeated rounds of assessment and education, in alignment with the guidelines and allowing tailored education based on each patient's needs	Decreases misuse from over 86% to less than 10% in adults More effective than verbal instructions at reducing misuse and also at reducing acute care utilization in adults	Interpersonal	[77–78]
In-person (tele-conferencing)	Tele teach-to-goal	TTG with trained pharmacists via telehealth visits to patients in their homes	Pharmacist-led interventions using telehealth sessions more effective than package inserts Multi-session pharmacist-led telehealth intervention that provided teach-to-goal education showed improvements across symptoms, technique, and self-efficacy	Interpersonal and organizational/institutional	[93, 96, 106]
Video	Video instruction + demonstration-person	Videos allows an intervention to provide consistent quality education without training the educators and ensuring their ongoing skills.	Generic video led to improved MDI skills among children with persistent asthma but did not impact self-efficacy or asthma control; skills waned within a month Tailored video delivered in school setting led to significant improvement in inhaler technique and this was sustained at 1-month follow-up	Individual	[53, 100]
Video-modules	Virtual teach-to-goal (V-TTG) interactive learning modules tailored via adaptive learning technology.	Patient-driven, technology-based approach that provide consistent quality education with adaptive learning approaches based on patients' knowledge and skills.	Studies show that V-TTG is similarly efficacious to in-person interventions for reducing inhaler misuse and holds promise for further dissemination across various populations and healthcare settings.	Individual	[80, 97, 102]

Method	Intervention	Description	Evidence	Levels	References
Gaming	CD-ROM intervention that included activity to order inhaler technique steps	The use of games or gaming strategies within the educational interventions	No significant improvements in inhaler technique	Interpersonal and Organizational/ Institutional	[108]
Community Pharmacies	Trained pharmacists provide inhaler education, often using multiple sessions	Use of community pharmacists to provide inhaler education at the time of medication prescription fill/refill	Feasible for pharmacists to recruit patients with asthma and deliver information in 3–4 sessions; no difference found between two groups Intervention that incorporate demonstration more effective than one that included only written and verbal instructions Community pharmacies effective for providing asthma and/or COPD education and improving inhaler technique Multiple community pharmacist-led educational sessions with the addition of instructional labels for daily reminders on the inhaler devices Small-group education in pharmacies for patients with asthma showed improved inhaler technique when compared to usual care from community pharmacists	Interpersonal and Organizational/ Institutional	[86, 88, 120–125, 127]
Schools	Education delivered by school or public health nurses or alternatively lay health educators	Use of school staff or school-based educational visitors to provide education	Sessions led lasting 15–60 minutes led to mixed impact on inhaler technique, with some studies showing retention at 12 months	Interpersonal and Organizational/ Institutional	[128]

Abbreviations: TTG = Teach-to-Goal; V-TTG = Virtual Teach-to-Goal; COPD = Chronic Obstructive Pulmonary Disease