



Published in final edited form as:

*J Asthma*. 2023 July ; 60(7): 1269–1279. doi:10.1080/02770903.2022.2152352.

## Appropriate inhaler use in children with asthma: barriers and opportunities through the lens of the socio-ecological model

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### Abstract

**Objective:** Proper use of inhaled medications is essential for management of asthma, as inhaled therapies are recommended as first-line for both prevention and treatment of asthma symptoms. Optimizing adherence requires identifying and understanding multiple layers of systemic complexity to obtaining and using these therapies and offering specific solutions to address these barriers. Bronfenbrenner's socio-ecological model provides a framework for examining multilevel systems – both internal and external – that contribute to the management of childhood asthma. The four levels in this model consist of factors related to the individual, interpersonal relationships, organizational entities, and societal structures and rules. This narrative review identifies influences and factors related to asthma inhaler adherence by each level and offers evidence-based solutions to each obstacle.

**Data Sources:** We conducted PubMed searches to identify relevant articles for barriers and solutions impacting asthma control at each level of the socio-ecological model.

**Study Selection:** Common barriers to asthma control at each model level were identified. Pertinent studies for each barrier were identified and reviewed by the writing group for inclusion into the narrative review.

**Results:** For each level of the socio-ecological model, three primary issues were identified based on the literature review. Approaches for addressing each issue in an evidence-based, systematic fashion are presented.

**Conclusion:** Understanding the obstacles and potential interventions to achieve proper use of inhaled medications is a critical step necessary to develop and implement systematic solutions

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Declaration of interest

S. Bickel, R. Cohen, J.P. Needleman, A. Volerman all declare they have no conflicts of interest, financial or otherwise to disclose.

aimed at improving asthma control and morbidity for the more than 6 million affected children in the United States.

### Keywords

Children; asthma; inhalers; insurance; pediatric

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### Introduction

Despite decades of medical research and established national guidelines (1), asthma remains a leading cause of pediatric healthcare utilization and poor quality of life (2). Uncontrolled asthma negatively impacts school performance (3), cognitive and physical development (4), and mental health (5). The foundation of asthma treatment includes quick-relief medication, and, for those who require it, daily preventive therapy. In most cases, both rescue and preventive therapies are inhaled. While most children with persistent asthma can prevent exacerbations, symptoms, and mortality with daily use of inhaled corticosteroids (ICS) (6), real-world adherence with asthma treatment plans as well as inhaler technique are suboptimal, resulting in reduced asthma control (7). Optimizing use of inhaled medication requires understanding and addressing multiple layers of systemic complexity combined with numerous artificial barriers.

Inhaled medications can be delivered by nebulization or hand-held inhalers. Each device type has different attributes as well as pros and cons for their use (Table 1). Selection of inhaled medication and device types should be tailored to the patient's specific needs with consideration given to age, asthma severity and control, ease of inhaler use, and pharmacologic properties of a particular agent. Payor factors, including formulary coverage and out-of-pocket cost, are often non-medical reasons that drive inhaler selection and may be at odds with medical considerations, especially in pediatric patients (8).

The pathway from needing asthma treatment to obtaining and using inhaler therapies has several steps with multiple potential barriers at each step (Figure 1). Historically, most children with persistent asthma have been prescribed two inhalers, an ICS-containing inhaler for maintenance and a short-acting bronchodilator for acute symptoms. With the 2020 National Heart, Lung, and Blood Institute (NHLBI) asthma guideline focused updates (1) and the 2022 Global Initiative for Asthma (GINA) guidelines (9), some children with asthma may only require a single combination inhaler containing ICS-formoterol for both maintenance and quick-relief purposes. Regardless of the specific medicines, education for patients and families on device use and written instructions (e.g. asthma action plan) are of paramount importance to promote real-world use and achieve asthma control. Once prescribed, families must be able to easily obtain the prescribed medications and accessories (e.g. valved holding chambers, "VHC") before using the devices.

All aspects of children's lives are influenced by multiple interacting levels in society. These influences play critical roles in almost all areas of childhood development and health, including asthma management. Many of these influences are outside of the control of the individual and their immediate family, and competing interests often exist within these levels

of influence. All influences at every level must be considered when working to optimize asthma care, including appropriate inhaler use.

Bronfenbrenner's socio-ecological model (10) provides a framework for examining multilevel systems – both internal and external – that contribute to childhood asthma management (Figure 2). The first level consists of factors directly related to the individual. The second level (or concentric layer) looks at the complex web of interpersonal relationships, including family, friends, peers, teachers, coaches, and religious leaders, who often directly influence children's perceptions and behaviors. Expanding outward, there are organizational influences, including school systems, pharmacies, and healthcare systems, which may have different levels of integration and cohesion that can affect care and outcomes. Finally, at a societal level, there are influences and factors at the societal level, including payors, pharmaceutical companies, pharmacy benefit managers, as well as state and national healthcare laws and policies.

## Methods

To conduct this review and frame it within the context of Bronfenbrenner's socio-ecological model, common barriers to proper inhaler use were identified and then organized by each level of Bronfenbrenner's socio-ecological model as outlined in Table 2. A literature search was conducted on PubMed using multiple keywords pertinent to the impact of each barrier along with potential solutions. Results were reviewed by all authors and synthesized into this focused review.

## Results and discussion by socio-ecological level

### Individual (child with asthma)

#### **Disease severity, control, comorbidities**

**Barriers:** The individual child's perception of their day-to-day symptoms and overall control are important factors in ongoing asthma management. A person who does not perceive their symptoms may be less inclined to use prescribed maintenance therapies and as a result experience worse outcomes (11). Conversely, one who over-perceives symptoms or misattributes symptoms of comorbidities (e.g. allergies, vocal cord dysfunction, anxiety) may inappropriately use quick-relief medications, placing them at risk for serious side effects.

**Opportunities:** Routine assessments of asthma control both in clinic and at home, including in-person and mobile symptom scales and spirometry, may help children and their families to better understand asthma overall, recognize symptoms and trends in asthma control, and improve adherence with inhaled therapies (12,13). Multidisciplinary clinics for management of severe or difficult-to-treat asthma can create a unified treatment plan that balances patient and family-centered goals with treatment burden (14).

## Knowledge and skills

**Barriers:** Children at different developmental stages may have varied understanding of their condition. Key skills include developing an understanding of when and how to use their inhalers and other asthma medications, including self-carry and self-administration of quick-relief medications. Adolescents should progressively acquire self-management skills to facilitate independence, yet this time period often presents many challenges with maintaining asthma control due to competing social and academic pressures (15).

**Opportunities:** Clinicians can assess knowledge and provide appropriate education, preferably within a broad socioecological framework encompassing multiple domains which affect knowledge and action (16). Important topics include rationale for daily use of controllers, when to use quick-relief medications, inhaler technique, and how and why to use VHCs. Older children and teenagers should be able to identify their controller and quick-relief medications. Patient and parent confidence in inhaler technique do not correlate well with actual technique, so objective assessment is crucial at every opportunity (17). Tailored educational opportunities with teach-back (18), pictorial asthma action plans (19), and mobile technology (13) can improve knowledge and management skills of children and their parents.

## Attitudes and self-efficacy

**Barriers:** Self-efficacy is a person's belief in their own capacity to engage in actions that have a meaningful impact on their lives. Recurrent asthma exacerbations or frequent symptom impairment may leave children feeling like they do not have power over their asthma management. These beliefs may be reinforced or challenged by interpersonal relationships with parents, peers, healthcare professionals, and other influential people in the child's life.

**Opportunities:** Clinicians can help children with goal setting and understanding how treatments, including inhalers, improve their condition while providing positive feedback as patients meet goals of care. For older children and teens that resist using VHCs, alternative devices (i.e. DPIs) may be more appropriate. Interviewing teenagers without parents during visits may also identify unique concerns, delineate barriers to care, and help teenagers progress toward independent self-management.

## Interpersonal

### Family/caregivers

**Barriers:** Many of the same barriers that can affect the individual child with asthma impact family and caregivers. Family members may lack knowledge and skills surrounding asthma and self-efficacy regarding their ability to improve their child's condition. Families may have concerns about chronic medication use, especially steroids. Some families may use alternative or complimentary therapies at the exclusion of guideline-based care (20). Others may delegate responsibility for medication administration to young children before they are old enough to assume this responsibility. Conversely, families may fail to appropriately empower children as they mature. Competing priorities, such as housing instability, food

insecurity, and multiple jobs, may impede medication pick-up from the pharmacy, daily/twice daily medication administration and/or ability to attend appointments (21). Lack of resources, such as transportation or comprehensive health insurance, may prevent families from attending routine visits for asthma management. Given the similarity in the appearance of multiple different inhaler products coupled with the fact that albuterol inhalers are available in 5+ colors, inhaler confusion and misuse is common (22), particularly for families with low health literacy or language barriers (23). Family dynamics, such as multiple primary households and caregivers, may add layers of complexity to optimal medical care and medication use.

**Opportunities:** Clinicians must have the time to assess caregiver knowledge, expectations, and goals while assessing potential barriers to asthma management. These discussions are fundamental to improving parental self-efficacy, which is critical as parent confidence in medication use is associated with improved parental quality of life (24). Caregivers should be encouraged to monitor adherence in their older children and adolescents as they progress toward independence. In addition to assessing beliefs and expectations about inhaler use, clinical teams should address potential solutions to logistical barriers that may inhibit a family's ability to administer asthma medications. Solutions may include facilitating medication home delivery, ensuring up-to-date prescriptions for inhalers and VHCs, strategizing approaches to transfer daily medications between different caregivers, and providing multiple copies of asthma action plans for all caregivers (e.g. parents, guardians, grandparents, school personnel).

### **Friends/peers**

**Barriers:** Acceptance within one's peer group is typically considered essential by children and teenagers and is a major driver of behavior and choices, including for asthma management. Adolescents may not want to use inhalers around peers for fear of negative reactions or bullying, contributing to suboptimal adherence (25). Supportive peers, on the other hand, may improve acceptance of the child's condition, adherence, and quality of life.

**Opportunities:** Discussing peer influences at routine asthma visits can help clinicians better understand a child's peer group and their values. Clinicians can meet one-on-one with adolescents to facilitate honest discussions. Inhaler strategies, such as using once-daily ICS dosing and using DPIs so VHCs are not required, may enhance adherence. Mobile applications may enable education and positive reinforcement while providing adolescents with accurate information, medication reminders, support, and means to securely and privately interact with healthcare professionals (13).

### **School/day care teachers, staff, nurses, leaders**

**Barriers:** Poorly controlled asthma negatively impacts school attendance and performance. Schools are integral in asthma management, yet direct communication between asthma healthcare professionals and schools is limited beyond providing paperwork to identify students with the condition and allow inhaler use. All school personnel, not just nurses, must be able to recognize when a child is experiencing an acute asthma exacerbation and poor asthma control as well as have knowledge, skills, and rescue inhalers available to take the

necessary next steps, especially in schools without a full-time nurse. Many children with asthma do not have their own quick-relief medication accessible at school (26) and those that do often lack a second VHC for in-school use due to insurance coverage often only for one VHC annually.

**Opportunities:** School-centered programs focused on improving coordination of asthma management, such as Building Bridges for Asthma Care Program, have significantly improved multiple domains of asthma care, including the proportion of students with completed school asthma action plans, quick-relief inhalers at school, and effective inhaler technique (27). Strong interest across stakeholders also exists for asthma management integration in Head Start programs (28). School nurse asthma programs that incorporate controller therapy administration in the school day to ensure adherence have reduced asthma-related hospital admissions and quick-relief medication refill rates (29,30). Given not every school has a full-time nurse, non-medical school staff should be trained on the indications and correct use of inhaled asthma medication during the school day, and inhalers should be accessible even if the nurse is not present. Fostering a supportive environment for inhaler self-carry amongst both peers and teachers may improve self-carry rates and asthma self-efficacy (26). Children who self-carry should know to alert teachers or parents when they are requiring albuterol more than once a day. Further, given the large percentage of children with asthma who do not keep a rescue inhaler at school, a small supply of undesignated quick-relief medications is critical in schools, as outlined by a recent policy statement by multiple professional medical organizations and key stakeholders, which also provides guidance for implementation (31).

## Organizational

### Pharmacies

**Barriers:** Patients and families encounter multiple barriers to receiving chronic medications at pharmacies, including unavailability of medications, inconsistent processing of secondary insurance coverage of co-pays, no streamlined communication processes between pharmacies and prescribers, and lack of knowledge about updated asthma guidelines, for example Single Maintenance and Reliever Therapy (SMART) (1). Thus, patients and families may leave their local pharmacy without medications in-hand, often not knowing why.

**Opportunities:** Partnerships and integration allowing direct receipt of medications by the patient in the clinic or hospital eliminates a major point of failure in obtaining medications (32). Educational partnerships can also assist pharmacists with understanding newer NHLBI guidelines which diverge from current FDA labeling, such as SMART. Pharmacists have the important opportunity with patients and families to review inhaler types, reinforce proper use and technique, and monitor refill rates. Improved integration between pharmacies and EMRs should provide clinicians with dispensing data to guide discussions and asthma management decisions during clinical encounters.

## Healthcare facilities and systems

**Barriers:** Patients receive asthma care in various settings – primary care, specialists, emergency departments/hospitals, free-standing urgent care sites. Without easy access to notes or prescription information across different electronic medical record (EMR) systems, clinicians do not have the most up-to-date information about acute exacerbations or revised asthma treatment plans (33). While mechanisms (including antiquated methods such as faxing) exist for communication amongst clinicians regardless of EMR, systemic barriers prevent fully integrated communication. Families seeking care through different healthcare systems may experience conflicting management recommendations if clinicians and stakeholders are not aware of all phases of care.

**Opportunities:** National mandates should facilitate secure exchange of up-to-date clinical data and communications between health care professionals across various settings, including clinics, emergency departments, hospitals, and pharmacies. EMRs should be integrated with accurate insurance formulary and direct patient cost information to support decision-making. EMRs should provide appropriate prompts and flags for at-risk patients (e.g. recent ED visits or hospitalizations, not on appropriate controller therapy) while minimizing prompts with little clinical impact.

## Clinicians, community health workers, asthma educators

**Barriers:** Healthcare professionals face considerable challenges in delivering comprehensive guideline-based asthma care to children, including limited time and personnel resources. Asthma is one of many items that need to be addressed in a brief primary care encounter. Furthermore, disparities exist regarding the extent to which asthma guidelines are followed by prescribing physicians. Children with persistent asthma who are Black or Latinx, have public insurance, and/or receive care in hospital-based clinics and community health centers are less likely to be prescribed inhaled steroids than children who are White, have private insurance, and/or receive primary care in private practice settings (34). Frequent changes in asthma formularies and multitudes of new inhaler devices with different instructions can contribute to clinician confusion, suboptimal prescribing patterns, and inadequate patient and family education.

**Opportunities:** Quality improvement projects, driven by key stakeholders and organizations, can help improve adherence to national guidelines in primary care. Easy Breathing<sup>®</sup>, a program that includes systematic symptom assessment, provider education on correct prescribing, and guidance on insurance formulary preferences, resulted in a three-fold increase in inhaled corticosteroid prescriptions and significant improvements in guideline adherence in urban primary care clinics in Hartford, CT (35). Development of an asthma specialty clinic within a primary care medical home can improve access to high-quality guideline-based asthma care, including correct identification of children who need to be prescribed ICS (36). Team members besides physicians and nurses, such as parent telephone coaches and trained health profession student educators can provide asthma education to patients and families to optimize correct use of inhaled medications (37,38). Other strategies for improving guideline adherence include appropriate electronic decision support tools (39), practice and community-level registries to promote guideline-based

chronic disease management (40), and expanded funding for complementary resources outside the clinic walls such as community health workers (CHW) (41).

## Societal

### Disparities in access to care and outcomes

**Barriers:** Disparities in access to care and outcomes continue to be significant problems. Asthma disproportionately affects minority and low-income youth with greater disparities among children under 5 years (33). Inequitable social determinants of health are associated with lower rates of guideline-based asthma care, including lower rates of maintenance inhaler prescriptions, and lower rates of specialist referral (42).

**Opportunities:** Programs aimed at addressing asthma disparities have shown efficacy. CHWs and patient navigators can help ensure at-risk families have access to transportation and other resources to minimize the negative effects of social determinants of health. In addition, they can deliver culturally tailored education about asthma and its management, including medications. While CHW programs have proven beneficial (41), opportunities exist to move beyond grant-funded, short-term models to those that are reimbursed by insurers and integrated with clinical care and community settings. Telehealth, home spirometry, and other mobile health innovations are tools that can expand access in underserved and/or rural areas, though these may require technology and high-speed internet which remains challenging in some locations. Stakeholders at local, regional, and national levels must be involved in coordinated efforts to reduce air pollution and work toward equity in housing and living standards.

### Payers

**Barriers:** Public and private insurers play a critical role in ensuring children have access to necessary asthma medications. Restrictive formularies limit clinicians' ability to prescribe guideline-based asthma medication, especially in children where consideration of device characteristics is essential to ensure proper use. Formulary changes for controller medication (sometimes called non-medical switching) leads to confusion and frustration for families and clinicians (43), resulting in reduction in lung function in pediatric asthma (44). Products preferred by insurance formularies may be inappropriate for younger children with asthma who are unable to use breath-actuated devices.

Out-of-pocket costs, even for covered medications, may be too expensive for families, leading to lower fill rates and increased healthcare utilization (45). Prescription drug costs in the United States are markedly higher than in other industrialized nations with no evidence of an association between research and development costs and prices; instead, prices are based almost solely on market conditions (46). Furthermore, complicated drug procurement, authorization, and distribution systems using pharmacy benefit managers as middlemen induce extra layers of complexity and lead to increased costs for patients (47). Prior authorization requirements contribute to administrative burden for clinic staff and lead to delays in obtaining therapy. Certain insurance plans may limit which specific pharmacies may be used, further limiting access. Barriers to obtaining prescription medications may lead to inappropriate, unregulated, and potentially dangerous use of over-the-counter



alternative quick-reliever medications (e.g. Primatene Mist [epinephrine aerosol]) (48) or use of medications prescribed for another person (e.g. friend, relative).

**Opportunities:** Formulary development should specifically consider children's needs and allow flexibility for clinicians to select age and size appropriate products for a given class of asthma therapy. Uniform formularies across payers in a geographic area, such as the Massachusetts Medicaid Unified Formulary (49), may also help reduce clinician confusion. Policies should be implemented to limit non-medical switching and specifically to allow patients who are stable on a given therapy to remain on that therapy regardless of future formulary changes. Out-of-pocket costs for critical medications such as asthma inhalers should be minimized. Payors need to cover the cost of a sufficient number of VHCs along with pMDIs to ensure cost is not a barrier to a child using inhaled medication correctly at home and school.

### Pharmaceutical companies

**Barriers:** The design and availability of inhalers affect patient access and proper use. Pharmaceutical companies have a financial incentive to extend patents on their products to maintain trademark exclusivity and derive further profits. This incentive, in part, has led to the development of an array of unique asthma inhaler devices, sometimes altering traditional pMDIs and inhibiting their use by younger children. For example, in 2018, Teva's pMDI version of QVAR<sup>®</sup>, readily usable in any age group with an appropriate VHC device, was replaced by the RediHaler<sup>®</sup> device, which is breath-actuated and therefore not practical for younger children. DPIs have assumed a dizzying array of proprietary formats, including Diskus<sup>®</sup>, Ellipta<sup>®</sup>, Flexhaler<sup>®</sup>, Handihaler<sup>®</sup>, Turbuhaler<sup>®</sup>, and Twisthaler<sup>®</sup>, each with unique idiosyncrasies and required sequence of steps for proper use.

Simple design choices may lead to confusion as well. Many patients differentiate their inhalers by color, such as blue for quick-relief inhalers and red for controller/maintenance inhalers. The lack of standardization of color schemes for different classes of inhalers makes it easy to confuse inhalers, especially when restrictive formularies and non-medical switching may lead to different products being prescribed than intended by the clinician. These issues may also contribute to families accumulating old inhalers, leading to confusion. In addition, canisters in pMDIs are interchangeable which, if done accidentally, can inadvertently lead to children using the wrong product.

Beyond device design, other factors related to pharmaceutical companies can affect access. Supply chain disruptions, which have worsened during the COVID-19 pandemic, may cause shortages of products, requiring patients to be transitioned to other products. These changes may then create coverage issues with insurance formularies. Pharmaceutical companies may also incentivize payers with discounts to give preference to newer products on their formularies, leading to non-medical switching.

**Opportunities:** Inhalers should be color coded by class across manufacturers to improve inhaler identification by patients, caregivers, and clinicians. Inhalers should be tamperproof to prevent inadvertent product switching, and device designs within product categories (e.g. pMDIs, DPIs) should be uniform for ease of use. In addition, stronger patent rules to

minimize extensions could lead to more robust generics and lower costs. Pharmaceutical companies and payors should work to ensure that product shortages do not affect patient access to equivalent medications. Pharmaceutical companies and the FDA should consider studying safer alternatives for over-the-counter asthma medications, including reliever therapies that combine a bronchodilator and inhaled steroid for anti-inflammatory benefit, as these are likely to be safer and more effective than over-the-counter inhaled epinephrine.

## Future directions and conclusions

The process for getting critical asthma medications to children and ensuring their proper use remains unnecessarily complex. Clinicians should be aware of how these barriers impact their patient population. Awareness is not sufficient; systematic changes are needed at various levels to remove barriers and ensure resources are available to address these barriers equitably. A comprehensive approach must be taken by national stakeholders and organizations across multiple domains to develop and implement strategies to ease this complexity and thereby improve pediatric asthma morbidity.

## Funding

Anna Volerman was supported by the National Heart, Lung, and Blood Institute (K23HL143128).

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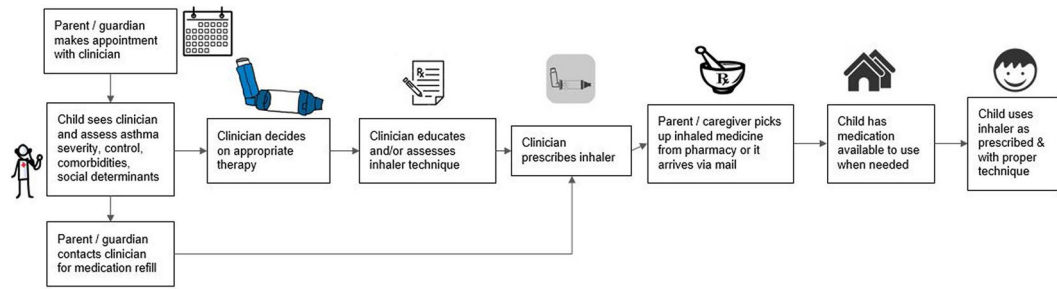
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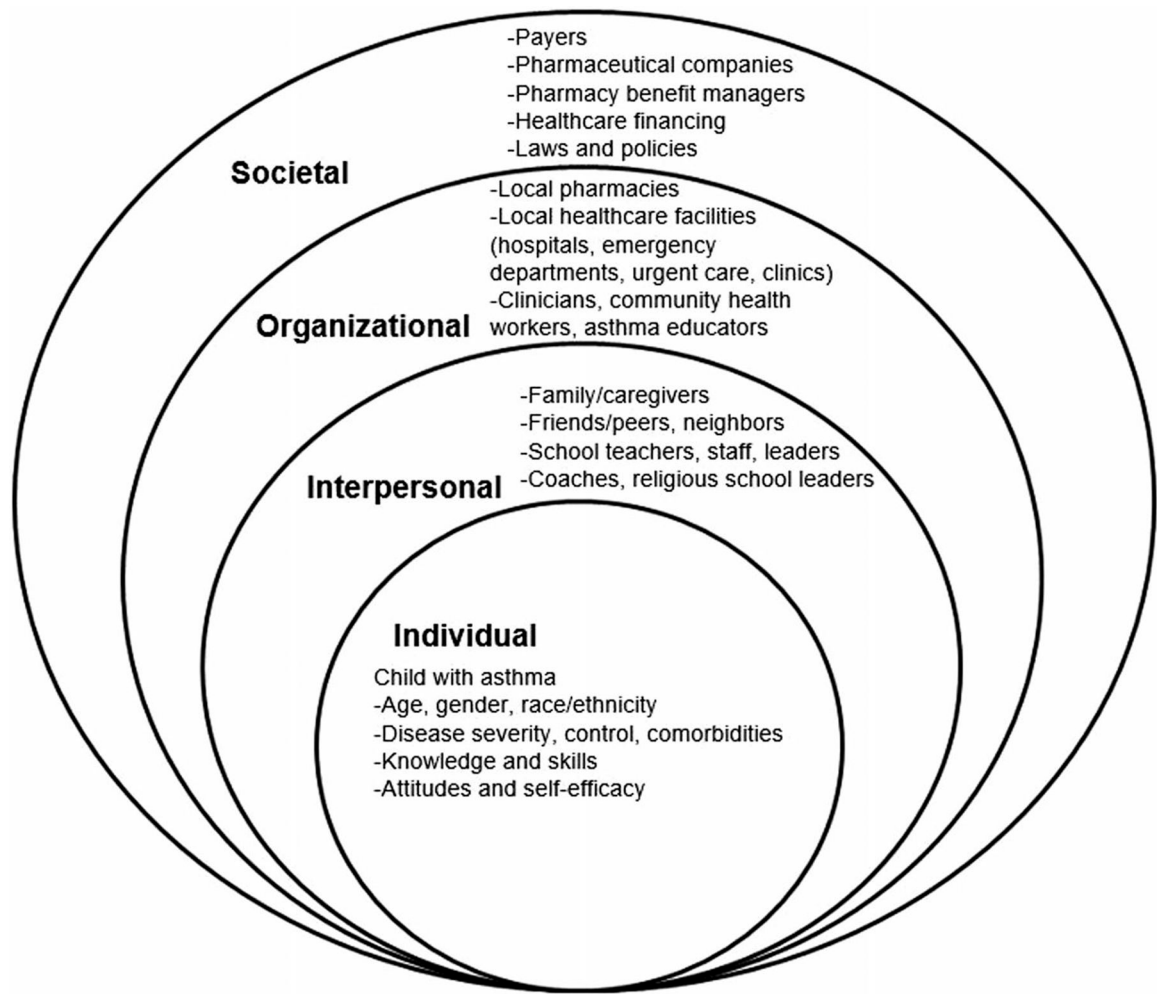
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**Barriers:**

<ul style="list-style-type: none"> <li>Limited access to medical home or clinician to manage asthma</li> <li>Difficulty contacting office or making appointment for convenient time</li> <li>Transportation barriers</li> </ul>	<ul style="list-style-type: none"> <li>Clinician not up to date on latest guidelines</li> <li>Clinician not aware which inhalers are covered by patient's insurance</li> </ul>	<ul style="list-style-type: none"> <li>Clinician does not know correct technique</li> <li>Clinician and/or staff does not have time to educate</li> </ul>	<ul style="list-style-type: none"> <li>Prescription not sent and/or received by pharmacy</li> <li>Prescription has incomplete instructions</li> </ul>	<ul style="list-style-type: none"> <li>No insurance or underinsured with high costs/co-pays</li> <li>Medication and/or valved holding chamber not covered by insurance</li> <li>Prescribed medication unavailable</li> <li>Insurance formulary changed</li> <li>Difficulty with transportation to pharmacy</li> </ul>	<ul style="list-style-type: none"> <li>Only one inhaler covered at a time</li> <li>Inhaler becomes lost</li> <li>Cumbersome storage requirements at school</li> <li>Adults caregivers do not know about asthma or best practices</li> </ul>	<ul style="list-style-type: none"> <li>Child not know frequency or proper technique</li> <li>Fear / stigma associated with medication use (i.e. steroids)</li> </ul>
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**Figure 1.** Pathway to achieve proper inhaler use in children with asthma, with examples of barriers at each step.



**Figure 2.**  
Socio-ecological model for childhood asthma.



Table 1.

Common device types for inhaled medications.

Device type	Description	Examples	Pros	Cons
Nebulizer	Medical device requiring a power source to generate fine mist from a liquid for inhalation	Albuterol, ipratropium, budesonide respules	Does not require effort on the part of the patient; can be used at any age	Requires a machine and electricity; medication administration is more time consuming than inhaler devices
Pressured metered dose inhaler (pMDI)	Small, pressurized canister in an inhaler that dispenses a preset dose of medication for inhalation with actuation of the device	Albuterol HFA, Flovent HFA, Dulera HFA	Quick and convenient medication administration; Can be used at any age	In most cases requires the use of a valved holding chamber for optimal deposition
Dry powder inhaler (DPI)	Handheld, breath actuated inhaler device with medication contained in a premeasured dose of inhaled powder	Proair Respiclick, Advair Diskus, Asmanex Twisthaler, Pulmicort Turbuhaler	Quick and convenient medication administration; does not require any attachments for use	Requires attainment of a minimum inhaled flow rate; not appropriate for younger children; multiple different styles and designs which can be confusing for users
Soft mist inhaler (SMI)	Handheld inhaler which releases a soft mist slower than a pMDI	Spiriva Respimat	Quick and convenient medication administration; does not require any attachments for use	Devices can be complex and requires assembly by end-user; requires cooperation and coordination for use, not appropriate for younger children

Barriers and possible solutions to obtaining and using inhalers organized by socio-ecological model levels.

**Table 2.**

Socio-ecological model levels	Examples of barriers to inhaler prescribing, accessibility, and proper use	Potential solutions for improving inhaler prescribing and accessibility
1. Individual	Perception of disease Child's knowledge about asthma, proper inhaler use Expectations of disease control / self-efficacy	<ul style="list-style-type: none"> <li>• Intentionally use strategies to improve health literacy (18,50)</li> <li>• Select specific inhalers that match patient needs/preferences/skills (51)</li> <li>• Incorporate on-line youth support groups and other mobile health technologies into care (13)</li> </ul>
2. Interpersonal	Family perceptions/knowledge about asthma and inhalers; barriers to medication administration, transportation Peer perceptions (e.g. bullying) School nurse availability, presence, knowledge, perceptions; teacher knowledge	<ul style="list-style-type: none"> <li>• Refer to community outreach or education programs (e.g. Boston Children's Community Asthma Initiative)</li> <li>• Use shared decision making (52)</li> <li>• School administration of medications (27,29,30)</li> <li>• Improved availability of asthma medications in schools (31)</li> </ul>
3. Organizational	Pharmacy access Navigation of complex health systems to obtain care and medication (53) Clinicians, community health workers, asthma educator limitations	<ul style="list-style-type: none"> <li>• Pharmacy delivery to homes, schools</li> <li>• Pharmacies integrated into clinic sites</li> <li>• Incentives for guideline based prescribing practices (54)</li> <li>• Team-based care approach in health settings (32,55) (for educating families, managing prior authorizations and other administrative burdens) (56)</li> <li>• Education programs for clinicians (35)</li> <li>• Use of information technology alerts based in guidelines and appropriately tailored to individuals with clinician input</li> </ul>
4. Societal	Lack of standardization of inhaler attributes (color, device style/instructions, etc.) by pharmaceutical companies Differences in coverage, co-pays, and formularies between payors Major disparities in healthcare access/outcomes caused by systemic/structural racism	<ul style="list-style-type: none"> <li>• Consistent color schemes for inhalers across manufacturers (one for quick-relief and another for controller) and standardization of devices</li> <li>• FDA approval of Single Maintenance and Reliever Therapy and widespread adaptation of updated asthma guidelines (1)</li> <li>• Pharmacy benefit managers reform</li> <li>• Uniform Medicaid formularies within states that remain stable over time (44)</li> <li>• Community health workers, patient navigators (57)</li> <li>• Increase diversity of clinicians and staff to improve concordance (58)</li> <li>• Increase access to telehealth and remote monitoring (e.g. home spirometry)</li> <li>• Address Social Determinants of Health (14,59)</li> </ul>