SYSTEMATIC REVIEW

# Impact of digital technologies on pediatric asthma care

Raffaella **Nenna** [1,°], Sara **Manti** [2,°,*], Giuliana **Ferrante** [3,4],
Velia **Malizia** [4], Pietro **Alfano** [4], Giuseppe Fabio **Parisi** [5], Domenico Paolo **La Regina** [1],
Luigi **Gallo** [6], Alessandra **Pandolfo** [4,7], Amelia **Licari** [8,9], Stefania **La Grutta** [4],
Italian Pediatric Respiratory Society's Task Force on digital technology in children with asthma

*Correspondence to:
smanti@unime.it

Doi
10.56164/PediatrRespirJ.2026.01

° These authors contributed equally
[1] Department of Maternal Infantile and Urological Sciences, Sapienza University of Rome, Rome, Italy
[2] Pediatric Unit, Department of Human and Pediatric Pathology "Gaetano Barresi", "G. Martino" Hospital, University of Messina, Messina, Italy
[3] Department of Surgery, Dentistry, Pediatrics and Gynaecology, Pediatric Division, University of Verona, Verona, Italy
[4] Institute of Translational Pharmacology (IFT), National Research Council of Italy (CNR), Palermo, Italy
[5] Pediatric Respiratory and CF Unit, San Marco Hospital, University of Catania, Department of Clinical and Experimental Medicine, Catania, Italy
[6] Department of Information Sciences and Technologies, Pegaso University, Napoli, Italy
[7] Department of Economics, Business and Statistics (dSEAS), University of Palermo (UNIPA), Palermo, Italy
[8] Pediatric Unit, Department of Clinical, Surgical, Diagnostic and Pediatric Sciences, University of Pavia, Pavia, Italy
[9] Pediatric Clinic, Fondazione IRCCS Policlinico, San Matteo, Pavia, Italy

## ABSTRACT

Asthma is one of the most common chronic diseases in children, significantly impacting their health, quality of life, and healthcare systems globally. Pediatric asthma accounts for substantial morbidity, including frequent exacerbations, emergency department visits, and missed school days. Despite the availability of effective treatments and clear management guidelines, achieving optimal asthma control remains a challenge. In recent years, digital technologies have emerged as transformative tools in asthma care, offering new ways to monitor, educate, and treat pediatric patients.

A systematic review was conducted to examine the impact of digital technologies on pediatric asthma care, synthesizing evidence on their effectiveness, challenges, and future directions. Covering studies from January 2020 to December 2024, the review analyzed 59 primary studies that involved mobile health (mHealth) applications, electronic medication monitoring systems, wearable devices, artificial intelligence (AI)-powered solutions, and school-based telemedicine programs.

Findings reveal that mHealth applications and serious games promote self-management, improve medication adherence, and support patient education. Telemedicine, including school-based and remote patient monitoring, enhances care accessibility, reduces emergency visits, and promotes continuity of care, particularly in underserved populations. Wearable devices and electronic monitoring tools enhance symptom tracking and evaluation of inhaler technique. AI-driven interventions, such as digital twin systems, show promise in personalizing treatment and predicting exacerbations.

Despite encouraging outcomes, challenges remain, including digital literacy gaps, limited access to devices and the internet, and difficulties integrating digital tools into clinical workflows. Usability and sustainability vary widely depending on design approaches, caregiver engagement, and infrastructure readiness.

## IMPACT STATEMENT

Digital technologies show promise in asthma management. Despite encouraging outcomes, challenges remain, including digital literacy gaps, limited access to devices and the internet, and difficulties integrating digital tools into clinical workflows.

KEY WORDS
*Asthma; artificial intelligence-powered solutions; children; mobile health applications; wearable devices.*

 © 2026 Pediatric Respiratory Journal - PRJ. Published by Edra Media S.r.l. All rights reserved.

## INTRODUCTION

Asthma is one of the most common chronic diseases in children, significantly impacting their health, quality of life, and healthcare systems globally. Pediatric asthma accounts for substantial morbidity, including frequent exacerbations, emergency department visits, and missed school days. Despite the availability of effective treatments and clear management guidelines, achieving optimal asthma control remains a challenge.

In recent years, digital technologies have emerged as transformative tools in asthma care, offering new ways to monitor, educate, and treat pediatric patients. These include mobile health (mHealth) applications, telemedicine platforms, wearable devices, and artificial intelligence (AI)-enabled solutions. Such technologies promise to improve asthma control by facilitating better disease monitoring, enhancing medication adherence, and enabling more proactive and personalized care (1-7).

Mobile health applications have also gained prominence for their potential to enhance asthma control. These apps often include features such as symptom tracking, medication reminders, educational resources, and real-time feedback for children and their caregivers (8-11). However, real-world implementation has revealed practical challenges such as recruitment barriers, communication issues, and low retention in pilot studies, emphasizing the need for adaptable strategies tailored to pediatric populations (12). Additionally, AI-powered solutions, such as digital twin systems (DTS), leverage real-time data to personalize care and predict exacerbation risks, enabling a more tailored approach to asthma management (7, 13).

School-based telehealth programs represent another effective intervention for pediatric asthma. By integrating healthcare services into school settings, these programs address logistical barriers, such as transportation issues and caregiver availability, while engaging school nurses in asthma management. These programs have been shown to improve asthma outcomes by ensuring regular follow-ups, medication adherence, and symptom monitoring during school hours (7, 14, 15).

Furthermore, wearable devices and electronic medication monitoring (EMM) systems have advanced the management of pediatric asthma. These technologies allow real-time tracking of medication use and provide objective data on treatment adherence, a critical factor in achieving asthma control. For instance, Bluetooth-enabled sensors attached to inhalers can monitor usage patterns, offering valuable insights for both caregivers and healthcare providers (16). Similarly, digital wheeze detectors and other wearable devices are enhancing early detection of symptoms, enabling timely interventions and reducing the risk of severe exacerbations (7, 17).

Despite the promising impact of these digital tools, their implementation faces several challenges. Social determinants of health, such as limited internet access, low health literacy, and economic constraints, can hinder the adoption of digital technologies, particularly in underserved populations (18-20).

Moreover, integrating digital technologies into existing healthcare workflows is complex. Healthcare providers often cite concerns about data privacy, the time required to learn new systems, and the lack of interoperability between digital tools and electronic health records (7, 18, 21).

Research on the effectiveness of digital health interventions in pediatric asthma is growing. Evidence suggests that these technologies improve medication adherence, reduce healthcare utilization, and enhance overall asthma control. However, gaps remain in understanding the long-term impact, scalability, and cost-effectiveness of these solutions (2, 7, 14, 15).

This systematic review examines the impact of digital technologies on pediatric asthma care, synthesizing evidence on their effectiveness, challenges, and future directions. By providing insights into the current state of digital asthma care, this review aims to guide clinicians, policymakers, and researchers in leveraging these tools to improve outcomes for children with asthma.

## METHODS

The systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, as specified in the reference literature (22).

### Outcomes

The primary outcome of this study is the systematic assessment of digital technologies implemented in pediatric asthma care. The analysis focused on evaluating the clinical effectiveness, adherence improvement,

healthcare utilization reduction, feasibility, usability, and equity implications of digital health interventions in children and adolescents with asthma.

The included studies were categorized into four thematic domains: School-Based Telehealth Studies; Serious Game Studies; Asthma Management Technologies; Impact of COVID-19 and Caregivers' Experience.

### Inclusion and exclusion criteria

The studies included in the systematic review were published between January 2020 and December 2024, a time frame chosen to ensure that the evidence was relevant and up to date in the context of the study. In order to adequately address the research question, the inclusion criteria are the following: 1) focused on a population with asthma, 2) involved children or adolescents aged 0-18 years, 3) primary study, 4) included an intervention involving a device, and 5) English language text. Our analysis excluded clinical guidelines, case reports, consensus documents, clinical trials and reviews. We also excluded conferences and congress abstracts because of limited data and the potential risk of bias.

### Search strategy

A sensitive search strategy was designed to retrieve all articles from the major online databases: PubMed, Web of Science, Embase, and Scopus. Searches were conducted using one or more search terms (**Table 1**). Studies of different methodological types were included, such as cross-sectional studies, non-randomized trials, quasi-experimental studies, before-after controlled studies, Cluster Randomized Trials (CRTs), Randomized Controlled Trials (RCTs), case-control studies, and cohort studies. The identification and removal of duplicate studies was automated using Zotero software. Then three independent reviewers (identified by the initials GP, DLR and PA) performed an initial assessment of the titles and abstracts of the identified studies. The aim of this evaluation was to select articles that met the inclusion criteria. Articles that passed this initial stage were retrieved in full text for a more thorough assessment, to determine whether they met the defined inclusion criteria and to identify the primary studies to be included. Any discrepancies were resolved by discussion and consensus with an additional researcher (RN and SM). The selected studies were then used for data extraction to gather the necessary information to address the objectives of the review.

As illustrated in the PRISMA flowchart (**Figure 1**), the final database search conducted in May 2025 yielded 428 records. Following the removal of 96 duplicate entries, the remaining records underwent a two-step screening process. Initially, titles and abstracts were assessed for relevance, after which full-text reviews were performed. A total of 273 publications were excluded based on predefined exclusion criteria. Ultimately, 59 articles that met all the inclusion criteria were deemed eligible and included in the systematic review.

***Table 1**. Query Research String.*

| Query Research String |
| --- |
| **PubMeD** |
| ((((“digital”[All Fields] AND “health”[All Fields]) OR “digital health”[All Fields] AND (“technology”[MeSH Terms] OR “technology”[All Fields] OR “technologies”[All Fields] OR “technology s”[All Fields])) OR (“telemedicine”[MeSH Terms] OR “telemedicine”[All Fields] OR “telemedicine s”[All Fields])) AND (“asthma”[MeSH Terms] OR “asthma”[All Fields] OR “asthmas”[All Fields] OR “asthma s”[All Fields]) AND (“child”[MeSH Terms] OR “child”[All Fields] OR “children”[All Fields] OR “child s”[All Fields] OR “children s”[All Fields] OR “childrens”[All Fields] OR “childs”[All Fields])) AND ((allchild[Filter]) AND (2020:2024[pdat])) |
| **Embase** |
| digital health technology OR telemedicine AND asthma AND children (All Fields) and 2020 or 2021 or 2022 or 2023 or 2024 or 2025 (Publication Years) and English (Languages) |
| **Web Of Science** |
| digital health technology (All Fields) AND telemedicine (All Fields) AND asthma (All Fields) AND children (All Fields) Timespan: 2020-01-01 to 2024-12-31 (Publication Date) |
| **Scopus** |
| TITLE-ABS-KEY ( digital AND health AND technology OR telemedicine AND asthma AND children ) AND PUBYEAR >2019 AND PUBYEAR <2025 |

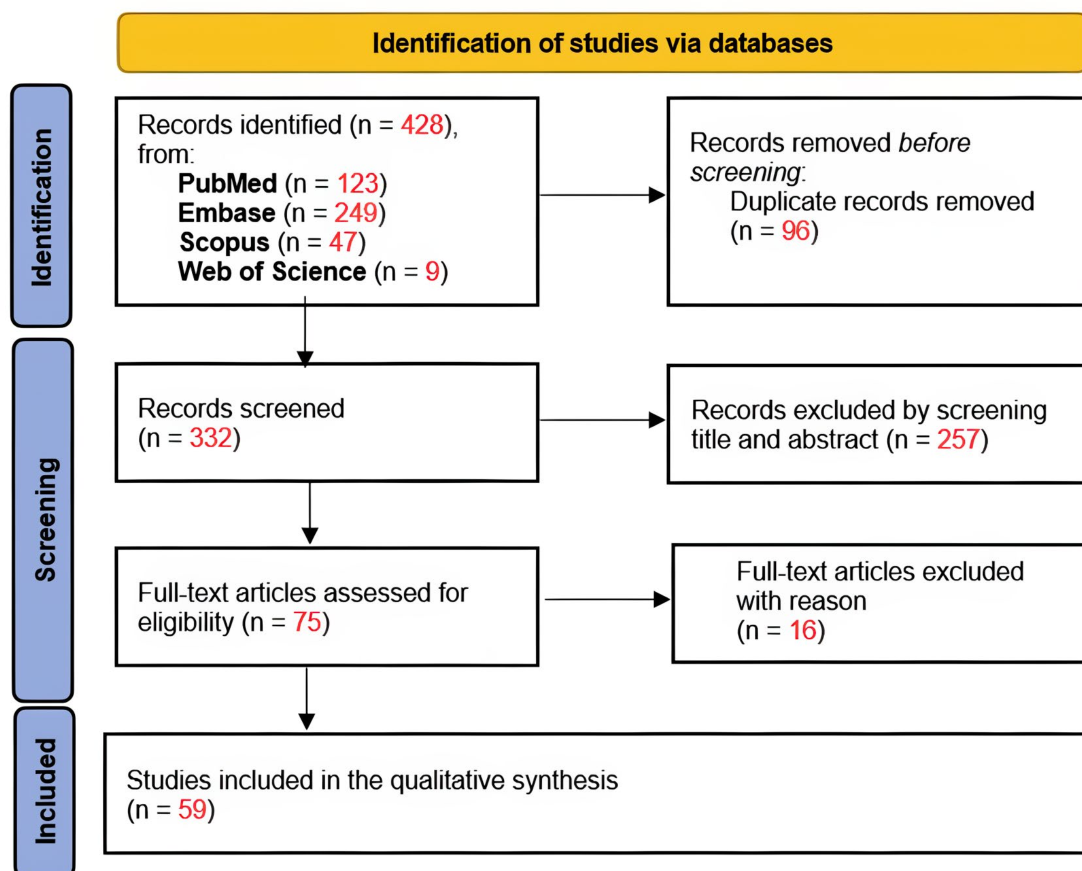


***Figure 1.*** *PRISMA flowchart showing the study selection process.*

### Risk of bias assessment

Two reviewers (RN and SM) independently assessed the risk of bias of the included studies, by using a validated checklist, the Johanna Briggs Institute critical appraisal tools (23), according to the design of the study. Selection and information bias, confounders, blinding, data analysis methods were the main domains checked for the risk of bias. An overall risk of bias was reported for each study, then normalized to 100 and expressed as "low", "medium" and "high" (first, second and third tertile, respectively).

## RESULTS

### Study characteristics

A total of 428 articles were found. After removing 96 duplicates, 332 were reviewed on title and abstract and 257 articles were excluded from this group. 75 full texts were screened, and 16 were excluded based on type of intervention, absence of a control group, small sample sizes, non-relevant context, and interventions not easily implementable in clinical practice. 59 articles were assessed for eligibility. The studies predominantly focus on pediatric populations, encompassing infants (0–12 months), school-aged children (6–12 years), and adolescents (12–18 years). A limited number extend to adult cohorts for comparative analyses. Most investigations center on children aged 5–15 years, a critical developmental window for asthma management and digital health interventions.

Specifically, 6 studies addressed the topic of *School-based Telehealth*, 6 studies where about *Serious games*, 30 studies investigated *Asthma management*, and 17 studies addressed *Impact of COVID-19, caregivers' experience* (**Supplementary Materials Table S1, Table S2** and **Table S3**).

Telemedicine monitoring strategies include remote patient monitoring (8, 24), and school-based telehealth programs

[25-27], and virtual home visits [28], aiming to enhance healthcare accessibility, reduce school absenteeism, and minimize emergency visits. Mobile health (mHealth) applications (2, 19, 29-31), and serious games (29, 32), emphasize asthma self-management, leveraging gamification and family engagement to improve adherence. Electronic medication monitoring devices (EMDs) and digital inhalers (17, 33-35), facilitate the tracking of inhalation techniques, adherence monitoring, and risk pattern identification. Additionally, emerging technologies such as Digital Twin Systems (13) and augmented reality (36), alongside advanced digital monitoring combined with AI solutions (35), offer innovative solutions for asthma education and clinical training. The primary outcomes of these interventions focus on asthma management, healthcare utilization, cost-effectiveness, and user engagement.

Digital tools have been shown to enhance medication adherence by 12–23% (33) and improve symptom control and exacerbation prevention. Telemedicine programs significantly reduce emergency room visits and hospitalizations (21, 24, 37), with some studies reporting a 100-fold increase in telehealth adoption (21). Economic analyses suggest that telehealth interventions mitigate caregiver wage loss and decrease school absenteeism (25, 28). Furthermore, usability studies (30-32, 36), showed feasibility and positive user feedback, especially in preschool and adolescent populations.

Overall, telemedicine has demonstrated substantial improvements in asthma care and accessibility, reducing absenteeism and hospitalization rates while increasing parental satisfaction (26, 27, 38, 39).

mHealth applications effectively promote self-management, with high engagement and better asthma control outcomes (19, 40, 41). Electronic monitoring systems significantly enhance medication adherence (33-35). While augmented reality and artificial intelligence present promising advancements, concerns remain regarding their potential to replace direct clinical interactions, necessitating further validation (36).

## DISCUSSION

### User-Centered Design for mHealth Applications and Serious Games

The integration of digital tools into pediatric asthma care necessitates a user-centered, strategically planned

***Table 2**. User-centered design methodologies.*

| Aspect / Solution | ARCA [1] | REACT [2] | MIRACLE [3] | AIM2ACT [4] |
| --- | --- | --- | --- | --- |
| **Application Type** | mHealth | mHealth | serious game | mHealth |
| **Target Users** | Adolescents with asthma and their caregivers | Adolescents with asthma | Children with asthma | Adolescents with asthma and their caregivers |
| **Key Features** | Monitoring, action plans, educational materials, medication adherence | Goal intention–formatted messages, motivation assessment, problem-solving modules | Interactive storytelling, educational gameplay | EMA, goal setting, behavioral contracting, skills-training videos |
| **Design Process** | Developed with a focus on usability, involved systematic reviews | User-centered design with iterative feedback and algorithm development | User-centered design with focus on engagement | User-centered design with feedback from adolescents and caregivers |
| **Development Approach** | Iterative development with usability testing | Iterative development with user feedback | Iterative design with user engagement focus | Iterative design with stakeholder feedback |
| **Implementation Strategy** | Multi-platform support, offline functionality | Mobile app with interactive modules | Game-based learning approach | Mobile app with interactive features |
| **Evaluation Methodology** | Usability assessed with System Usability Scale | Feasibility, acceptability, and preliminary efficacy evaluated through pilot studies | Engagement and educational impact assessment | Feasibility, acceptability, and preliminary efficacy evaluated through pilot studies |

approach that balances technological innovation with clinical utility. Telemedicine, supported by advanced wireless communication, should complement traditional care models (7). Mobile applications, interactive platforms, and serious games for children and adolescents introduce unique challenges in design and implementation. Employing a user-centered design (UCD) framework ensures these tools remain engaging, usable, and responsive to the needs of young patients and caregivers. Continuous end-user involvement throughout development enhances usability, adherence, and clinical outcomes.

Studies indicate that digital interventions can address key adherence barriers, such as forgetfulness, irregular medication use, and insufficient educational resources. Across various models, the literature underscores the necessity of iterative development and systematic incorporation of user feedback.

The ARCA platform (30) exemplifies structured UCD, offering a color-coded dashboard for patient-reported outcomes (PROs) and developed through a seven-phase process, though patient and family involvement was limited to later stages. Usability was evaluated with the System Usability Scale (SUS). REACT (40) focuses on adolescent adherence via a self-regulation tool, integrating feedback from interviews and national crowdsourcing; formal usability testing is still pending. MIRACLE (7), an educational program for Indonesian children, uses storytelling and games based on the NEMD theory and SERES framework, with usability testing planned.

AIM2ACT (29) combines ecological momentary assessment, goal setting, behavioral contracts, and skill-building for adolescents and caregivers, and has undergone feasibility and acceptability testing with positive preliminary outcomes. The JASMIN app (12), based on the pediatric self-management model, enhances communication and collaborative care through symptom tracking and shared action plans. Despite methodological differences, these interventions converge on iterative refinement and stakeholder engagement. Of these, only AIM2ACT (29) has progressed to advanced evaluation stages.

## Digital technologies and asthma care

Integrating digital technologies into asthma care represents a transformative shift in managing this chronic condition, particularly among pediatric populations. Multiple studies highlight the potential and challenges of digital interventions, including mHealth applications (19), telemedicine, wearable devices [42], augmented reality (AR) (36), and Electronic Medication Monitoring Systems (EMM) (17) (**Table 3**). These innovations aim to address critical barriers in asthma care, such as poor adherence, limited access to specialized healthcare, and inadequate patient education, fostering better outcomes. Likewise, technologies offering real-time provider-patient communication may enhance diagnostic precision for children with asthma who may need ongoing adjustments to treatment (19).

## Mobile health applications

Mobile health (mHealth) tools are increasingly integrated into pediatric asthma care, offering functionalities such as symptom tracking, medication reminders, and educational support. A retro-prospective study on the Nemours app found that 56% of providers and 61% of caregivers used the app to enhance communication and caregiver health literacy. Use of its messaging function was positively associated with higher health literacy scores ($\beta = 0.44$, $p = 0.041$) and improved symptom reporting that supported asthma action plan adjustments (19).

In a pilot RCT, the AIM2ACT intervention, combining ecological momentary assessment, tailored feedback, and skills training, significantly improved Asthma Control Test (ACT) scores in adolescents aged 12–15 and their caregivers [29]. Retention was high (97% at follow-up), especially in underserved populations, supporting the feasibility and acceptability of personalized mHealth strategies.

Beyond asthma, mHealth tools like “AllergyMonitor” have addressed allergic rhinoconjunctivitis, a frequent asthma comorbidity. A study of 125 children from Berlin and Ascoli Piceno used the app to collect daily symptom and medication data, analyzed using fuzzy k-medoid clustering of Combined Symptom and Medication Score (CSMS) trajectories (43). This identified symptom severity clusters and linked them to environmental exposures, showing the value of real-time, personalized feedback.

Despite promising outcomes, implementation challenges remain. Wyatt *et al.* (12) reported consistent difficulties across all phases of participant recruitment

in a pediatric asthma mHealth study, highlighting the need for flexible, iterative recruitment strategies. Similarly, "Asmapp" was piloted in preschoolers with recurrent wheeze, allowing daily symptom tracking and clinician access to real-time data (31). Although no clinical improvements were seen, caregiver acceptability exceeded 95%, and app-collected data were more detailed than retrospective questionnaires, underscoring the value of continuous digital monitoring for early childhood asthma management.

***Table 3.*** *Digital technologies and asthma care*

| Device/ Instrument Type | Brief Description | Pros | Cons | Impact on Pediatric Asthma Care |
|---|---|---|---|---|
| **Mobile Health Applications (mHealth)** | mHealth apps are digital tools designed to support asthma management by providing features like symptom tracking, medication reminders, air quality alerts, and patient education. (Ex:Nemours; AIM2ACT) | • Improves health literacy and self-management.<br>• Provides tailored feedback and real-time insights.<br>• Facilitates communication between patients, caregivers, and providers.<br>• Enables precision medicine approaches.<br>• Effective in fostering caregiver involvement and autonomy in adolescents. | • Dependent on internet access and device availability.<br>• Engagement varies based on socioeconomic factors.<br>• Potential for data overload without proper filtering and presentation.<br>• Some challenges in integrating with clinical workflows. | • **Enhances medication adherence and asthma control**: studies indicate that mHealth apps can improve adherence to treatment plans and overall asthma control in children and adolescents.<br>• **Facilitates parent-child shared management**: apps designed for joint use by parents and children promote collaborative management, leading to better health outcomes.<br>• **Potential to reduce healthcare utilization**: while some studies did not find a significant decrease in emergency visits, mHealth apps have been associated with improved self-management and patient confidence. |
| **Electronic Medication Monitoring (EMM) Systems** | EMM systems are devices or sensors attached to inhalers that monitor medication adherence and inhalation technique in real time. (EX Popeller Health sensor; Digihaler) | • Enhances medication adherence monitoring.<br>• Reduces emergency visits through early intervention.Combines data tracking with inspiratory effort measurement (Digihaler).<br>• Promotes provider-patient collaboration.<br>• Improves ICS adherence significantly in pediatric populations. | • Requires integration with existing healthcare workflows.<br>• Interoperability issues with EHR systems.<br>• Limited by technology literacy and administrative burdens.<br>• Occasional discrepancies in data due to incorrect usage of devices. | • **Improves adherence and health outcomes**: EMM systems have been shown to enhance adherence to inhaled corticosteroids and reduce asthma-related exacerbations in children.<br>• **Provides reassurance to caregivers**: parents report increased confidence and a sense of security when using EMM systems, knowing their child's medication use is being monitored.<br>• **Engages children in self-management**: the interactive nature of EMM devices can motivate children to take an active role in their asthma care. |

| Device/ Instrument Type | Brief Description | Pros | Cons | Impact on Pediatric Asthma Care |
|---|---|---|---|---|
| **Wearable Devices** | Wearable devices are technologies designed for continuous monitoring of asthma-related parameters such as lung function, activity levels, and sleep patterns. (Ex: Activity trackers; Handheld spirometers; Smart inhalers) | • Enables continuous real-world monitoring.<br>• Provides insights into trends that episodic evaluations may miss.<br>• Facilitates early detection of poor control and severe exacerbations.<br>• Strong correlation with clinical assessments.<br>• High compliance in pediatric populations when designed for ease of use. | • May not be accessible or affordable for all populations.<br>• Requires adherence to wearing and maintaining the device.<br>• Limited by battery life and potential data syncing issues.<br>• Data accuracy can vary based on compliance and device calibration. | • **Enables personalized asthma management**: continuous monitoring allows for tailored interventions based on individual patterns and triggers.<br>• **Early detection of exacerbations**: wearable devices can identify early signs of asthma attacks, prompting timely interventions.<br>• **Encourages proactive health behaviors**: the use of wearable technology can motivate children to engage in their health management actively. |
| **Augmented Reality (AR) Tools** | AR tools are interactive educational technologies that use augmented reality to enhance engagement and understanding of asthma management. (Ex: MIRACLE) | • Highly engaging and user-friendly for children.<br>• Increases retention of educational content.<br>• Improves inhaler techniques and knowledge of asthma triggers.<br>• Encourages proactive self-management behaviors.<br>• Can address educational gaps using immersive, culturally adapted narratives. | • Initial development costs can be high.<br>• Limited usability for older populations.<br>• Requires specific hardware (AR-enabled devices), potentially limiting accessibility.<br>• Challenges in widespread deployment due to technical barriers or resource constraints. | • **Enhances learning and retention**: AR tools make asthma education more engaging, leading to better understanding and recall of management techniques.<br>• **Improves inhaler technique**: interactive simulations help children master proper inhaler use, reducing medication errors.<br>• **Addresses educational disparities**: culturally adapted AR content can bridge knowledge gaps in diverse pediatric populations. |
| **Telemedicine Platforms** | Telemedicine platforms are digital systems that enable remote consultations, monitoring, and education through video calls, messaging, or specialized apps. (Ex: MCAV; Remote monitoring systems that integrate wearables) | • Expands access, especially for underserved populations.<br>• Reduces logistical barriers like transportation.<br>• Allows real-time symptom tracking and timely interventions.<br>• Enhances patient-provider communication.<br>• Addresses social determinants of health via resource linkage.<br>• Reduces no-show rates in pediatric programs. | • Internet and device access are prerequisites.<br>• Less effective for populations with low digital literacy.<br>• Requires careful planning to avoid excluding vulnerable groups.<br>• Challenges in integrating with existing clinical practices and workflows.<br>• Limited ability to conduct physical assessments remotely. | • **Increases access to care**: telemedicine overcomes geographical barriers, providing timely medical advice to children in remote areas.<br>• **Facilitates continuous monitoring**: integration with wearable devices allows healthcare providers to monitor patients' conditions in real-time, leading to proactive care adjustments.<br>• **Reduces healthcare costs**: by minimizing emergency visits and hospitalizations through early interventions, telemedicine can lower overall healthcare expenses. |

### Electronic Medication Monitoring Systems

Electronic Monitoring and Management (EMM) devices, such as the Propeller Health sensor and Digihaler, integrate adherence tracking with real-time feedback. The Digihaler also measures inspiratory effort, providing insight into both inhaler use and drug delivery effectiveness. A non-interventional study comparing the Digihaler with the inhalation profile recorder (IPR) showed accurate, clinically relevant data in pediatric patients, supporting treatment decisions on technique and adherence (34).

EMM systems enable personalized asthma care. In the iTRACC trial, automated alerts prompted timely interventions that addressed issues like prescription delays and missed doses (35). A qualitative study based on the Consolidated Framework for Implementation Research (CFIR) explored how ten healthcare providers perceived EMM integration. Interviews highlighted both the benefits and challenges of implementation in pediatric outpatient settings.

By embedding digital monitoring into clinical workflows, EMM tools improved provider-patient communication, identified nonadherence early, and helped prevent exacerbations and emergency visits (17, 29, 34, 43). These systems show promise in optimizing asthma management across diverse care contexts.

### Wearable technologies

The WEARCON study adopted a prospective observational design, focusing on children aged 4–14 years (42). The study highlighted their potential by integrating multiple devices to track real-world asthma management. For instance, pre-exercise lung function variation and respiratory rate recovery post-exercise emerged as reliable indicators of asthma control, correlating strongly with clinical assessments. Additionally, wearable devices enable ongoing symptom monitoring, addressing the limitations of episodic outpatient evaluations (42).

Remote Patient Monitoring programs, which integrate wearable and mobile devices, provide real-time monitoring of asthma symptoms and physiological data. A study explored the utility and effectiveness of the New Mexico Pictorial Asthma Action Plan, a telehealth delivery of a pictorial action plan, focused on youth aged 10 to 17 years, significantly improved asthma control scores, particularly in low-literacy, underserved populations. By combining RPM with tailored educational tools, this approach reduced barriers to care and enhanced patient-provider communication (39).

### Augmented reality tools

Digital technologies offer innovative tools to improve pediatric asthma management by combining education, engagement, and prediction. Augmented reality (AR) and serious games are increasingly used to enhance asthma education among children. The MIRACLE program (29), for example, integrated culturally adapted interactive storytelling and games to teach Indonesian children about asthma triggers and inhaler use while promoting self-management skills. Another study applied the Theoretical Framework of Acceptability to evaluate AR-based teaching tools co-designed with clinicians, children, and caregivers (36). These tools improved comprehension and retention by using animations and interactive content to support correct inhaler techniques. Beyond education, digital platforms are being used for early prediction of asthma exacerbations. The DIGIPREDICT study (35) is a prospective observational project that integrates data from wearable sensors, smart inhalers, and mobile apps to detect early physiological, behavioral, and environmental signals associated with asthma attacks. Using machine learning algorithms, the system generates personalized alerts aimed at preventing exacerbations and supporting clinical decision-making. DIGIPREDICT illustrates how AI-driven, patient-centered tools can address limitations in symptom recognition and enable real-time, remote asthma monitoring. These approaches show particular promise for underserved pediatric populations with inconsistent adherence and high variability in exposure patterns.

### Telemedicine

The COVID-19 pandemic catalyzed a rapid transition toward digital care in pediatric asthma management. A retrospective cohort study of 3,959 children aged 5–17 showed a sharp decline in in-person visits during the pandemic, offset by a rise in telehealth use. Asthma exacerbations fell from 12.7% to 3.2%, suggesting that remote care-maintained disease control (21).

Peláez *et al.* (44) reported similar findings in Argentina. Their prospective study within a severe asthma program found a 41% reduction in total exacerbations and a 46% decline in severe episodes after transition-

ing to teleconsultations. Remote ACT assessments via WhatsApp and virtual follow-ups helped sustain asthma control, underscoring the feasibility of hybrid care models combining telemedicine and mHealth.

The TEAM-ED program (Telemedicine Enhanced Asthma Management through the Emergency Department) linked ED care with school-based telehealth follow-ups. Though symptom-free days did not improve significantly, the program increased preventive medication use and follow-up visit rates among underserved children (27). These outcomes support integrating structured telehealth into pediatric care, especially in low-resource settings.

Remote patient monitoring (RPM) further extended care beyond acute episodes. At Cincinnati Children's Hospital, a pilot program used inhaler-attached sensors and nurse-led daily monitoring for recently discharged children. The intervention reduced ED visits and improved outpatient follow-up, despite challenges in engagement and retention (37).

Telemedicine has also addressed logistical and social barriers. The Mobile Clinic Asthma Van in Chicago reduced no-show rates through video consultations, improving care access for underserved families (45). At a tertiary academic hospital, a pediatric asthma telemedicine program helped link low-income families to housing and food support during the pandemic (8).

Yet, disparities remain. Pathak *et al.* (10) studied telehealth use in four New York clinics serving low-income, mostly Latino families. They found that Spanish speakers were 48% less likely to activate patient portals than English speakers, and non-Latinos had a 36% lower activation rate. These results emphasize the need for multilingual platforms, virtual rooming, and digital health navigators to close equity gaps.

Hall *et al.* (4) analyzed trends among 6,754 children, finding that telemedicine accounted for 74.3% of asthma visits at the pandemic's peak in April 2020, declining to 13.6% in 2022. Telehealth use was higher among children with persistent asthma, comorbidities, or public insurance. The Social Vulnerability Index did not significantly predict use, but access remained uneven for Black children and non-English speakers.

The BREATHE program in Louisiana employed virtual home visits (VHVs) via the ANDOR platform for Black children in low-income communities. Participants completing all three VHVs showed the greatest improvements in ACT scores, along with increased knowledge of triggers and self-management confidence (28).

Gümüş *et al.* (41) conducted an RCT in Turkey using Zoom-based education and remote monitoring tools. Compared to standard care, their Virtual Care model improved symptom control, increased symptom-free days, and reduced exacerbations and unplanned visits.

Suvarna *et al.* (46) ran an RCT comparing WhatsApp video consultations with standard in-person care in 192 children. Asthma control (ACT/C-ACT) and quality of life (PQLI) scores showed no significant differences, confirming the non-inferiority of telemedicine. High parental satisfaction reinforced its role as a low-cost, scalable option in resource-limited settings.

### School-based telemedicine

School-based telemedicine for pediatric asthma management (SBTH) offers an innovative model to improve access, continuity, and outcomes in chronic disease care, particularly for underserved populations. SBTH delivers remote asthma care within schools using video consultations, digital diagnostics, and coordination with healthcare providers. Its appeal lies in reducing emergency visits, increasing treatment adherence, and minimizing disruptions to learning. It is especially relevant for asthma, a major cause of school absenteeism and pediatric emergency department visits (38).

Programs like the School-Based Telemedicine Enhanced Asthma Management (SB-TEAM) integrate monitoring, education, and treatment adjustments into routine school activities. SB-TEAM has shown positive effects on symptom control and quality of life, with fewer emergency visits and hospitalizations (25, 47).

However, operational barriers can impair program sustainability. These include time constraints for school nurses, insufficient telehealth training, and limited caregiver engagement. Facilitators include dedicated telehealth coordinators, strong provider-school partnerships, and active family participation. Engagement of caregivers improves adherence and communication, while support staff can help overcome technological and logistical hurdles (14).

The economic sustainability of SBTH is supported by cost-benefit analyses. For example, the SB-TEAM program reported that operational costs were offset by decreased healthcare utilization, fewer missed school

and workdays, and improved productivity among caregivers (25). The relatively low per-child cost enhances its scalability (26).

## CONCLUSIONS

Despite their promise, digital technologies face several barriers to widespread adoption. Limited access to the internet and devices, particularly in rural and underserved communities, continues to restrict the equitable use of these tools. Additionally, caregiver engagement often varies, with socioeconomic factors playing a significant role. Addressing these disparities requires targeted efforts, such as subsidizing technology and designing culturally relevant interventions (19).

Healthcare providers also encounter challenges in integrating digital tools into existing workflows. The lack of interoperability between digital systems and EHRs remains a significant obstacle, increasing administrative burdens and hindering seamless adoption. Training programs and infrastructure investments are essential to address these gaps (36).

The future of digital asthma care lies in harnessing the potential of personalized and precision medicine (17). Moreover, longitudinal studies are needed to evaluate the long-term effectiveness, scalability, and cost-efficiency of digital interventions. While current evidence highlights the potential for improved asthma control, a positive change in QOL, reduced healthcare utilization, and decreased economic burden, understanding the sustainability of these outcomes is crucial (33, 48-51). Finally, addressing socioeconomic barriers and prioritizing inclusivity can extend the benefits of digital technologies to all children with asthma, regardless of their circumstances (52).


## ACKNOWLEDGMENTS

We would like to thank the SIMRI executive committee for approving and supporting the “Impatto delle tecnologie digitali sul controllo dell’asma in età pediatrica” Task Force.

## COMPLIANCE WITH ETHICAL STANDARDS

### Conflict of interests

The authors declare that they have no conflicts of interest relevant to the content of this article.

### Financial support

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.


### Authors’ contributions

RN, SM, SLG conceived and supervised the study, coordinated the development of the paper and led the drafting of the manuscript. GF, VM, GFP, DPLR, AL contributed to data extraction and organization. PA, AP, LG contributed to data organization, descriptive statistical analysis, prepared tables and figures. SLG assisted in interpreting clinical data and reviewing the manuscript critically for intellectual content. All authors contributed to the study design, led the drafting of the manuscript, revised the manuscript critically, and approved the final version. They all agree to be accountable for the integrity and accuracy of the work.

### Data sharing and data accessibility

The data that support the findings of this study are available from the corresponding author upon reasonable request. Data sharing will be considered for academic and research purposes in compliance with applicable data protection regulations.

### Publication ethics

The authors declare that this manuscript is original, has not been previously published, and is not under consideration for publication elsewhere. All authors have approved the final version of the manuscript and agree with its submission to this journal.

The authors affirm that the work complies with the highest standards of research integrity. No data have been fabricated, manipulated, or falsified. The manuscript is free from plagiarism, and all sources and contributions have been appropriately acknowledged.

The authors confirm adherence to ethical principles regarding authorship, data transparency, and responsible communication of scientific results.

## REFERENCES


1. Taquechel K, Diwadkar AR, Sayed S, Dudley JW, Grundmeier RW, Kenyon CC, et al. Pediatric Asthma Health Care Utilization, Viral Testing, and Air Pollution Changes During the COVID-19 Pandemic. J Allergy Clin Immunol Pract. 2020;8(10):3378-87. doi: 10.1016/j.jaip.2020.07.057.

2. Al-Iede M, Waters K, Aleidi SM, Alqutawneh B, Alnawaiseh H, Alshraideh A, et al. Impact of COVID-19 Lockdown on Children with Asthma in Jordan: A Parental Questionnaire. BMJ Paediatr Open. 2021;5:e001136. doi: 10.1136/bmjpo-2021-001136.
3. Radhakrishnan D, Higginson A, Thipse M, Tessier M, Radhakrishnan A. Optimizing Pediatric Asthma Education Using Virtual Platforms During the COVID-19 Pandemic. Allergy Asthma Clin Immunol. 2022;18:72. doi: 10.1186/s13223-022-00713-y.
4. Hall K, Kafashzadeh D, Chen L, Dudovitz R, Ross MK. Trends in telemedicine visits among pediatric asthma patients during COVID-19. J Allergy Clin Immunol Glob. 2024;3(2):100239. Published 2024 Mar 1. doi:10.1016/j.jacig.2024.100239.
5. Haynes SC, Kamerman-Kretzmer R, Khan SS, Crossen S, Lieng MK, Marcin JP, et al. Telemedicine use for pediatric asthma care: a mixed methods study. J Asthma. 2022;59(12):2431-40. doi:10.1080/02770903.2021.2019265.
6. Foronda C, Prather S, Snowden K, Gonzalez JM, Gattamorta KA, Lee J, et al. Asthma academy: A student nurse-led telehealth education program for low-income family caregivers of children with asthma. Nurs Open. 2022;9(2):1486-96. doi:10.1002/nop2.1123.
7. Smolinska S, Popescu FD, Izquierdo E, Antolín-Amérigo D, Price OJ, Alvarez-Perea A, et al. Telemedicine with special focus on allergic diseases and asthma-Status 2022: An EAACI position paper. Allergy. 2024;79(4):777-92. doi:10.1111/all.15964.
8. Justvig SP, Haynes L, Karpowicz K, Unsworth F, Petrosino S, Peltz A, et al. The Role of Social Determinants of Health in the Use of Telemedicine for Asthma in Children. J Allergy Clin Immunol Pract. 2022;10:2543-9.
9. Walters J, Johnson T, DeBlasio D, Klein M, Sikora K, Reilly K, et al. Integration and Impact of Telemedicine in Underserved Pediatric Primary Care. Clin Pediatr (Phila). 2021;60(11-12):452-458. doi:10.1177/00099228211039621.
10. Pathak PR, Stockwell MS, Lane MM, Robbins-Milne L, Friedman S, Pethe K, et al. Access to Primary Care Telemedicine and Visit Characterization in a Pediatric, Low-Income, Primarily Latino Population: Retrospective Study. JMIR Pediatr Parent. 2024;7:e57702. doi:10.2196/57702.
11. Iio M, Miyaji Y, Yamamoto-Hanada K, Narita M, Nagata M, Ohya Y. Beneficial Features of a mHealth Asthma App for Children and Caregivers: Qualitative Study. JMIR Mhealth Uhealth. 2020;8(8):e18506.
12. Wyatt TH, Li X, Fancher S, Samih Mitoubsi A, Pardue J. Recruitment Barriers of an mHealth Pediatric Asthma Pilot Study. West J Nurs Res. 2024;46(2):152-9. doi:10.1177/01939459231217919.
13. Gonsard A, AbouTaam R, Prévost B, Roy C, Hadchouel A, Nathan N, et al. Children's Views on Artificial Intelligence and Digital Twins for the Daily Management of Their Asthma: A Mixed-Method Study. Eur J Pediatr. 2023;182:877-888. doi: 10.1007/s00431-022-04754-8.
14. MacGeorge CA, King K, Andrews AL, Sterba K, Johnson E, Brinton DL, et al. School Nurse Perception of Asthma Care in School-Based Telehealth. J Asthma. 2021;58(10):1203-10. doi: 10.1080/02770903.2021.1904978.
15. Dramburg S, Dellbrügger E, van Aalderen W, Matricardi PM. The impact of a digital wheeze detector on parental disease management of pre-school children suffering from wheezing-a pilot study. Pilot Feasibility Stud. 2021;7(1):185. doi: 10.1186/s40814-021-00917-w.
16. Porto A, et al. Impact of Pediatric Electronic Consultations in a Federally Qualified Health Center. Telemed J E Health. 2021;27(12):1379-84.
17. Kan K, Shaunfield S, Kanaley M, Chadha A, Boon K, Foster CC, et al. Parent Experiences With Electronic Medication Monitoring in Pediatric Asthma Management: Qualitative Study. JMIR Pediatr Parent. 2021;4(2):e25811. doi: 10.2196/25811.
18. Mörelius E, Robinson S, Arabiat D, Whitehead L. Digital Interventions to Improve Health Literacy Among Parents of Children Aged 0 to 12 Years With a Health Condition: Systematic Review. J Med Internet Res. 2021;23(12):e31665. doi: 10.2196/31665.
19. Lewis K, Zettler-Greeley CM, Blake KV, Milkes A. A digital health application for managing pediatric asthma: Use and benefits. Inform Health Soc Care. 2023;48(4):370-86. doi:10.1080/17538157.2023.2250435.
20. Smith L, Koid Jia Shin C, Abdi N, Zhou C, Brown JC, Hartford EA, et al. Digital divide: Differences between digital access, preference, and use among parents of pediatric research participants. Digit Health. 2024;10:20552076241302251. doi: 10.1177/20552076241302251.
21. Hurst JH, Zhao C, Fitzpatrick NS, Goldstein BA, Lang JE. Reduced pediatric urgent asthma utilization and exacerbations during the COVID-19 pandemic. Pediatr Pulmonol. 2021;56(10):3166-73. doi: 10.1002/ppul.25578.
22. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi: 10.1136/bmj.n71.
23. Moola S, Munn Z, Tufanaru C, Aromataris E, Sears K, Sfetcu R, et al. 2020. Chapter 7: systematic reviews of etiology and risk. In: JBI Manual for Evidence Synthesis. JBI. https://doi.org/10.46658/jbimes-20-08.
24. Coffey JD, Christopherson LA, Williams RD, Gathje SR, Bell SJ, Pahl DF, et al. Development and implementation of a nurse-based remote patient monitoring program for ambulatory disease management. Front Digit Health. 2022;4:1052408. doi:10.3389/fdgth.2022.1052408.
25. Crabtree-Ide C, Lillvis DF, Nie J, Fagnano M, Tajon RS, Tremblay P, et al. Evaluating the Financial Sustainability of the School-Based Telemedicine Asthma Management Program. Popul Health Manag. 2021;24(6):664-74. doi:10.1089/pop.2020.0361.
26. Williams S, Xie L, Hill K, Mathew MS, Perry T, Wesley D, Messiah SE. Potential Utility of School-Based Telehealth

in the Era of COVID-19. J Sch Health. 2021;91(7):550-4. doi:10.1111/josh.13031.

27. Halterman JS, Fagnano M, Tremblay P, Butz A, Perry TT, Wang H. Effect of the Telemedicine Enhanced Asthma Management Through the Emergency Department (TEAM-ED) Program on Asthma Morbidity: A Randomized Controlled Trial. J Pediatr. 2024;266:113867. doi:10.1016/j.jpeds.2023.113867.
28. Bakshi A, Apantaku E, Marquette T, Jacob C, Dumas SA, Friedman K, et al. The Utility of Virtual Home Visits to Reduce Asthma Burden in Low-Income Black Communities in Louisiana During the COVID-19 Pandemic. Public Health Rep. 2024;139(1_suppl):53S-61S. doi:10.1177/00333549241236090.
29. Fedele DA, Thomas JG, McConville A, McQuaid EL, Voorhees S, Janicke DM, et al. Using Mobile Health to Improve Asthma Self-Management in Early Adolescence: A Pilot Randomized Controlled Trial. J Adolesc Health. 2021;69(6):1032-40. doi:10.1016/j.jadohealth.2021.06.011.
30. Mayoral K, Garin O, Caballero-Rabasco MA, Praena-Crespo M, Bercedo A, Hernandez G, et al. Smartphone App for monitoring Asthma in children and adolescents. Qual Life Res. 2021;30(11):3127-44. doi:10.1007/s11136-020-02706-z.
31. Ullmann N, Fracchiolla A, Boni A, Negro V, Porcaro F, Di Marco A, et al. A smartphone app for preschool wheezing and reliability of medical history collection. Ital J Pediatr. 2024;50(1):220. doi:10.1186/s13052-024-01792-w.
32. Sarasmita MA, Larasanty LPF, Kuo LN, Cheng KJ, Chen HY. A Computer-Based Interactive Narrative and a Serious Game for Children With Asthma: Development and Content Validity Analysis. J Med Internet Res. 2021;23(9):e28796. doi:10.2196/28796.
33. Almutairi M, Marriott JF, Mansur A. Effect of monitoring adherence to regular inhaled corticosteroid (ICS) alone or in combination with a long-acting β2-agonist (LABA) using electronic methods on asthma outcomes: a narrative systematic review. BMJ Open. 2023;13(8):e074127. doi:10.1136/bmjopen-2023-074127.
34. Chrystyn H, Saralaya D, Shenoy A, Toor S, Kastango K, Calderon E, et al. Investigating the Accuracy of the Digihaler, a New Electronic Multidose Dry-Powder Inhaler, in Measuring Inhalation Parameters. J Aerosol Med Pulm Drug Deliv. 2022;35(3):166-77. doi:10.1089/jamp.2021.0031.
35. Chan AHY, Te Ao B, Baggott C, Cavadino A, Eikholt AA, Harwood M, et al. DIGIPREDICT: physiological, behavioural and environmental predictors of asthma attacks-a prospective observational study using digital markers and artificial intelligence-study protocol. BMJ Open Respir Res. 2024;11(1):e002275. doi:10.1136/bmjresp-2023-002275.
36. O'Connor A, Tai A, Brinn M, Hoang ANTH, Cataldi D, Carson-Chahhoud K. The Acceptability of Using Augmented Reality as a Mechanism to Engage Children in Asthma Inhaler Technique Training: Qualitative Interview Study With Deductive Thematic Analysis. JMIR Pediatr Parent. 2023;6:e40231. doi:10.2196/40231.
37. Walters J, Denker K, Curry S, Burkhardt MC. Post-Discharge Remote Patient Monitoring for Children Hospitalized with Acute Asthma Exacerbations. Acad Pediatr. 2024;24(2):373-5. doi:10.1016/j.acap.2023.11.018.
38. Johnson EE, MacGeorge C, King KL, Andrews AL, Teufel RJ 2nd, Kruis R, et al. Facilitators and Barriers to Implementation of School-Based Telehealth Asthma Care: Program Champion Perspectives. Acad Pediatr. 2021;21(7):1262-72. doi:10.1016/j.acap.2021.04.025.
39. Vallabhan MK, Jimenez EY, McCauley GL, Willyard H, Kong AS. Formative Evaluation for Implementation of a Low Literacy Pictorial Asthma Action Plan Delivered via Telehealth Improves Asthma Control. Am J Med Qual. 2021;36(4):229-37. doi:10.1177/1062860620946838.
40. Fedele DA, Cushing CC, Koskela-Staples N, Patton SR, McQuaid EL, Smyth JM, et al. Adaptive Mobile Health Intervention for Adolescents with Asthma: Iterative User-Centered Development. JMIR Mhealth Uhealth. 2020;8(5):e18400. doi:10.2196/18400.
41. Gümüş M, Yardimci F, Duman Şenol H, Demir E. Virtual care for paediatric asthma: A randomized controlled trial. Int J Nurs Pract. 2024;30(6):e13290. doi:10.1111/ijn.13290.
42. van der Kamp MR, Klaver EC, Thio BJ, Driessen JMM, de Jongh FHC, Tabak M, et al. WEARCON: wearable home monitoring in children with asthma reveals a strong association with hospital based assessment of asthma control. BMC Med Inform Decis Mak. 2020;20(1):192. doi:10.1186/s12911-020-01210-1.
43. Giordani P, Perna S, Bianchi A, Pizzulli A, Tripodi S, Matricardi PM. A study of longitudinal mobile health data through fuzzy clustering methods for functional data: The case of allergic rhinoconjunctivitis in childhood. PLoS One. 2020;15(11):e0242197. doi:10.1371/journal.pone.0242197.
44. Peláez G, Castaños C, Figueroa JM, Giubergia V. Follow-up of children diagnosed with severe asthma before and during the COVID-19 pandemic. Seguimiento de niños con diagnóstico de asma grave antes y durante la pandemia por COVID-19. Arch Argent Pediatr. 2024;122(2):e202310165. doi:10.5546/aap.2023-10165.eng.
45. Van Houten L, Deegan K, Siemer M, Walsh S. A Telehealth Initiative to Decrease No-Show Rates in a Pediatric Asthma Mobile Clinic. J Pediatr Nurs. 2021;59:143-50. doi:10.1016/j.pedn.2021.04.005.
46. Suvarna KC, Kumar P, Singh K, Kumar J, Goyal JP. Comparison of Telemedicine versus In-Person Visit for Control of Asthma in Children aged 7-17 years: A Randomized Controlled Trial [published correction appears in Indian J Pediatr. 2025;92(5):569-71. doi: 10.1007/s12098-025-05487-w.]. Indian J Pediatr. 2025;92(5):467-73. doi:10.1007/s12098-024-05028-x.
47. Kim CH, Lieng MK, Rylee TL, Gee KA, Marcin JP, Melnikow JA. School-Based Telemedicine Interventions for Asthma: A Systematic Review. Acad Pediatr. 2020;20(7):893-901. doi:10.1016/j.acap.2020.05.008.
48. Ramsey RR, Plevinsky JM, Kollin SR, Gibler RC, Guilbert TW, Hommel KA. Systematic Review of Digital Interventions

for Pediatric Asthma Management. J Allergy Clin Immunol Pract. 2020;8(4):1284-93. doi:10.1016/j.jaip.2019.12.013.

49. Snoswell CL, Rahja M, Lalor AF. A Systematic Review and Meta-Analysis of Change in Health-Related Quality of Life for Interactive Telehealth Interventions for Patients With Asthma. Value Health. 2021;24(2):291-302. doi:10.1016/j.jval.2020.09.006.

50. Shdaifat MBM, Khasawneh RA, Alefan Q. Clinical and economic impact of telemedicine in the management of pediatric asthma in Jordan: a pharmacist-led intervention. J Asthma. 2022;59(7):1452-62. doi:10.1080/02770903.2021.1924774.

51. Culmer N, Smith T, Stager C, Wright A, Burgess K, Johns S, et al. Telemedical Asthma Education and Health Care Outcomes for School-Age Children: A Systematic Review. J Allergy Clin Immunol Pract. 2020;8(6):1908-18. doi:10.1016/j.jaip.2020.02.005.

52. Lin NY, Ramsey RR, Miller JL, McDowell KM, Zhang N, Hommel K, et al. Telehealth delivery of adherence and medication management system improves outcomes in inner-city children with asthma. Pediatr Pulmonol. 2020;55(4):858-65. doi:10.1002/ppul.24623.