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# School-Based Telemedicine Interventions for Asthma: A Systematic Review

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**Abstract**

**Background:** School health systems are increasingly investing in telemedicine platforms to address acute and chronic illnesses. Asthma, the most common chronic illness in childhood, is of particular interest given its high burden on school absenteeism.

**Objectives:** Conduct a systematic review evaluating impact of school-based telemedicine programs on improving asthma-related outcomes.

**Data Sources:** PubMed, Cochrane CENTRAL, CINAHL, ERIC, PsycINFO, Embase, and Google Scholar

**Study Eligibility Criteria:** Original research, including quasi-experimental studies, without restriction on the type of telemedicine.

**Participants:** School-aged pediatric patients with asthma and their families.

**Interventions:** School-based telemedicine.

**Study Appraisal and Synthesis Methods:** Two authors independently screened each abstract, conducted full-text review, assessed study quality, and extracted information. A third author resolved disagreements.

**Results:** Of 371 articles identified, 7 were included for the review. Outcomes of interest were asthma symptom-free days, asthma symptom frequency, quality-of-life, healthcare utilization, school absences, and spirometry. 4/7 studies reported significant increases in symptom-free days and/or decrease in symptom frequency. 5/6 reported increases in at least one quality-of-life metric, 2/7 reported a decrease in at least one healthcare utilization metric, 1/3 showed reductions in school absences, and 1/2 reported improvements in spirometry measures.

**Limitations:** Variability in intervention designs and outcome measures make comparisons and quantitative analyses across studies difficult. Only 2/7 studies were randomized controlled trials.

**Conclusions and Implications of Key Findings:** High-quality evidence supporting the use of school-based telemedicine programs to improve patient outcomes is limited. While available evidence suggests benefit, only two comparative trials were identified, and the contribution of telemedicine to these studies' results is unclear.

**Systematic Review Registration Number:** CRD 42018095644

**Introduction**

Asthma is the most common chronic illness of childhood and a major contributor to school absenteeism, accounting for nearly 11 million days of missed school per year.[1] Health care costs incurred due to all patients with asthma in the United States were estimated at $50.3 billion per year over 2008-2013 and overall societal costs are estimated at $82 billion when accounting for mortality and missed work and school.[2] Given the burden of asthma on healthcare and school systems, as well as society at large, a growing body of literature has begun to focus on efforts to address asthma through school-based interventions.

Prior reviews have examined school-based health interventions for asthma, generally concluding that the interventions can improve asthma related outcome measures, though none had examined telemedicine interventions specifically.[3-6] Halterman et al.[6] recommended a shift in school-based asthma interventions to include technology to encourage dissemination and sustainability of these programs. A Cochrane review and meta-analysis explored general telemedicine interventions for asthma, finding a potential reduction in hospital admissions, but no impact on quality of life in adults and children,[7] though a separate systematic review for adult patients found significant improvements in asthma control and quality of life compared to usual care.[8] Although initially deployed and studied as a means of delivering health care to remote and rural areas, the wider implementation of high-speed internet connections in schools and decreasing costs of telemedicine equipment have led to deployment in both urban and rural school districts, and commercial telemedicine suites are marketed for use in school settings.[9] Though the literature has provided evidence of some benefit from school-based asthma interventions and general telemedicine asthma interventions independently, there has not been a single systematic review that explores school-based telemedicine program to address pediatric asthma.

We conducted a systematic review of school-based telemedicine interventions for children with asthma to assess whether these interventions, when compared to standard care delivery, lead to improved asthma-specific outcomes. Outcomes included—but were not limited to—symptom-free days or symptom frequency, quality of life, health care utilization, school absences, and spirometry measures.

## Methods

We followed the reporting guidelines suggested by the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA).[10] The review protocol was submitted to the Prospective Register of Systematic Reviews (PROSPERO) on May 21, 2018, and registered on June 11, 2018 (CRD42018095644).

### *Search Strategy and Study Selection*

We searched Cochrane, PubMed, CINAHL, ERIC, PsycINFO, Embase, and Google Scholar using MeSH terms and keywords related to asthma and school-based telemedicine. We initially completed searches in June 2018, limiting studies to those conducted in the previous 20 years, where broadband internet and computing technology would be closer to what is more widely available today. We conducted a bridge search in May 2019 to identify studies conducted in the previous year. Two authors independently searched each of the included databases. For database-specific search strategies, including terms used in the query, see the Supplementary Material. Additional records were sought through a database search of ClinicalTrials.gov. We also searched article citations for relevant "ancestral" articles. When conference abstracts and clinical trials were identified, we attempted to contact abstract authors for additional data and outcomes for inclusion. We did not seek additional records or unpublished data from experts in this nascent field, or authors of studies that were included in this review. Each step in the search process was conducted with the assistance of a health sciences university librarian.

### *Eligibility Criteria*

Our inclusion criteria for this systematic review limited studies to original research (e.g., randomized clinical trial, observational study, quasi-experimental study) published in English, with populations including pediatric patients (less than 18 years old) who have an asthma diagnosis, an intervention incorporating school-based telemedicine, and reported study outcomes including at minimum asthma symptom-free days or asthma symptom frequency, without restrictions on other outcome types reported, or inclusion of a comparison group.

The definition of telemedicine used for inclusion was based on that employed by the Cochrane review of telemedicine interventions for asthma,[7] which the authors adapted from Miller[11] and consisted of three factors: information obtained from the patient, electronic transfer of this information to a health care professional over a distance, and personalized feedback tailored to the patient. There were no restrictions on the type of electronic transfer, the distance of transfer, type of health care professional, or whether the interpretation of data and personalized feedback occurred synchronously or asynchronously. In order to qualify as "school-based," some component of the telemedicine interaction (data collection and/or the provision of individualized feedback) needed to take place in the school setting with assistance or administration by either a school health professional or a dedicated research team member positioned at the school site. Two authors independently screened titles and abstracts to identify articles that fit the inclusion criteria. A third author served as an arbitrator for any discrepancies in the agreement of inclusion of articles. All eligible full-text articles included in this review were reviewed independently by at least two of the review authors.

*Study quality assessment and data collection*

Each of the articles were assessed for study quality by two authors independently completing the Joanna Briggs Institute's critical appraisal tools for quasi-experimental studies and randomized controlled trials, with a third reviewer serving as an arbitrator for disagreement in study quality assessments. Due to the small number of identified eligible studies, we did not exclude articles from the review based on quality. At least two reviewers independently extracted study details of each article that met all selection criteria using a standardized form created by the authors, including study design, demographic information of participants, details of health professional involved, school staff involvement, and our primary outcome measures of symptom-free days and/or symptom frequency. Where reported, we also extracted outcome measures for quality of life, utilization of health care (visit to a health care facility), missed school days, and spirometry results. If result values were only reported graphically, reviewers independently estimated the numerical value and then reached an agreement based on the available figure.

*Data synthesis*

Syntheses were limited to descriptive statistics and reporting of the measures reported in the studies. No pooled analyses were performed due to the variability and inconsistency in study designs and reported outcome measures. Summary plots were generated using the R environment version 3.4.3[12] and the package *ggplot2*.[13]

**Results**

*Study selection*

Database searches identified an initial 371 records for screening and 98 relevant "ancestral" articles from full-text review. Following removal of duplicate records, a total of 171 unique records were screened by title and abstract for inclusion. See Figure 1 and Supplementary Material for search strategies and the number of articles discovered by each database. One additional completed clinical trial, identified through ClinicalTrials.gov, described a telemedicine screening component for school-based asthma management. When contacted, the trial researchers reported that outcomes specific to the telemedicine component of the trial were unavailable for inclusion in the review.

*Study characteristics*

Seven studies formed the sample for this systematic review (Tables 1-2).[14-20] Five of the studies were quasi-experimental study designs with single group pre-post intervention comparisons; two were randomized clinical trials (RCTs), one of which was a cluster RCT. Article publication dates ranged from 2001–2018. All studies were longitudinal in design, with follow-up measurement periods ranging from 12 – 56 weeks from the start of the study. All studies were conducted in the United States, with 4 urban and 3 rural school settings. Participant age range varied among studies, but all participants were between 3 – 18 years old. Two studies included participants with persistent asthma only, while the others did not limit by severity. It should be noted that some studies predated the commonly referenced 2007 National Asthma Education and Prevention Program Expert Panel Report-3 asthma severity classification guidelines.[21] Outcomes reported included symptom-free days, symptom(s) frequency, quality of life measures, health care utilization, school absences, and spirometry.

Interventions included asthma education and management programs delivered and/or monitored via telemedicine visits,[14,18,19] direct asthma provider visits delivered via telemedicine,[15,16,19] and direct observed therapy of asthma medications at school supplemented with telemedicine visits and monitoring.[17] Outcome measures presented in only one study are not discussed in this review. Study quality rating assessments showed limitations and risk of bias in all studies. See Tables 1 and 2 for individual study characteristics, intervention descriptions, and limitations.

*Mean asthma symptom-free days*

Three studies examined asthma symptom-free days (SFD), reporting results as a mean number of SFDs per two-week[17,18] or one-week recall period.[19] We standardized these means to one-week periods for graphical comparison across studies (Supplemental Figure 1). Significant increases in mean SFDs over the course of follow-up were seen in Halterman 2018 (estimated mean difference between groups 0.69 SFDs; 95% CI 0.15 – 1.22; $P$=0.01)[17] and Romano 2001 (week 0: 2.35 SFDs vs. week 24: 4.31 SFDs per one-week recall period, $P$<0.05).[19] However, as with the other pre-post studies with no comparison group examined in this review, the findings in Romano 2001 may be subject to bias from temporal/seasonality effects associated with asthma.[19] Perry 2018 showed no significant difference in mean SFDs per two-week recall period in either intervention or control clusters from baseline.[18]

*Asthma symptom frequency*

The inconsistency in outcome measures reported for asthma symptomatology makes direct comparisons difficult across studies. Three studies reported daytime and nighttime symptom frequency.[16,17,20] Halterman 2018 showed significant reductions in both daytime (estimated mean difference -0.46, 95% CI -0.85 – -0.09) and nighttime symptoms (estimated mean difference -0.41, 95% CI -0.74 – -0.09) over two-week recall period in telemedicine subjects compared to control subjects, averaged over all follow-up assessments.[17] Bynum 2011 showed no significant decreases in mean days with daytime or nighttime symptoms within their study group at any point over the 20-month follow-up period.[16] Tinkelman 2004 showed significant reductions in daytime and

nighttime symptoms at 12 months from baseline; however, the authors reported this outcome as a change in mean categorical values assigned to ranges of asthma symptom frequencies, rather than the frequencies themselves, making comparisons across studies impossible.[20] Arnold 2012 and Bergman 2008 reported outcomes for wheezing and asthma attacks, with only Arnold 2012 showing a significant decrease in the number of participants with wheezing (*n*=9 vs. *n*=2, *P*=0.02) and in the average number of wheezing episodes (1.86 vs. 0.43, *P*=0.02) over two-week recall periods in their cohort pre-post intervention.[14,15] Halterman 2018 and Romano 2001 reported no significant differences in rescue medication/albuterol usage.[17,19]

*Quality of life measures*

Six studies evaluated quality of life (QOL) using measures such as the Child Health Survey for Asthma (CHSA),[14,15,18] the Pediatric Asthma Quality of Life Questionnaire (PAQLQ) for patients,[18,19] the Pediatric Asthma Caregiver Quality of Life Questionnaire for caregivers (PACQLQ)[17,19,20] and the Pediatric Quality of Life Inventory 3.0 Asthma Module (PedsQL).[18] A detailed description and comparison of these pediatric asthma-related quality of life measures has been previously published.[22] Romano 2001 showed increased caregiver total QOL at week 4 (mean PACQLQ score 5.75, *P*=0.02) and 24 (6.2, *P*<0.01) compared to week 0 (5.15), as well as increased patient quality of life score at week 24 compared to week 0 (mean PAQLQ scores 5.75 vs. 5.2, *P*<0.01).[19] Conversely, Halterman 2018 showed no significant difference in mean PACQLQ between intervention and controls (Difference 0.14, 95% CI -0.08 – 0.37) and Perry 2018 showed no difference in PAQLQ scores for both intervention and control groups from baseline to 6 months (values not reported).[17,18] Tinkelman 2004 reported a significant improvement in the perceived activity level component of the PACQLQ at 6 months compared to baseline (6.76 vs. 6.11, *P*=0.04), though this difference was not significant at 12 months.[20] No significant differences were seen in total quality of life or emotional function at 6 or 12 months compared to baseline. The other studies examining PACQLQ scores did not report specific components. Perry 2018 reported no significant difference in PedsQL 3.0 scores at 3-month follow-up.[18]

For studies reporting CHSA QOL outcomes, Perry 2018 showed an improvement in family activity among their usual care (control group) from baseline to 6-month follow-up (91.5 vs. 94.6, *P*=0.02), but no improvement

was seen in the intervention group.[18] Arnold 2012 showed a significant increase in child physical health score from pre to post intervention (65.6 to 76.3, $P = 0.045$), but had no control group for comparison.[14] Bergman 2008 demonstrated improved child health score (84.2 to 87.4, $P<0.01$) and child activity score (92.4 to 94.7, $P<0.01$) from baseline to 32 weeks without a control group for comparison.[15] No studies showed statistically significant differences in child or family emotional health scores. Supplemental Figure 2 compares CHSA QOL measures.

*Health care utilization*

Seven studies reported outcomes related to the utilization of health care services: visits to urgent care, visits to the emergency department (ED), hospitalization (inpatient care), preventive medication prescriptions, and appointments with a primary care physician. Studies reported these results with different categorizations of care (e.g., Halterman 2018 combined ED and hospitalization visits together),[17] different recall times (any asthma-related hospitalization during study versus hospitalization during past two-weeks), and different follow-up times (8 weeks to 56 weeks). Both Bynum 2011 and Arnold 2012 reported no change in average emergency department visits and non-statistically significant decreases in average hospitalizations from baseline to follow-up (56 weeks and 52 weeks respectively).[14,16] Arnold 2012 reported a decrease in average doctor or clinic visits from 1.23 to 0.38 ($n$=14, $P$=0.04).[14] These studies lacked control groups for comparison. In Halterman 2018, the telemedicine group and control group had similar rates of ED visits/hospitalizations at baseline (48.8% vs. 45.5% had 1 or more visit). After the completion of the study, the telemedicine group showed lower odds of experiencing 1 or more ED visits or hospitalizations (OR = 0.52; 95% CI 0.32 – 0.84).[17] Halterman 2018 and Perry 2018 reported rates of preventive medication prescriptions, with only Halterman 2018 demonstrating a significant increase in the intervention group (91% vs 67%; OR = 8.67; 95% CI, 4.19 – 17.95).[17,18]

*School Absences*

Three studies reported school absence outcomes. Bynum 2011 showed a 34% reduction in absences at follow-up compared to baseline, though this result was not significant.[16] Halterman 2018 reported an odds ratio of 0.79

(95% CI 0.56 – 1.11) of missing ≥1 day of school among the intervention group compared to standard care, suggesting a reduction in absenteeism, though not statistically significant.[17] Tinkelman 2004 showed a statistically significant 67.1% reduction in missed school days among 41 participants from baseline to 6-month follow-up ($P$<0.01).[20] Only 10 participants completed the 12-month follow-up; they showed a 74.4% reduction from baseline, but the sample was likely too small to evaluate statistical significance and none was reported.

*Spirometry*

Two studies reported outcomes from spirometry. Bynum 2011 reported forced expiratory flow (FEF) 25-75% predicted and saw a statistically significant reduction in this measure (Baseline: 0.74, 12-month follow-up: 0.55, $P$ <0.01), indicating worsening lung function, though 29 of 39 initial subjects were lost to follow up.[16] Bergman 2008 did not detect statistically significant differences in predicted forced expiratory volume at the end of one second (FEV1), FEF 25-75%, FEF Max, and FEF/FVC (forced vital capacity) from baseline to follow-up at week eight.[15]

**Discussion**

While there is growing interest in the use of telemedicine in schools to treat children with asthma, our systematic review of school-based telemedicine interventions for asthma found limited evidence supporting its effectiveness. Although four studies reported significant positive results with respect to increased symptom-free days and/or decreased asthma symptom frequency, study quality and methodologic issues limit the conclusions that can be drawn from the available evidence. Over 70% of the studies identified used quasi-experimental designs with high potential for bias and questionable validity of results. With interventions that followed a single group over the course of a school year, the magnitude of temporal and seasonal effects were not quantified, and asthma symptoms and exacerbations are typically most frequent in the fall-season start of the school year.[23] Of the two RCTs, only Halterman 2018 showed a significant increase in symptom-free days and neither showed significant differences in quality of life measures.[17,18]

Generalizability of results from the identified body of literature is also limited. Although the studies were split between rural and urban settings, these schools have vastly different implementation challenges for health programs, with disparate access to asthma training and school nursing resources.[24] Future appraisals of the evidence may need to examine rural and urban districts separately, as was done in a recent clinical management review by Perry et al.[25] Well-funded vs. impoverished school systems, regardless of locale, also have a large effect on the applicability of study results in a wider context. Six of the seven studies utilized school nursing in their interventions, including a nurse practitioner in Arnold 2012, and a school-based health center in Romano 2001.[14,19] Districts and schools with low school nursing availability may find these interventions infeasible.

No studies reported the costs associated with equipment and implementation, and only three examined school attendance (a primary funding mechanism for schools). Two out of the three studies examining school absenteeism reported quantitative reductions that were not statistically significant, indicating larger sample sizes are needed to examine this important issue. Economic analyses and cost-effectiveness ratios from a school perspective cannot be determined from the data provided in these studies. Insurance coverage and reimbursement for telemedicine services also remains a barrier to broader adoption,[26,27] particularly in the school setting where a student population may be covered by a mix of public and private payers. Halterman 2018 submitted telemedicine visits for reimbursement, but policies governing telemedicine reimbursements vary by state. However, the recent SARS-CoV-2 pandemic has necessitated a fundamental shift toward both telemedicine and tele-learning, and aspects of these delivery systems may persist beyond the current emergency use case.

As telemedicine is a method of service delivery rather than an intervention in and of itself, the outcomes observed in these studies are primarily influenced by the design of the intervention being delivered. Quantifying the contribution of telemedicine on the outcome would necessitate a direct comparison to the intervention without the telemedicine component, as was the case with the Halterman 2018 study. This study was a telemedicine-enhanced version of a prior intervention called the School-Based Asthma Therapy trial evaluating the direct provision of asthma control medicines at the school, which showed similar effect sizes for symptom-

free days, though it has not yet been reported whether the addition of the telemedicine component decreased the overall staffing needs and costs of this intervention.[17,28] Prior reviews of school-based asthma educational interventions have shown positive results for intermediate outcomes, such as quality of life and self-efficacy, but inconsistent results regarding health outcomes and school absences.[3-5] It is plausible that telemedicine could be incorporated to address some of the limitations of prior school-based asthma education programs in effecting health outcomes, such as short intervention duration and limited access to health care to accompany educational programs.[3] In addition, many previously reviewed studies were cluster designs. Future studies aimed at generalizability and feasibility in multiple settings may prefer a larger cluster-based design, while studies aimed at estimating the effect differences between telemedicine interventions may benefit from randomizing at the individual school.[29]

Our efforts to review a broad evidence base within the narrow field of school-based telemedicine interventions for asthma necessitated both a liberal definition of telemedicine and a permissive scope of study designs and outcome measures. The variability in interventions delivered and inconsistency in reported outcome measures, as well as the paucity of high-quality studies, limited our ability to perform quantitative analyses and robust assessments of publication bias. The broad definition of telemedicine we employed necessitated the use of several keywords and synonyms for telemedicine (e.g. telehealth, e-health, e-consult, virtual visit, remote visit, remote consult), but we may not have captured all types of technologies that would fall into our definition of telemedicine. In addition, limiting to school-based interventions proved challenging as "school" often appears in author affiliations. We addressed these challenges with the use of wildcards, MeSH terms, and limiting "school" keywords to specific fields of each search in order to ensure our searches were relevant but comprehensive (see Supplementary Material).

**Conclusions**

This systematic review of school-based telemedicine interventions showed inconsistencies in clinically significant effects for asthma symptom-free days, asthma symptom episodes, health care utilization, and school absences. Notably, only two studies identified were RCTs, and with the seasonal pattern of asthma

exacerbations peaking at the time the school year traditionally starts,[23] studies examining school-based asthma programs may be particularly sensitive to bias from temporal effects without appropriate comparison groups. School-based telemedicine interventions have shown promise in reducing disparities in access to care, the provision of counseling and special-needs services, and in the management of other conditions such as acute illnesses, diabetes, and ADHD.[30-33] Despite the interest and investment in school-based telemedicine for management of asthma, the available evidence supporting its usage is still evolving. Early research focused on implementation, technological feasibility and requirements, and user satisfaction rather than clinical outcomes. Higher-quality studies employing RCT designs are needed to draw conclusions on efficacy regarding health outcomes. Perhaps most importantly, these studies should include school absences and cost-effectiveness analyses to help schools determine whether to invest limited resources in telemedicine technologies.

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**Table 1.** Overview of Study Population and Telemedicine Intervention Description

| Reference Number | Age Range | Asthma Severity | Location (School Setting) | Intervention Description | Telemedicine Frequency | School staff member |
|---|---|---|---|---|---|---|
| Romano 2001[19] | 5 to 18 | Persistent only | Hart, TX (Rural) | Initial in-person evaluation and spirometry with specialist to confirm asthma diagnosis, establish severity level, provide asthma action plan, and inhaler technique assessment, followed by re-evaluation through **synchronous video,** consisting of asthma history and physical, spirometry, and review of symptom diary and healthcare utilization. Patient and school nurse (on-site at school) to remote specialty physician. | Week 4, 12, 24 | School Nurse |
| Tinkelman 2004[20] | 5 to 15 | All severity | Denver CO; Carrolton, TX (Urban) | Respiratory nurse care manager or respiratory therapist assisted patient daily to enter peak flow data into interactive asthma diary on school computers. Interactive asthma diary reviewed by National Jewish care managers, with alerts sent to patients for worsening asthma (**Asynchronous telemonitoring**). Paired with in-person/online interactive education sessions. | Daily | Unclear, Study Nurse not specified as school staff member |
| Bergman 2008[15] | 5 to 12 | Mild to Moderate | San Francisco, CA (Urban) | **Synchronous video** of patient and school nurse (on-site at school) with a remote specialist for initial assessment and follow-up visits. Week 0 and 8: evaluation and asthma severity classification, asthma action plan and treatment recommendations provided to family to give to PCP. Week 16: "Open airways for schools" curriculum. Week 32: data collection completion and graduation | Week 0, 8, 16, 32 | School Nurse |
| Bynum 2011[16] | 5 to 18 | All severity | Various Locations, AL (Rural) | **Synchronous video** of patient and school nurse (on-site at school) with remote pediatric nurse practitioner or pharmacist assessing inhaler technique, with in-person spirometry and asthma severity assessments by respiratory therapist. | 2x/ week | School Nurse (specifically hired as a school telemedicine nurse for study) |
| Arnold 2012[14] | 6 to 12 | All severity | Harlem, NY (Urban) | Patient entered peak flow data daily and completed an asthma symptom questionnaire weekly via Automated Live E-Health Response Tracking System (ALERTS) on school computers. Reports automatically generated and sent to school health center and PCP. Real-time recommendations provided to students based on a prescribed asthma action plan. Periodic review of peak flow meter data with students by program staff. Direct escorting of students to school health center if severe symptoms identified. (**Asynchronous telemonitoring**) | 1x-5x/week, depending on asthma severity | School Nurse Practitioner |
| Halterman 2018[17] | 3 to 10 | Persistent only | Rochester, NY (Urban) | Sync**hronous video** of patient and school telemedicine assistant (on-site at school) or asynchronous telemonitoring (data entered by school telemedicine assistant) with remote clinician (PCP when available) to assess asthma control and severity. Bundled with daily observed therapy of asthma control medications delivered at school. Symptom assessment and treatment recommendations provided to families with recommendations for PCPs provided to usual care group at similar intervals to telemedicine group. | 3 assessments. Baseline and two follow-up visits 4-6 weeks apart | School Clinical Telemedicine Assistant |
| Perry 2018[18] | 7 to 14 | All severity | Various Locations, AR (Rural) | **Synchronous video** of patient, patient caregiver or school nurse with board certified allergist, respiratory therapist or asthma educator to provide asthma education. **Asynchronous telemonitoring** of spirometry data entered by school nurse, asthma symptom questionnaires. | Video: Once every 2 weeks. Telemonitoring: Month 0, 3 | School Nurse and Caregiver |

**Table 2.** Study design

| Reference Number | Study Design | Sample Size | Outcomes; (*) Indicates Primary | Survey Recall Period | Data Collection | Study Limitations |
|---|---|---|---|---|---|---|
| Romano 2001[19] | Quasi-Experimental (Pre-Post) | 17 | Symptom-free days*, max FEV1, quality of life, annualized rates of steroid bursts, health care utilization | 1 week | 0, 4, 12, 24 weeks | No control group. Small sample size. Reported follow-up intervals may correspond to seasonal variability in asthma. |
| Tinkelman 2004[20] | Quasi-Experimental (Pre-Post) | 76/41** | Symptom frequency*, health care utilization, quality of life, medication use | -- | 0, 1, 6, 12 months (Moderate Asthma) 0, 1, 3, 6, 9, 12 months (Severe Asthma) | No control group. No characterization of 35 enrolled subjects that did not complete 6 months in program. High loss to follow-up at 12 months. Proprietary categorical scheme used for reporting of symptom frequency. Survey recall period not specified. |
| Bergman 2008[15] | Quasi-Experimental (Pre-Post) | 83 | Quality of life*, symptom frequency, health care utilization*, satisfaction, spirometry, asthma knowledge | 2 weeks | 0, 8, 32 weeks | No control group. Limited symptomatology information collected. |
| Bynum 2011[16] | Quasi-Experimental (Pre-Post) | 40 | Symptom frequency*, health care utilization, school absences, FEF 25-75% | -- | 0, 4, 8, 12, 16, 20 months | No control group. High variability in number of telemedicine consultations completed per student (Range: 2-148). >50% loss to follow-up at 12, 16, 20 month intervals |
| Arnold 2012[14] | Quasi-Experimental (Pre-Post) | 24 | Quality of life*, symptom frequency*, health care utilization. | 2 weeks | 0 – 15 months, mean participation 12 months | No control group. Small sample size. Non-standardized participation time/follow-up intervals. Selection bias likely due to higher severity of asthma and larger effect sizes seen in subjects participating > 8 months. |
| Halterman 2018[17] | RCT | 395/382** | Symptom-free days*, symptom frequency, health care utilization, quality of life, school absences, fractional exhaled nitric oxide (FeNO), preventive medication prescriptions | 2 weeks | 0, 4, 6 months. Final assessment at end of school year (~10 months) | Not blinded, and allocation concealment methods not described. Patients in intervention group received daily observed therapy in addition to telemedicine visits, vs. control group receiving usual care. Contribution of telemedicine component to outcomes difficult to assess. |
| Perry 2018[18] | Cluster RCT | 393 | Symptom-free days*, quality of life, peak flow, preventive medication prescriptions, self-efficacy, caregiver knowledge, asthma control | 2 weeks | 0, 3, 6 months | Not blinded, and allocation concealment methods not described. Selection bias possible due to low survey completion at follow-up. PedsQL measure only completed by intervention group |

** Indicates N at beginning of study and N at final follow-up

**Figure Legends**

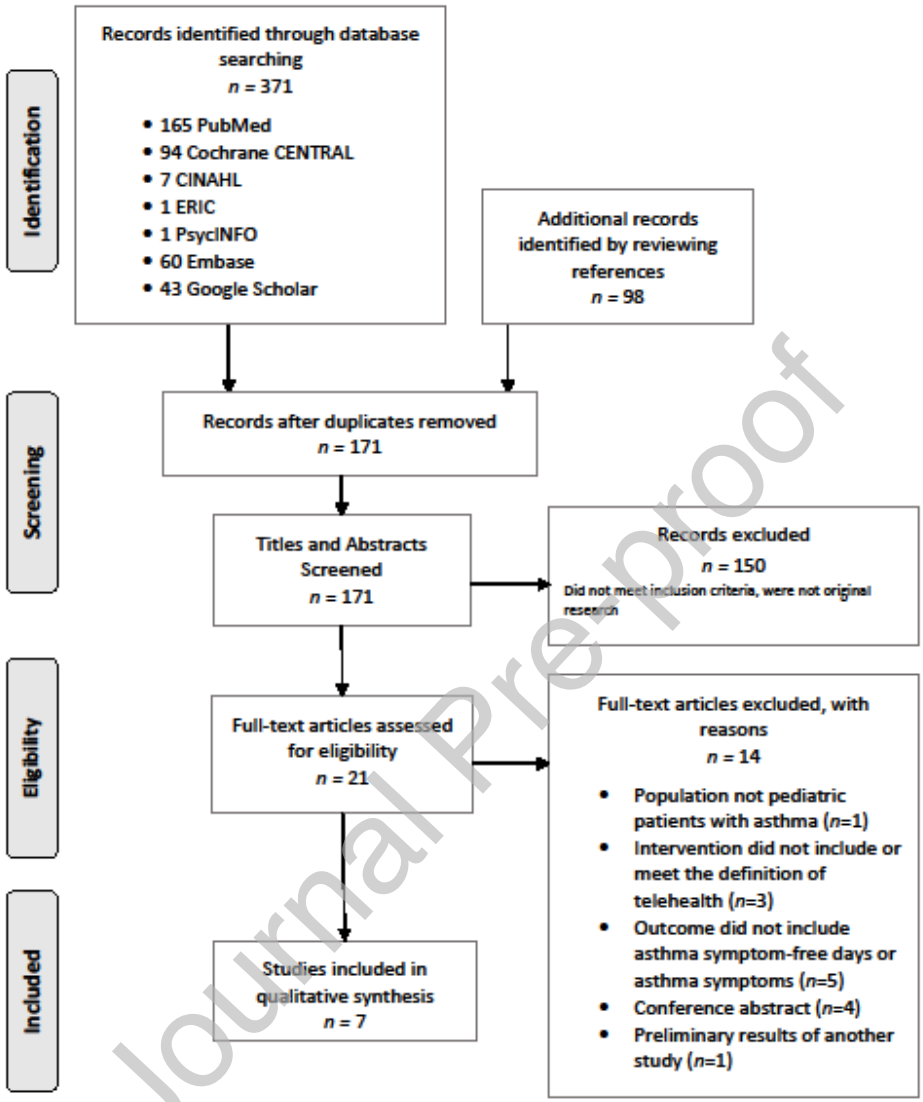


**Figure 1:** Study inclusion flow diagram

**What this systematic review adds:**

- While school-based interventions and telemedicine interventions for asthma management have been reported on previously, this review synthesizes the available evidence for a growing trend toward school-based telemedicine interventions.
- Calls attention to the need for higher-quality study designs with larger sample sizes, as well as a greater focus on costs and school absence measures that are relevant to key stakeholders.

**How to use this systematic review:**

- School health stakeholders should use this review when considering how to best implement telemedicine technologies. The findings in this review suggest a cautious approach, with more evidence needed, when considering if school-based telemedicine is appropriate in the management of asthma.
- Research evaluating school-based telemedicine interventions for asthma and other conditions should carry out high-quality studies that report cost measures and school absence outcomes.