Original Article

Telemedical Asthma Education and Health Care Outcomes for School-Age Children: A Systematic Review

Nathan Culmer, PhD, Todd Smith, PhD, Catanya Stager, MA, Andrea Wright, MLIS, Karen Burgess, MD, Samantha Johns, Mykaela Watt, and Madison Desch *Tuscaloosa, Ala*

What is already known about this topic? Community- and school-based partnerships are a promising solution in developing effective asthma management. Such programs provide effective asthma management instruction by supporting the needs of children with asthma with the resources of health care services.

What does this article add to our knowledge? Telemedicine solutions paired with school-based asthma care are as effective as in-person visits for patients with asthma. This study identifies and examines existing evidence regarding the effect of live 2-way telemedical education on school-age children with asthma.

How does this study impact current management guidelines? Real-time telemedically delivered asthma education may improve quality of life, enhance symptom management ability, enhance educational outcomes, and reduce symptom burden on patients with asthma and their care providers.

BACKGROUND: Telemedicine in a school-based setting involving partnerships between a child with asthma and health care provider can provide patients and caregivers with opportunities to better manage chronic conditions, communicate among partners, and collaborate for solutions in convenient locations.
OBJECTIVE: This systematic review examined outcomes for school-age children with asthma involving asthma-based telemedical education.
METHODS: Guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, we searched 4 databases with terms related to asthma, education, and pediatrics. Included articles involved a school-based setting, children and adolescents, a telemedical mechanism for training, empirical study designs, and peer review. We extracted data regarding (a) participant background, (b) research methods and purpose, and (c) outcomes.
RESULTS: A total of 408 articles were identified. Five met inclusion criteria. Three studies were randomized and 2 were cohort studies. In addition to clinical and educational outcomes, studies reported on satisfaction, self-management, asthma knowledge gain, and quality of life (QOL). We found support for caregiver/parent QOL and participant self-management behaviors. We also found mixed results for participant QOL. Clinical outcomes showed mixed support regarding airway inflammation improvement, medication use improvement, improvements in symptom burden and symptom-free days, and spirometry improvements.
CONCLUSIONS: Results of real-time telemedically delivered asthma education to improve QOL, enhance symptom management ability, and reduce symptom burden were positive or nonsignificant. No study indicated negative effects due to telemedicine. Limited results indicate that patient education can, under certain circumstances, positively influence asthma burden. Further validation of intervention methods and tools as well as outcome measurement consistency is recommended. © **2020 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2020;8:1908-18)**

Key words: *Telemedicine; Asthma; Tele-education; Quality of life; Patient education; Pediatrics; Asthma management; Chronic disease management*

INTRODUCTION

Asthma affects nearly 6 million children in the United States,[1] with asthma-related school absences totaling 13.8 million days annually,[2] and with family costs averaging $800 in additional annual health care expenses.[3] Asthma management is one aspect of patient-centered care, including teaching children, as patients, to appropriately manage their condition[4,5] and to modify behaviors for symptom reduction.[6,7]

To help children achieve optimal asthma management, patient-centered care requires children and parents, and their health care providers, to be in a health education partnership.[8] Lack of patient-centered care contributes to children's nonadherence in daily use of controller medicine.[9]

College of Community Health Sciences, The University of Alabama, Tuscaloosa, Ala
Conflicts of interest: The authors declare that they have no relevant conflicts of interest.
Received for publication November 19, 2019; revised February 5, 2020; accepted for publication February 6, 2020.
Available online February 19, 2020.
Corresponding author: Nathan Culmer, PhD, College of Community Health Sciences, The University of Alabama, 850 Peter Bryce Blvd, Tuscaloosa, AL 35401. E-mail: npculmer@ua.edu.
2213-2198

https://doi.org/10.1016/j.jaip.2020.02.005

Abbreviations used
CHSA- Children's Health Survey for Asthma
EPHPP- Effective Public Health Practice Project
QOL- Quality of life
SFD- Symptom-free day

Research has shown that community- and school-based partnerships are a promising solution in helping parents and children develop effective asthma management.[10] Such programs provide effective asthma management instruction[11] by supporting the self-care learning needs of children with asthma with health care services resources.[5,12]

With limited health care access in remote locations, as well as evidence of greater asthma morbidity among children living in poverty and minority children including children in urban areas,[13] telemedicine solutions paired with school-based asthma health care have been shown in noninferiority studies to be just as effective as in-person visits for patients with asthma.[14-16] However, no systematic reviews have examined how live 2-way telemedical education affects outcomes for children with asthma in schools.[17]

Patient experiences that use telemedical synchronous video consultations benefit patients with asthma[16,18] and present more learning opportunities than models that only secure and transmit asynchronous data.[19,20] Using the school as the originating site for the consultation can reduce costs and efforts for families with limited resources.[21]

RESEARCH QUESTIONS

The purpose of this review was to determine the extent to which 2-way live streaming of asthma-based telemedical education improves outcomes for school-age individuals with asthma (ages 5-18 years) and their families. This review aimed to answer 3 research questions:

1. In school-age children with asthma, do live 2-way streaming of asthma-based telemedical-education interventions affect asthma-related clinical outcomes?
2. In school-age children with asthma, do live 2-way streaming of asthma-based telemedical-education interventions affect asthma-related educational outcomes?
3. In school-age children with asthma, do live 2-way streaming of asthma-based telemedical-education interventions affect any additional asthma-related outcomes?

Clinical outcomes relate to (1) assessment and monitoring (eg, pulmonary function tests), (2) symptom severity and frequency, (3) effective control of asthma triggers and symptoms, (4) health care utilization, and (5) medical use. Educational outcomes refer to measures of school days missed, and academic score improvement. We anticipate that additional outcomes might include satisfaction and overall quality of life (QOL).

Definitions

We define telemedicine as technologically mediated bidirectional transmission of remote medical knowledge or data between provider and patient. Tele-education is defined as live, synchronous, and remote presentations of health education related to health and can occur during or independent of a clinical encounter.

TABLE I. PubMed search terms

("telemedicine"[mesh] OR "remote consultation"[mesh] OR telemed*[tw] OR tele-med*[tw] OR telecon*[tw] OR tele-con*[tw] OR telehealth*[tw] OR tele-health*[tw] OR telemonitor*[tw] OR tele-monitor*[tw] OR telecare*[tw] OR tele-care*[tw] OR telehome*[tw] OR tele-home*[tw] OR teleteach*[tw] OR tele-teach*[tw] OR teletrain*[tw] OR tele-train*[tw] OR telepharm*[tw] OR tele-pharm*[tw] OR telepulmon*[tw] OR tele-pulmon* OR videocon*[tw] OR video-con*[tw] OR ehealth*[tw] OR e-health*[tw] OR mhealth*[tw] OR m-health*[tw] OR mobile-health*[tw] OR remote-consult*[tw] OR distance-consult*[tw]) AND ("schools"[mesh] OR "school health services"[mesh] OR "child"[mesh] OR "adolescent"[mesh] OR "minors"[mesh] OR "pediatrics"[mesh] OR school*[tw] OR highschool*[tw] OR kindergar*[tw] OR preschool*[tw] OR child*[tw] OR schoolchild*[tw] OR kid[tw] OR kids[tw] OR boy*[tw] OR girl*[tw] OR minors*[tw] OR adoles*[tw] OR teen*[tw] OR pediatric*[tw] OR paediatric*[tw]) AND ("asthma"[mesh] OR asthma*[tw])

METHODS

This project adheres to the Quality of Reporting of Meta-analyses statement[22] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses standards.[23,24] Search strategies were peer-reviewed by a third party using the Peer Review for Electronic Search Strategies guidelines.[25]

Literature search

We completed searches in CINAHL, Embase, PubMed, and Scopus databases on October 19, 2018 (with no date restrictions), with keywords and index-specific subject headings related to *asthma*, *education*, and *pediatrics*. See Table I for the specific search criteria and keywords for the PubMed search (with similar search terms and methods for the other databases).

Inclusion and exclusion criteria

Inclusion criteria specified that a study (a) was school-based, (b) involved children and adolescents aged 5 to 18 years, (c) involved a telemedical mechanism to provide training (eg, involved face-to-face asthma-based tele-education via a video conferencing link as part of a clinical visit or a stand-alone session), (d) included asthma as the primary or secondary variable, (e) used empirical study designs, (f) appeared in peer-reviewed journals, and (g) was available in the English language. Excluded articles included unpublished studies, gray literature, and single-case studies. See Figure 1 for details on exclusion criteria.

Articles presenting web portals or phone apps (with no tele-education) were excluded on the assumption that interaction with technology does not necessarily require patient education. Articles on printed asthma material were excluded because this definition of patient education is aligned with health literacy and only peripherally with patient-provider interactions. Finally, asthma management refers to a patient's ability to use learned information to reduce asthma symptoms and severity.

Study selection

Titles and abstracts from our initial search were independently reviewed by at least 2 blinded researchers, and a decision to exclude or include was based on the eligibility criteria.

Reporting criteria

Once the final articles were selected, 2 authors independently and methodically extracted data from each study and reconciled findings by consensus. Specifically, we extracted data related to (a) participant

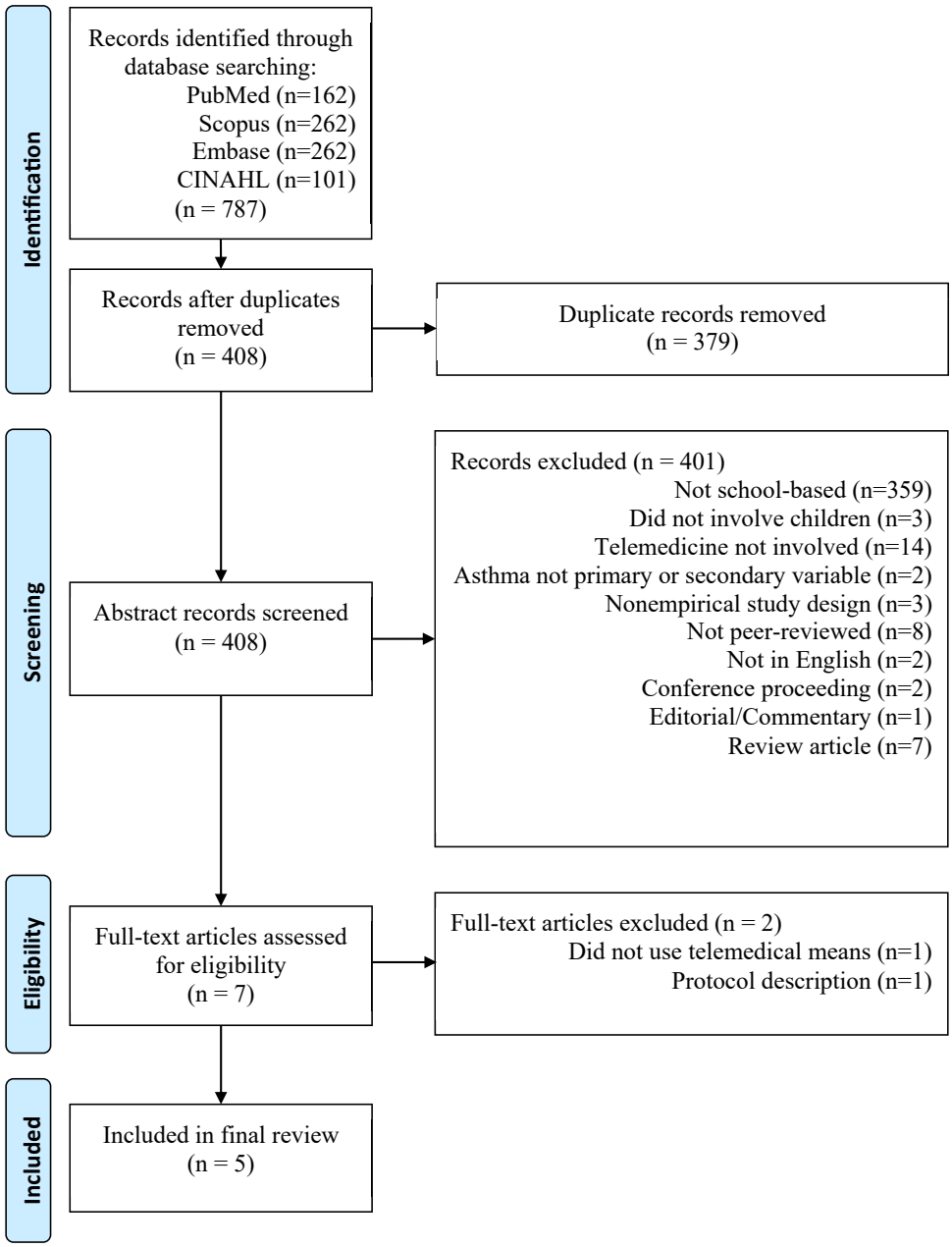

FIGURE 1. PRISMA flow diagram. *PRISMA*, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

characteristics, (b) study design, (c) study characteristics, (d) curricular tools used to provide asthma education, (e) clinical outcomes, (f) educational outcomes, (g) satisfaction with intervention, (h) asthma self-management outcomes, (i) self-efficacy outcomes, (j) asthma knowledge gain outcomes, and (k) QOL outcomes.

Assessment of rigor

We used the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool[26,27] to evaluate the methodological rigor of each study. Consistent with EPHPP guidelines, articles with no weak ratings are deemed strong, ones with 1 weak rating are moderate, and those with 2 or more weak ratings are weak.[28] The 2 lead authors independently reviewed and compared each included article using the EPHPP tool. All conflicts were resolved by consensus.

RESULTS

Search results

Database searches initially led to 787 relevant abstracts. After removing 379 duplicates, 408 abstracts remained. After applying inclusion and exclusion criteria, 5 articles remained. Figure 1 displays the Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.[23]

Participant characteristics

Study participants' ages ranged from 3 to 17 years.[29,30] Participants were more likely to be male and of African American ethnicity. When reported, participants' income levels indicated lower socioeconomic status. Overall, sample

TABLE II. Participant and study characteristics

Characteristic	Study (first author, year)				
	Bergman, 2008[33]	Bynum, 2001[30]	Halterman, 2018[32]	Perry, 2018[31]	Romano, 2001[29]
Sample size	96	49	400	363	27
Age (y)	5-12	12-17	3-10, average 7.8	7-14, median 9.6	13.4 average
% male	54	31	61.8	56	58.8
Ethnicity	71% African American; 14.8% Latino; 14.8% other	97.8% Black/African American; 2.2% white/Caucasian	31.8% Hispanic; 57.5% African American	81% African American; 15% white; 4% multiple races	70.5% Hispanic; 2.4% Caucasian; 5.9% black
Location	San Francisco, Calif, USA	Southeastern AR, USA	Rochester, NY, USA	Arkansas Delta Region, USA	Hart, Texas, USA
Urban vs rural	Urban	Rural	Urban	Rural	Rural
Study design	Cohort	Randomized	Randomized	Randomized	Cohort
No. at follow-up	83	36	381	279 (3 mo) 187 (6 mo)	17
Duration	32 wk	4 wk	1 school year	1 y	6 mo
Intervention length for patients (min, sessions)	30, 2 or 4	15, 2	Not specified	30-45, 5	Not specified
Tele-education provider	"Asthma specialist"	Pharmacist	Intervention group only: Clinician (PCP or study clinician), supervised by study team	Board-certified allergist, respiratory therapist, or trained asthma educator	Nurse
Total number of visits in which participants took part	4	3	4	5	4
Number of tele-education sessions in which participants took part	1	3	3 (not all subjects completed all 3 sessions)	5	3*

*Article did not specifically mention education at the follow-up visits; only the initial/baseline face-to-face encounter specifically mentioned education.

sizes ranged from 27 participants to 400 participants.[31,32] For more detail on patient characteristics, see Table II.

Study design

Project scopes of studies involved testing a school-based care model,[31,33] improving asthma management and self-efficacy,[30,31] improving QOL,[29,33] and reducing the burden of asthma.[32] Three studies examined how programs could directly decrease asthma symptom severity and episodes for children with asthma.[29,31,32] The other 2 studies examined indirect support of asthma, through assessment of asthma at schools[33] and through use of metered dose inhalers.[30] These and other study design characteristics—including number of educational visits versus clinical visits, where applicable—are listed in Table II.

Study characteristics: Funding, type of telemedicine, and caregiver involvement

Our review includes 5 articles published between 2001 and 2018 in the United States. Two projects were conducted in urban settings[32,33] and 3 in rural settings.[29-31]

The type of telemedicine and/or tele-education provided in the 5 projects varied as did the telemedicine provider. One study[32] used asynchronous visits and live video streaming. All study designs provided asthma education through telemedicine: 2 of the included studies[30,31] focused exclusively on educational methodologies, and the 3 remaining studies[29,32,33] provided clinical and educational methodologies. In the first of the 3 to include a clinical component to the intervention, it appears usual care is considered the control condition, but it is not clear in this article[32] or the related protocol article[34] whether that usual care occurs via telemedicine or face-to-face. In the second article, clinical recommendations assessed via telemedicine were sent to the primary care provider.[33] For the final study, the study physician and team appeared to focus on asthma and related to conditions (including providing medications, changes in plans, etc) regarding patients with asthma for the study duration.[29] This was done primarily via telemedicine except for initial assessment. It is also unclear in this case whether usual care is done face-to-face or via telemedicine because the clinic that conducted the research held regular telemedicine clinics at the time of publication.

Curricular tools used to provide asthma education

Although all studies provided education to school-age individuals with asthma via tele-education, only 1 study[33] identified their educational curriculum source.[35]

TABLE III. Instruments and outcomes

Outcome Type	Outcome	Measure (units)	Study	n	Mean (SD or %, if indicated)				Significance, MD, or OR
					Treatment	Control	Baseline	Postintervention	
Clinical	Airway inflammation	Change in exhaled nitric oxide (ppb)	Halterman et al, 2018[32]	364	−5.44 (19.5)	0.10 (21.9)			MD: −5.54 95% CI: −9.8 to −1.3
	Spirometry/ pulmonary function	FEV_1 (L)	Bergman et al, 2008[33]	83			96.5 (NR)	96.7 (NR)	NS
			Perry et al, 2018[31]		NR	NR			NS
			Romano et al, 2001[29]	17			NR	NR	NR
		FEF_{25-75} (L/s)†	Bergman et al, 2008[33]	83			86.9 (NR)	86.3 (NR)	NS
		FEF_{Max} (L/s)	Bergman et al, 2008[33]	83			97.5 (NR)	98.0 (NR)	NS
		FEF-Unspecified (L/s)	Perry et al, 2018[31]		NR	NR			NS
		FVC (L)	Bergman et al, 2008[33]		NR	NR			NR
			Perry et al, 2018[31]		NR	NR			NS
		FEV_1/FVC (%)	Bergman et al, 2008[33]	83			94.5 (NR)	95.9 (NR)	NS
		PEFR (L/min)	Bergman et al, 2008[33]	83			NR	NR	NR
	Symptoms and SFDs	SFDs/14 d	Halterman et al, 2018[32]	395	11.6 (2.7)	10.97 (3.2)			MD: 0.69 95% CI: 0.15 to 1.22
			Perry et al, 2018[31]	186	8.8* (5.1)	9.4 (5.1)			$P = .55$
		SFDs/7 d	Romano et al, 2001[29]	17			4.31 (NR)	2.35 (NR)	$P < .05$
		Days with daytime symptoms/14 d	Halterman et al, 2018[32]	395	1.7 (2.0)	2.1 (2.2)			MD: −0.46 95% CI: −0.85 to −0.07
		Days with nighttime symptoms/14 d	Halterman et al, 2018[32]	395	0.9 (1.5)	1.4 (2.0)			MD: −0.41 95% CI: −0.74 to −0.09
		Days with limited activity/ 14 d	Halterman et al, 2018[32]	395	1.3 (2.1)	1.6 (2.2)			MD: −0.40 95% CI: −0.77 to −0.03
		Mean symptom scores (NR)	Romano et al, 2001[29]	17			2.32	1.31	$P < .001$
		No. of wheezing episodes/ 14 d	Bergman et al, 2008[33]	83			1.18	0.99	NS
		No. of asthma attacks/14 d	Bergman et al, 2008[33]	83			0.33	0.153	$P = .07$
	Health care utilization	No. of overnight in hospital/14 d	Bergman et al, 2008[33]	83			0.012	0.012	NS
		No. of ED visits/14 d	Bergman et al, 2008[33]	83			0.059	0.024	NS
		No. of sick visits/14 d	Bergman et al, 2008[33]	83			0.072	0.072	NS
		≥1 ED visit or hospitalization/1 y	Halterman et al, 2018[32]	395	14 (7.0)	29 (14.8)			OR: 0.52 95% CI: 0.32 to 0.84
	Medication use	Days with rescue medication use/14 d	Halterman et al, 2018[32]	395	1.9 (2.5)	2.0 (2.5)			MD: −0.14 95% CI: −0.62 to 0.33
		Preventative medication prescription (N)	Halterman et al, 2018[32]	395	181 (91.0)	132 (67.3)			OR: 8.67 95% CI: 4.19 to 17.95

Education	Education	School absenteeism: ≥1 d absent from school due to asthma per 14-d period (N)	Halterman et al, 2018[32]	395	89 of 199 (44.7%)	103 of 196 (52.6%)			OR: 0.79, 95% CI: 0.56 to 1.11
Satisfaction	Parental satisfaction	Parent/caregiver satisfaction with intervention (NR)	Bergman et al, 2008[33]				0.85	0.87	$P = .02$
		Parent/caregiver endorsement of the intervention/control (N)	Halterman et al, 2018[32]	377	152 of 193 (78.8%)	111 of 184 (60.3%)			NR
		Parent/caregiver report of better communication with school nurse (N)	Halterman et al, 2018[32]	377	105 of 193 (54.4%)	74 of 184 (40.2%)			NR
		Parent/caregiver comfort with nurse giving medications (N)	Halterman et al, 2018[32]	377	187 of 193 (96.9%)	162 of 184 (88.0%)			NR
	Patient satisfaction	Patient satisfaction with intervention (Likert, 1/low) to 5/high)†	Bynum et al, 2001[30]	36	4.58	4.15			$P = .13$
Self-management	Technique	Metered Dose Inhaler Technique (steps correct)	Bynum et al, 2001[30]	36	7.33/8.00 (0.72)	5.14/8.0 (1.62)			$P < .001$
	Taking personal responsibility	Peak flow meter use (yes)	Perry et al, 2018[31]	187	79 of 100 (79%)	39 of 87 (45%)			$P < .01$
		Takes medication as prescribed all or most of the time (yes)	Perry et al, 2018[31]	187	78 of 100 (78%)	55 of 87 (63%)			$P = .03$
Self-efficacy	Self-efficacy	Participant self-efficacy (0/none of the time to 3/all of the time)	Perry et al, 2018[31]	145	52.1 (11.0)	51.8 (9.1)			$P = .66$
		Parent/caregiver self-efficacy (1/not at all to 5/completely sure)	Perry et al, 2018[31]	186	47.2 (5.0)	46.9 (5.4)			$P = .66$
Knowledge gain	Participant	Participant asthma knowledge (number correct)	Bergman et al, 2008[33]	83			16.6/23	17.4/23	$P = .03$
	Caregiver	Caregiver asthma knowledge (number correct)	Perry et al, 2018[31]	184	15.3/20 (2.3)	15.3/20 (2.5)			$P = .62$
		Parent/caregiver asthma knowledge (number correct)	Bergman et al, 2008[33]				11.9/25	14/25	$P < .001$
QOL	Participant	CHSA: Physical	Bergman et al, 2008[33]	83			84.2	87.4	$P = .009$
			Perry et al, 2018[31]	185	77.5 (17.3)	83.6 (14.5)			$P = .19$

(continued)

TABLE III. *(Continued)*

Outcome Type	Outcome	Measure (units)	Study	n	Mean (SD or %, if indicated)				Significance, MD, or OR
					Treatment	Control	Baseline	Postintervention	
		Health (Likert, 1/low to 5/high)	Bergman et al, 2008[33]	83			92.4	94.7	$P = .008$
		CHSA: Activity − Child (Likert, 1/low to 5/high)	Perry et al, 2018[31]	179	83.8 (18.5)	86.6 (14.6)			$P = .83$
		CHSA: Activity − Family (Likert, 1/low to 5/high)	Bergman et al, 2008[33]	83			92.2	95.2	NS
			Perry et al, 2018[31]	186	89.2 (14.4)	94.6 (8.7)			$P = .02$
		CHSA: Emotional Health − Child (Likert, 1/low to 5/high)	Bergman et al, 2008[33]	83			91.8	91.5	NS
			Perry et al, 2018[31]	186	74.4 (25.2)	81.7 (23.5)			$P = .31$
		CHSA: Emotional Health − Family (Likert, 1/low to 5/high)	Bergman et al, 2008[33]	83			80.1	81.1	NS
			Perry et al, 2018[31]	185	78.2/100 (12)	81.9/87 (11.3)			$P = .12$
		PedsQL 3.0 (Likert, 1/low to 5/high)	Perry et al, 2018[31]		NR	NR			$P = .06$
		Mini-PAQLQ (Likert, 1/no impairment to 5/maximum impairment)	Perry et al, 2018[31]		NR	NR			NS
		PAQLQ (Likert, 1/no impairment to 5/maximum impairment)	Romano et al, 2001[29]				"Significant Improvement" (p284)‡		$P < .01$
	Parent/caregiver	PACQLQ (Likert, 1/low to 7/high)	Halterman et al, 2018[32]	379	0.79 (1.1)	0.65 (1.1)			MD: 0.14
									95% CI: −0.08 to 0.37
			Romano et al, 2001[29]				"Significant Improvement"(p 284)‡		$P < .002$

ED, Emergency department; FEF_{25-75}, forced expiratory flow at 25% to 75% of forced vital capacity; FEF_{Max}, forced expiratory flow maximum; *FVC*, forced vital capacity; *MD*, mean difference; *NR*, not reported; *NS*, nonsignificant; *OR*, odds ratio; *PACQLQ*, Pediatric Asthma Caregiver's Quality of Life Questionnaire; *PAQLQ*, Pediatric Asthma Quality of Life Questionnaire; *PedsQL 3.0*, Pediatric Quality of Life Inventory 3.0; *PEFR*, peak expiratory flow rate.
Note: Empty cells indicate no data reported.
*Results listed here reflect the comparison between intervention and control at study end, not improvement within these 2 conditions.
†This score aggregates 13 satisfaction questions, none of which showed a significant difference between treatment and control conditions.
‡No baseline or postintervention scores given on the PAQLQ or PACQLQ.

Instruments used for outcome measurements

All included studies identified education as an intervention mechanism; however, not all assessed understanding or asthma management as an outcome. Two assessed knowledge gain[31,33] and 1 measured inhaler skill—a self-management factor.[30] The remaining 2 did not measure knowledge or skill.[29,32] All but 1 study[30] measured some form of clinical outcome (eg, FEV_1) and 3 measured intervention satisfaction,[30,32,33] with 2 assessing parent satisfaction[32,33] and 1 patient satisfaction.[30] One study mentioned school absenteeism,[32] 1 measured self-efficacy,[31] and 4 measured QOL.[29,31-33] For details regarding the instruments used and the outcomes reported, please see Table III.

Outcomes

Clinical outcomes. Research question 1 asked whether live 2-way streaming of asthma-based telemedical education improves asthma-related clinical outcomes. Four studies[29,31-33] measured clinically related outcomes across 5 categories—airway inflammation, pulmonary function, symptoms and symptom-free days (SFDs), health care utilization, and medication use. Only 1 examined airway inflammation,[32] reporting a mean difference of 5.54 parts per billion (95% CI, −9.8 to −1.3) between treatment (mean, −5.44 ± 19.5) and control (mean, 0.10 ± 21.9) by measuring change in exhaled nitric oxide.

Three different studies measured spirometry/pulmonary function using 7 different tests, all of which used FEV_1.[29,31,33] Other tests included forced expiratory flow and forced vital capacity. No study found any significant changes.

Four studies measured symptom occurrence or absence.[29,31-33] Three reported SFDs, though with mixed results. One reported a mean difference of 0.69 days between treatment and control conditions over 14 days across 395 respondents (95% CI, 0.15-1.22).[32] Another reported no significant changes between treatment and control over 14 days across 186 respondents.[31] The last noted a statistically significant reduction in symptoms between baseline and postintervention over 7 days ($P < .05$).[29]

Symptoms and days with limited activity were measured, reporting some improvement compared with the control group (mean differences of −0.46 days [95% CI, −0.85 to −0.07], −0.41 days [95% CI, −0.74 to −0.09], and −0.40 days [95% CI, −0.77 to −0.03], respectively).[32] Another study noted a significant reduction in mean symptom scores from baseline to postintervention ($P < .001$).[29] The final study examining symptoms reported no significant improvements in wheezing episode and asthma attack frequency.[33]

Two studies reported health care utilization.[32,33] One measured the number of overnight hospital stays and emergency department visits, but reported no significant differences. This same study reported provider biweekly visits and found a significant reduction in unscheduled sick visits to participants' primary care physician after 8 weeks ($P = .05$), but this significance disappeared by study end (32 weeks).[33] The other study noted a decrease in the number of participants visiting the hospital/emergency department over the past year compared with the control group (odds ratio, 0.52; 95% CI, 0.32-0.84).[32]

To summarize, 4 studies measured clinical outcomes. One found improvements in airway inflammation and medication use.[32] However, no study found any significant changes in pulmonary function. Symptom burden and health care utilization demonstrated mixed results, though symptoms were generally reduced in terms of SFDs.

Educational outcomes. Research question 2 asked whether telemedically delivered asthma education affects asthma-related educational outcomes. One study looked at intervention-related educational outcomes and reported decreased asthma-related absenteeism (≥1 day absent from school due to asthma in a 14-day period; odds ratio, 0.79; 95% CI, 0.56-1.11).[32]

Additional outcomes. Our final research question asked whether additional outcomes have been measured with this type of intervention. The studies included here also reported outcomes related to satisfaction, self-management, self-efficacy, asthma knowledge, and QOL.

Satisfaction. Three articles measured satisfaction with the study's program from baseline to postintervention or between treatment and control groups, 2 related to parental/caregiver satisfaction[32,33] and the other student/participant satisfaction.[30] Regarding caregiver satisfaction, 1 study found a significant difference ($P = .02$) whereas the other reported higher satisfaction levels but cited no statistics.[32] The third study looked at participant satisfaction and found no significant difference.[30]

Self-management and self-efficacy. Two studies reported the child's abilities to manage their asthma.[30,31] One found significant improvements in inhaler technique compared with the control ($P < .001$).[30] The other study[31] showed significant improvements in terms of both peak flow meter use ($P < .01$) and taking responsibility to use asthma management tools and resources over time ($P = .03$).

Knowledge gain. Two studies[31,33] examined knowledge gain. One found no improvement in asthma knowledge among caregivers over the control group.[31] The other reported statistically significant knowledge gain among children and parents from baseline to intervention end ($P = .03$ and $P < .001$, respectively).[33]

Quality of life. Five different QOL measures were used by 4 studies.[29,31-33] The only QOL measure used by more than 1 study was the Children's Health Survey for Asthma (CHSA).[36-38] Of the 2 using the CHSA, 1 study[33] found significant differences between baseline and postintervention on 2 dimensions: Physical Health and Social Activity—Child ($P = .009$ and $P = .008$, respectively). The other study using the CHSA found a significant difference between treatment and control on Social Activity—Family ($P = .02$).[31] Neither study found a significant difference on the remaining 2 dimensions: Emotional Health—Child (or Family).

One study used the Pediatric Quality of Life Inventory 3.0[38-41] and the Mini-Pediatric Asthma Quality of Life Questionnaire[40] in addition to the CHSA and found no significant differences between treatment and control groups on either of these measures.[31]

The Pediatric Asthma Quality of Life Questionnaire[41] was used by 1 study.[29] This study reported "significant improvement" between baseline and postintervention ($P < .01$) but reports no specific baseline or postintervention scores.

The Pediatric Asthma Caregiver's Quality of Life Questionnaire[42] focuses on parents and caregivers of participants with asthma and was used by 2 studies.[29,32] One reported a mean difference of 0.14 between treatment and control groups (95% CI, −0.08 to 0.37), whereas the second study reported

TABLE IV. Quality assessment ratings of included studies using the EPHPP quality assessment tool

Study (author, year)	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and dropouts	Global rating
Bergman et al, 2008[33]	Moderate	Moderate	Strong	Weak	Strong	Strong	Moderate
Halterman et al, 2018[32]	Moderate	Strong	Strong	Strong	Strong	Strong	Strong
Perry et al, 2018[31]	Moderate	Strong	Strong	Weak	Strong	Weak	Weak
Romano et al, 2001[29]	Moderate	Moderate	Strong	Weak	Strong	Moderate	Moderate
Bynum et al, 2001[30]	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong

Note: Each article used multiple data collection tools. In each, at least 1 measure was deemed reliable and valid by EPHPP guidelines. However, not all articles completely described all included tools and the EPHPP offers no guidance regarding multiple measures. Because each article had at least 1 reliable and valid tool, we designated each as strong regarding data collection methods.

"significant improvement" between baseline and postintervention ($P < .002$), but reported no baseline or postintervention scores.

Methodological rigor

Using the EPHPP tool, we rated 2 articles strong, 2 moderate, and 1 weak, with mixed results for blinding, withdrawals/dropouts, and study design. All articles were rated moderate in their selection bias and strong in their handling of confounders and data collection methods. Blinding was generally the weakest criterion, with 1 exception.[32] Table IV presents study ratings by category.

Curricular tools used by studies

One study specified an educational curriculum for an intervention.[33] Two other studies[30,31] gave only slight curricular information. As such, we can offer no comparison between curricula.

DISCUSSION

The purpose of this review was to determine the extent to which 2-way live streaming of asthma-based tele-education improves outcomes for school-age individuals (ages 5-18 years) with asthma and their families. We sought to capture these outcomes by focusing our literature search on delivery methods and finding patterns in the study outcomes. We reported on various measured outcomes despite the relatively small number of studies meeting the inclusion criteria. Although most outcome measures were reported as reliable and valid, not all can be verified.

Clinical outcomes

Clinical outcomes exhibited mixed results in terms of both which studies reported significant findings and clinical burdens affected by the intervention. Pulmonary function does not appear affected by this type of intervention, but there is support for symptom reduction. In addition, although we believe that airway inflammation, health care utilization, and medication use are ideas worthy of measurement, our findings from these articles indicate that these areas need further examination. In response to our first research question—does live 2-way streaming of asthma-based telemedical education improve asthma-related clinical outcomes—the evidence from the studies included here, although not negative, is inconsistent and inconclusive.

Educational outcomes

With only 1 study measuring school-related outcomes, and with only 1 variable (asthma-related absenteeism), the educational value of a program such as this for participants with asthma is very limited and not generalizable.[32] Furthermore, other school-related activities (eg, students' academic well-being, including grades and test scores) were not included in these studies.

Satisfaction outcomes

Parent/caregiver satisfaction was measured by 4 methods in 2 studies,[32,33] with one of these[32] not reporting the statistical strength and the other study[33] reporting a statistically significant improvement, and patient satisfaction was measured only by 1 study.[30] Thus, it is difficult to draw any conclusions regarding patient/participant satisfaction.

Self-management and self-efficacy outcomes

Self-management was measured in 3 ways by 2 studies,[30,31] with encouraging improvements in asthma-related behaviors in each case. Interestingly though, 1 of these studies[31] also measured changes in self-efficacy and found no statistically significant difference, which is somewhat peculiar in that an individual's ability to self-manage would improve, without a commensurate improvement in belief that they can better manage their own condition.

Knowledge outcomes

Given the mixed results in improvements in asthma knowledge and that only 2 studies measured it,[31,33] we encourage future research on this matter because, intuitively, it is closely related to the ability to control manageable factors that can affect asthma burden.

QOL outcomes

In terms of QOL of children with asthma, we believe that further research is warranted. We found mixed support for the Physical Health, Activity—Child, and Activity—Family dimensions of the CHSA, but no support for the emotional health dimensions of the CHSA, the Pediatric Quality of Life Inventory 3.0, or the Mini-Pediatric Asthma Quality of Life Questionnaire.[31,33] With increased self-management ability may come increased health and freedom to be active for both the child and family, but to our knowledge, this relationship has not yet been tested. Parental/caregiver QOL was measured in 2 studies,[29,32] and both reported significant improvements using the Pediatric Asthma Caregiver's Quality of Life Questionnaire. We believe this should be interpreted with caution, however, because 1 study[32] reported their test statistics and the other[29] did not. With the mixed and sometimes questionable results in mind—and trusting the validity of the measures used—a relationship between telemedically delivered pediatric asthma education and improved QOL may exist. However, we are reluctant to assert such a claim without further testing.

Rural versus urban

Within our 5 included articles, 2 projects were conducted in urban settings[32,33] and 3 in rural settings.[29-31] Although any potential changes in the curricula for differences in the study setting (rural vs urban) were not specifically addressed in these articles, Halterman et al state that their model "could serve as a model….in both rural and urban communities."[34(p1)] Thus, we believe that similar curricula could be used in both rural and urban settings, especially given evidence of greater asthma morbidity among children living in poverty and minority children regardless of the rural or urban setting for the children.[13] This is one very distinctive advantage of telemedical education: the distance between patient and provider is not a limiting factor.

Methodological rigor

Using the EPHPP tool, we objectively assessed the quality of each study on methodological rigor. To strengthen future studies, we suggest researchers consider blinding the researchers, as well as the participants, to the intervention, though this is often difficult in scenarios outside of a research laboratory. In addition, future studies could be strengthened with the consistent use of both valid and reliable tool data collection tools, including a specific discussion regarding these factors for each tool.

Curricular concerns

Unfortunately, with no or limited details regarding the educational curriculum used in each study, all measured outcomes are difficult to interpret. Furthermore, the lack of an identifiable educational intervention calls those outcomes into question because the nature of the intervention is not entirely understandable, validated, or reproducible in most cases. To be useful, curricula need to cover a specific and relevant set of issues. We believe that children and their families worldwide would benefit from a standardized curriculum on asthma self-management and suggest that asthma educators and national bodies of health care experts prioritize the development and testing of such a curriculum. The potential for improved knowledge outcomes, in combination with results about improved self-management,[30,31] suggest that a validated curriculum and evaluation delivered to children with asthma would, under most circumstances, result in an improved understanding and self-management of their asthmatic condition.

Limitations and future directions

All systematic reviews are subject to both the nature of the subjects they examine and their studies' strengths and limitations. In developing search criteria, we encountered difficulties with developing the most accurate search terms because it is the combination of concepts that makes the search unique, not the terms themselves. For example, there are many terms associated with the prefix "tele" that apply to health care, and then additionally, we had to capture the appropriate age group within these applicable studies. However, we felt confident in our results given that we used the professional expertise of a medical librarian in our literature search and had the search strategies peer-reviewed by a third party using the Peer Review for Electronic Search Strategies guidelines.[25]

Another challenge is that the studies reviewed here consistently used different measures for the same variables of interest, making direct comparisons less evident. We anticipate that as more studies emerge and the body of knowledge matures, more standardized measures will be used.

In addition, with the lack of measures relating cost of care in our included studies, and especially because of the socioeconomic scales for most participants and the potential for cost-savings with tele-education, we suggest the addition of cost of care as a measure that would relate to self-management and QOL.

Only 2 studies[30,31] focused solely on education as an intervention. The other 3 studies[29,32,33] had some form of a clinical component, though each did not always isolate portions of the interventions relative to the measured outcomes. Thus, we anticipate that certain outcomes, such as asthma knowledge, would be more heavily influenced by an educational component. Nonetheless, we suggest that future studies make an effort to better isolate components of their interventions to avoid an interaction.

Measures that tend toward precision are more often not significant and those that tend toward less precision appear more likely to be significant (eg, participants report measures such as reporting symptom intensity and/or frequency over time). Many of the interesting clinical results, for example, are those related to self-reported items such as SFDs or days with wheezing. Although we know that self-report mechanisms hold certain advantages, such as information richness, as well as response motivation and practicality,[43] they also carry certain disadvantages, such as a social desirability bias[44] and self-report bias.[45]

We found variables measuring other outcomes, including self-management, satisfaction, self-efficacy, and QOL. Just as important as the gains (or lack thereof) in the outcome categories is the variety of variables used in the intervention studies. We believe that future research would benefit from consistent use of other outcome measures and encourage further exploration of the relevant variables that influence symptomatic control and asthma-related QOL through educational asthma interventions delivered via telemedicine.

CONCLUSIONS

Real-time telemedically delivered asthma education may improve QOL, enhance symptom management ability, and reduce symptom burden on patients with asthma and their care providers. Although we find no evidence of additional burden, we also find varied results regarding the benefits. Given both the potential of such a simple intervention[46-48] and this review's inconclusive findings, more studies are needed that consider telemedically delivered asthma education to school-age individuals with asthma, as well as further tool development and validation of the methods and evaluating instruments used for an intervention.

We suggest that future studies focus on 2 main themes: (1) refinement of the curricular requirements to maximize the effectiveness of educationally oriented telemedical offerings and (2) a more thorough analysis of how this type of educational offering impacts its intended beneficiaries—including more clarity on evaluative tool validity and a better understanding of variables related to improved QOL as it applies to patients aged 5 to 18 years with asthma.[44,49-51]

REFERENCES

1. Zahran HS, Bailey CM, Damon SA, Garbe PL, Breysse PN. Vital signs: asthma in children—United States, 2001-2016. MMWR Morb Mortal Wkly Rep 2018; 67:149-55.

2. Expert Panel Report 3 (EPR-3): Guidelines for the Diagnosis and Management of Asthma—Summary Report 2007. J Allergy Clin Immunol 2007;120:S94-138.
3. Sullivan PW, Ghushchyan V, Navaratnam P, Friedman HS, Kavati A, Ortiz B, et al. The national cost of asthma among school-aged children in the United States. Ann Allergy Asthma Immunol 2017;119:246.
4. Dahl J, Gustafsson D, Melin L. Effects of a behavioral treatment program on children with asthma. J Asthma 1990;27:41-6.
5. Kirk S, Beatty S, Callery P, Gellatly J, Milnes L, Pryjmachuk S. The effectiveness of self-care support interventions for children and young people with long-term conditions: a systematic review. Child Care Health Dev 2013;39:305-24.
6. Bernard-Bonnin AC, Stachenko S, Bonin D, Charette C, Rousseau E. Self-management teaching programs and morbidity of pediatric asthma: a meta-analysis. J Allergy Clin Immunol 1995;95:34-41.
7. Barlow J, Wright C, Sheasby J, Turner A, Hainsworth J. Self-management approaches for people with chronic conditions: a review. Patient Educ Couns 2002;48:177-87.
8. Buford TA. School-age children with asthma and their parents: relationships with health care providers. Issues Compr Pediatr Nurs 2005;28:153-62.
9. Klok T, Kaptein AA, Brand PLP. Non-adherence in children with asthma reviewed: the need for improvement of asthma care and medical education. Pediatr Allergy Immunol 2015;26:197-205.
10. Clark NM. Community-based approaches to controlling childhood asthma. Annu Rev Public Health 2012;33:193-208.
11. Bruzzese J-M, Kattan M. School-based interventions: where do we go from here? J Allergy Clin Immunol 2019;143:550-1.
12. Reynolds CA, Maughan ED. Telehealth in the school setting: an integrative review. J Sch Nurs 2015;31:44-53.
13. Akinbami LJ, LaFleur BJ, Schoendorf KC. Racial and income disparities in childhood asthma in the United States. Ambul Pediatr 2002;2:382-7.
14. Ozuah PO, Reznik M. The role of telemedicine in the care of children in underserved communities. J Telemed Telecare 2004;10:78-80.
15. Reznik M, Sharif I, Ozuah PO. Use of interactive videoconferencing to deliver asthma education to inner-city immigrants. J Telemed Telecare 2004;10:118-20.
16. Portnoy JM, Waller M, De Lurgio S, Dinakar C. Telemedicine is as effective as in-person visits for patients with asthma. Ann Allergy Asthma Immunol 2016;117:241-5.
17. Perry TT, Turner JH. School-based telemedicine for asthma management. J Allergy Clin Immunol Pract 2019;7:2524-32.
18. Kew KM, Cates CJ. Remote versus face-to-face check-ups for asthma. Cochrane Database Syst Rev 2016;4:CD011715.
19. Reznik M, Ozuah PO. Asthma educational videoconferencing for parents: a case-control study. J Telemed Telecare 2004;10:83-5.
20. Wu AC, Rehman N, Portnoy J. The good, the bad, and the unknown of telemedicine in asthma and allergy practice. J Allergy Clin Immunol Pract 2019;7:2580-2.
21. Elliott T, Shih J, Dinakar C, Portnoy J, Fineman S. American College of Allergy, Asthma & Immunology Position Paper on the Use of Telemedicine for Allergists. Ann Allergy Asthma Immunol 2017;119:512-7.
22. Moher D, Cook DJ, Eastwood S, Olkin I, Rennie D, Stroup DF. Improving the quality of reports of meta-analyses of randomised controlled trials: the QUOROM statement. Quality of Reporting of Meta-analyses. Lancet 1999;354:1896-900.
23. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Ann Intern Med 2009;151:264-9.
24. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 2015;4:1.
25. McGowan J, Sampson M, Salzwedel DM, Cogo E, Foerster V, Lefebvre C. PRESS peer review of electronic search strategies: 2015 guideline statement. J Clin Epidemiol 2016;75:40-6.
26. Armijo-Olivo S, Stiles CR, Hagen NA, Biondo PD, Cummings GG. Assessment of study quality for systematic reviews: a comparison of the Cochrane Collaboration Risk of Bias Tool and the Effective Public Health Practice Project Quality Assessment Tool: methodological research. J Eval Clin Pract 2012;18:12-8.
27. Thomas BH, Ciliska D, Dobbins M, Micucci S. A process for systematically reviewing the literature: providing the research evidence for public health nursing interventions. Worldviews Evid Based Nurs 2004;1:176-84.
28. National Collaborating Centre for Methods and Tools. Quality Assessment Tool for Quantitative Studies. Hamilton, ON: McMaster University; 2008.
29. Romano MJ, Hernandez J, Gaylor A, Howard S, Knox R. Improvement in asthma symptoms and quality of life in pediatric patients through specialty care delivered via telemedicine. Telemed J E-Health 2001;7:281-6.
30. Bynum A, Hopkins D, Thomas A, Copeland N, Irwin C. The effect of telepharmacy counseling on metered-dose inhaler technique among adolescents with asthma in rural Arkansas. Telemed J E Health 2001;7:207-17.
31. Perry TT, Halterman JS, Brown RH, Luo C, Randle SM, Hunter CR, et al. Results of an asthma education program delivered via telemedicine in rural schools. Ann Allergy Asthma Immunol 2018;120:401-8.
32. Halterman JS, Fagnano M, Tajon RS, Tremblay P, Wang H, Butz A, et al. Effect of the School-Based Telemedicine Enhanced Asthma Management (SB-TEAM) program on asthma morbidity: a randomized clinical trial. JAMA Pediatr 2018;172:e174938.
33. Bergman DA, Sharek PJ, Ekegren K, Thyne S, Mayer M, Saunders M. The use of telemedicine access to schools to facilitate expert assessment of children with asthma. Int J Telemed Appl 2008;2008:159276.
34. Halterman JS, Tajon R, Tremblay P, Fagnano M, Butz A, Perry TT, et al. Development of school-based asthma management programs in Rochester, New York: presented in honor of Dr Robert Haggerty. Acad Pediatr 2017;17:595-9.
35. Evans D, Clark NM, Feldman CH, Rips J, Kaplan D, Levison MJ, et al. A school health education program for children with asthma aged 8-11 years. Health Educ Q 1987;14:267-79.
36. Asmussen L, Olson LM, Grant EN, Fagan J, Weiss KB. Reliability and validity of the Children's Health Survey for Asthma. Pediatrics 1999;104:e71.
37. Sullivan SA, Olson LM. Developing condition-specific measures of functional status and well-being for children. Clin Perform Qual Health Care 1995;3:132-9.
38. Josie KL, Greenley RN, Drotar D. Health-related quality-of-life measures for children with asthma: reliability and validity of the Children's Health Survey for Asthma and the Pediatric Quality of Life Inventory 3.0 Asthma Module. Ann Allergy Asthma Immunol 2007;98:218-24.
39. Greenley RN, Josie KL, Drotar D. Self-reported quality of life among inner-city youth with asthma: an empirical examination of the PedsQL 3.0 Asthma Module. Ann Allergy Asthma Immunol 2008;100:106-11.
40. Wing A, Upton J, Svensson K, Weller P, Fletcher M, Walker S. The standardized and mini versions of the PAQLQ are valid, reliable, and responsive measurement tools. J Clin Epidemiol 2012;65:643-50.
41. Juniper EF, Guyatt GH, Feeny DH, Ferrie PJ, Griffith LE, Townsend M. Measuring quality of life in children with asthma. Qual Life Res 1996;5:35-46.
42. Juniper EF, Guyatt GH, Feeny DH, Ferrie PJ, Griffith LE, Townsend M. Measuring quality of life in the parents of children with asthma. Qual Life Res 1996;5:27-34.
43. Paulhus DL, Vazire S. The self-report method. Handbook Res Meth Pers Psychol 2007;1:224-39.
44. Fisher RJ. Social desirability bias and the validity of indirect questioning. J Consumer Res 1993;20:303-15.
45. Donaldson SI, Grant-Vallone EJ. Understanding self-report bias in organizational behavior research. J Business Psychol 2002;17:245-60.
46. Butz A, Pham L, Lewis L, Lewis C, Hill K, Walker J, et al. Rural children with asthma: impact of a parent and child asthma education program. J Asthma 2005;42:813-21.
47. Halterman JS, Riekert K, Bayer A, Fagnano M, Tremblay P, Blaakman S, et al. A pilot study to enhance preventive asthma care among urban adolescents with asthma. J Asthma 2011;48:523-30.
48. Shames RS, Sharek P, Mayer M, Robinson TN, Hoyte EG, Gonzalez-Hensley F, et al. Effectiveness of a multicomponent self-management program in at-risk, school-aged children with asthma. Ann Allergy Asthma Immunol 2004;92:611-8.
49. Mclean S, Sheikh A, Cresswell K, Nurmatov U, Mukherjee M, Hemmi A, et al. The impact of telehealthcare on the quality and safety of care: a systematic overview. PLoS One 2013;8:e71238.
50. Zhao J, Zhai Y-K, Zhu W-J, Sun D-X. Effectiveness of telemedicine for controlling asthma symptoms: a systematic review and meta-analysis. Telemed J E Health 2015;21:484-92.
51. McConnochie KM, Wood NE, Kitzman HJ, Herendeen NE, Roy J, Roghmann KJ. Telemedicine reduces absence resulting from illness in urban child care: evaluation of an innovation. Pediatrics 2005;115:1273-82.