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A Comprehensive Scoping Review of Technology in the Care of Historically Marginalized Populations With Asthma: A Work Group Report of the AAAAI Diversity, Equity, and Inclusion Committee

Alan P. Baptist, MD, MPH[a,*], George E. Freigeh, MD, MA[b,*], Emily Capellari, MLIS[c], Priya Bansal, MD[d,e], Don A. Buckstein, MD[f], Maria Y. Cardozo, MD[g], Aasha Harish, MD[h], Margee Louisias, MD[i,j,k], Anil Nanda, MD[l,m], Sharmilee M. Nyenhuis, MD[n], Princess U. Ogbogu, MD[o,p], Jorge A. Rodriguez, MD[j,q], Ruchi Singla, MD[r], and Giselle Mosnaim, MD, MS[s] *Detroit and Ann Arbor, Mich; St Charles, Chicago, and Evanston, Ill; Milwaukee, Wis; Buffalo, NY; Boston and Cambridge, Mass; Lewisville and Flower Mound and Dallas, Tex; and Cleveland, Ohio*

[a]Division of Allergy and Clinical Immunology, Department of Medicine, Henry Ford Health and Michigan State University, Detroit, Mich
[b]Division of Allergy and Clinical Immunology, Department of Internal Medicine, Michigan Medicine, Ann Arbor, Mich
[c]Taubman Health Sciences Library, University of Michigan, Ann Arbor, Mich
[d]Asthma and Allergy Wellness Center, St Charles, Ill
[e]Northwestern Feinberg School of Medicine, Division of Allergy and Immunology, Chicago, Ill
[f]The Inner City Milwaukee Clinic: Allergy, Asthma & Sinus Center, Milwaukee, Wis
[g]Division of General Pediatrics/Ambulatory Care, Department of Pediatrics, Michigan Medicine, Ann Arbor, Mich
[h]Division of Allergy and Immunology, Department of Medicine, University of Buffalo Jacobs School of Medicine and Biomedical Sciences, Buffalo, NY
[i]Division of Allergy and Immunology, Brigham and Women's Hospital, Boston, Mass
[j]Harvard Medical School, Boston, Mass
[k]Harvard Medical School, Sanofi, Cambridge, Mass
[l]Asthma and Allergy Center, Lewisville and Flower Mound, Tex
[m]Division of Allergy and Immunology, University of Texas Southwestern Medical Center, Dallas, Tex
[n]Section of Allergy, Immunology and Pediatric Pulmonology, Department of Pediatrics, University of Chicago, Chicago, Ill
[o]Division of Pediatric Allergy, Immunology, and Rheumatology, University Hospitals Rainbow Babies and Children's Hospital, Cleveland, Ohio
[p]Case Western Reserve University School of Medicine, Cleveland, Ohio
[q]Division of General Internal Medicine and Primary Care, Brigham and Women's Hospital, Boston, Mass
[r]Section of Allergy and Immunology, Department of Pediatrics, University of Chicago Medicine and Biological Sciences, Chicago, Ill
[s]Division of Allergy and Immunology, Department of Medicine, Endeavor Health, Evanston, Ill

*Co-first author.

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Corresponding author: Alan P. Baptist, MD, MPH, 1 Ford Place, Detroit, MI 48202. E-mail: abaptis1@hfhs.org.

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Abbreviations used
AAAAI- American Academy of Allergy, Asthma, and Immunology
RCT- randomized control trial

BACKGROUND: Health care technology strategies are increasingly being used in research and clinical care in asthma. The use of technology in addressing asthma disparities has not been reported.
OBJECTIVE: To determine the effect of technology in historically marginalized racial and ethnic populations with asthma.
METHODS: A comprehensive literature search was conducted to identify studies that included the use of health technology in patients with asthma from historically marginalized populations. Authors reviewed studies to determine study characteristics and intervention efficacy according to predetermined outcome measures. Studies were categorized as generalized, unidirectional, or bidirectional according to the degree to which they used personalized participant data.
RESULTS: A total of 1516 studies were initially identified, with 44 studies included in the final analysis. Most studies included a majority Black population, followed by Latino population. Bidirectional studies that collect patient-specific data and provide tailored recommendations, education, or treatment options were most effective as compared with generalized and unidirectional studies. No specific technology methodology was found to be superior to others, though technology modalities that used personalized participant data and allowed for bidirectional information exchange were more effective than those that relied on generalized data.
CONCLUSION: Health care technology strategies can provide an avenue to decrease asthma disparities in historically marginalized populations. © **2025 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2025;13:1980-90)**

Key words: *Asthma; Health care technology; Race and ethnicity; Social determinants of health; Text messaging; Telehealth; Inhaler device monitor*

INTRODUCTION

Asthma is a prevalent chronic disease with a high degree of morbidity, mortality, and health care utilization in the United States.[1] Certain racial and ethnic groups, including Black and Latino populations, are disproportionately affected by asthma.[2,3] These groups continue to face significantly higher rates of asthma symptom burden,[4] decreased rates of controller use,[5] and higher rates of asthma emergency department visits, hospitalizations, and mortality.[6,7] There are multiple reasons behind these health disparities including socioeconomic factors, lack of access to care, and bias within the institution of medicine and society.[4] Bias in medicine and society relates to the direct actions of providers and health care systems, including individual implicit bias[8] and structural racism at institutional and organizational levels leading to worse health outcomes.[9,10]

Health care technology strategies remain an ever-emerging opportunity to improve population health. These tools have been implemented across various diseases and include a multitude of methods, including text messaging, audio/visual materials, electronic educational programs, medical device monitors, and telehealth, among others.[11] As internet access becomes more ubiquitous, technology-based health care interventions will continue to grow more prevalent. Technology has the potential to decrease health disparities; alternatively, it may exacerbate such disparities due to a lack of digital equity, where certain demographic groups do not have the same access to reliable and affordable internet and communication services as others.[12]

Although previous literature has examined the use of technology in asthma care,[13] there has not been a comprehensive analysis of the use of technology in asthma for historically marginalized populations. The purpose of this article was to perform a scoping review examining the use of technology in asthma in historically marginalized populations. The objective was to identify the populations such interventions have been studied in, to describe the specific types of interventions that are being performed, and to identify the efficacy of these interventions in improving asthma outcomes.

METHODS

This scoping review was conducted by the American Academy of Allergy, Asthma, and Immunology (AAAAI) Diversity, Equity, and Inclusion committee. A scoping review was conducted to examine health disparities in technology-based interventions for asthma. The scoping review adheres to the methodology guidance in the Joanna Briggs Institute Evidence Synthesis Manual and reporting guidance in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses − Scoping Review extension. A protocol was developed at the project outset by members of the AAAAI Diversity, Equity, and Inclusion committee and is available in Appendix 1 in this article's Online Repository at www.jaci-inpractice.org.

Literature search

The databases PubMed.gov, Embase.com, Cumulative Index to Nursing and Allied Health Literature via EBSCOhost, and Cochrane Library via Wiley were searched from database inception to September 28, 2023. The search strategies consisted of controlled vocabulary and an extensive list of related terms for each concept: *asthma*, *technology*, and *health disparities* (including terms for health equity, antiracism, social determinants of health, and traditionally marginalized and minoritized populations). No date or language limits were applied to the search. Appendix 2 in this article's Online Repository at www.jaci-inpractice.org contains the full search strategy used in the PubMed database.

Study selection

The inclusion criteria included articles (1) with patients with asthma; (2) with use of health technology; (3) addressing health disparities, health equity, social determinants of health, or a predominantly marginalized or minoritized population, and (4) with research conducted in the United States. For the purposes of this review, marginalized or minoritized populations were defined according to the Office of Management and Budget in line with the National Institute of Health. The minority racial and ethnic groups defined by the Office of Management and Budget are American Indian or Alaska Native, Asian, Black or African American, and Native Hawaiian or Pacific Islander. The ethnicity used is Latino or Hispanic.[14] The exclusion criteria were (1) not focused on patients with asthma; (2) health technology not relevant to asthma care (eg, general use of electronic health records); (3) does not address health

disparities, health equity, social determinants of health, or marginalized or minoritized populations; (4) research not conducted in the United States; (5) conference proceedings; and (6) review articles.

The scoping review was conducted using DistillerSR (DistillerSR, Inc, Ottawa, Ontario, Canada), a cloud-based systematic review tool, to efficiently screen studies for inclusion in the scoping review. Each title and abstract were independently screened by a minimum of 2 authors to identify articles that met inclusion and exclusion criteria. Screening conflicts were discussed to arrive at consensus and if consensus could not be achieved, a third author provided the prevailing decision.

Articles were then advanced to full-text review. During full-text review, studies were organized into 3 categories adapted from strategies from a previous scoping review[13]: (1) generalized studies; (2) patient-specific, noninteractive, unidirectional studies; and (3) patient-specific, interactive, bidirectional studies. Generalized studies are defined as those where nonindividualized information was provided to participants (eg, a reminder to take an inhaler daily). Unidirectional studies are defined as those where individualized information was collected from or sent to participants. Bidirectional studies are defined as those with an interactive relationship with the participant, in which insights based on data collected from the participant or resulting from participant behavior were fed back to the participant to assist with asthma management on a personalized basis. Studies were organized into these 3 categories as each category had progressively greater interaction between patient and intervention, thereby offering the potential to assess whether increased interactions improve outcomes, while considering the increasing technical and cost constraints.

Data extraction and synthesis

The lead authors of the scoping review collaboratively developed a data extraction spreadsheet, which team members independently completed for each included study. Information on study size, duration, majority race and ethnicity of participants, study type, and intervention details was collected for each study. Studies were categorized by their design. Randomized controlled trials (RCTs) included studies in which subjects were randomly allocated to control or intervention group. Nonrandomized trials included prospective interventional studies without a control group. Interventional pre-post studies included those with a single intervention with immediate measurement of outcomes in a single day. Cross-sectional observational studies included those without a direct intervention by the researchers. Prespecified outcome measures, including asthma medication adherence (as defined by the individual studies), asthma control (defined by using a validated questionnaire such as the Asthma Control Test[15] or an objective measure such as FEV_1), asthma symptoms, asthma quality of life (defined by using a validated measure such as the Asthma Quality of Life Questionnaire[16]), cost-effectiveness, feasibility, acceptability, and health care utilization were determined for each study and coded as either significant positive effect, nonsignificant positive effect, or no effect. They were alternatively coded as not reported if that particular aspect was not included in the study. Given the heterogeneity in the included studies, the authors purposefully selected these outcome measures to provide a basis for meaningful comparison between studies. This is also in line with Preferred Reporting Items for Systematic Reviews and Meta-Analyses methodology.[17]

RESULTS

The search strategy yielded a total of 1516 results. After removing duplicate references, 986 items remained for title and abstract screening, of which 664 were excluded for not meeting study criteria (Figure 1). Application of the eligibility criteria to the 320 studies advanced for full- text review led to an initial set of 71 included studies. An additional 17 studies were excluded during data extraction due to not focusing on asthma (n = 1), not providing race or ethnic minority data (n = 7), not providing health outcomes data (n = 3), study proposals of incomplete or ongoing studies (n = 4), review article (n = 1), and clinical commentary (n = 1) (Figure 1).

A total of 44 studies were included in the final analysis. There were 6 generalized studies, 10 unidirectional studies, and 28 bidirectional studies. Table I summarizes the key demographic details, interventional type, and outcome measure effects for each included study.

Although most studies had a mixed racial and ethnic composition, we sought to identify the racial and ethnic composition of the majority (ie >50%) of a study's participant population. Accordingly, 34 studies (77%) had a majority Black participant population, with 10 studies (23%) having a majority Latino participant population. No studies had a primarily Native American participant population.

There was a skew toward pediatric studies (n = 23 [52%]) as compared with adult studies (n = 15 [34%]), with 6 studies (13%) having a mixed adult and pediatric population. In general, participants nearly always found the use of technology to be feasible and acceptable when such an outcome was reported, and cost-effectiveness was rarely reported. Therefore, these factors were not included in the final analysis.

Generalized studies

There were 6 generalized studies included in the analysis. Two studies (33%) used text message reminders, 2 studies (33%) used text message reminders with additional supplemental interventions such as focus groups without individualized feedback, and 2 studies (33%) used audio/visual materials such as audio messages or educational videos (Table II). Most studies were RCTs (n = 5 [83%]), and a single study (17%) was an interventional pre-post study. Study size ranged from 20 to 217 participants (median, 50), and duration ranged from 1 day to 1 year (median, 12 weeks). Four studies had a majority Black population (67%), and 2 studies had a majority Latino population (33%).

Only 1 study[23] found a significant effect on asthma control and asthma symptoms. No studies found a significant effect on medication adherence, asthma quality of life, or health care utilization (Figure 2, *A*).

Unidirectional studies

There were 10 unidirectional studies included in the analysis. Studies used various electronic methods, with the 2 most common being an inhaler device (including electronic medication monitor to monitor usage and/or technique) in 3 studies (30%) and some form of ecological momentary assessment in 2 studies (30%), a self-report assessment tool whose key characteristic is behavior and environmental assessment in real time.[62] The next most common electronic tool was a noninhaler device (including activity trackers, noninhaler medication monitors for non−inhaler-based asthma medications such as a pill tracker) in 2 studies (20%). The most common study design was nonrandomized trial (n = 7 [70%]) followed by RCT (n = 2 [20%]). Study sizes ranged from 20 to 333 participants (median,

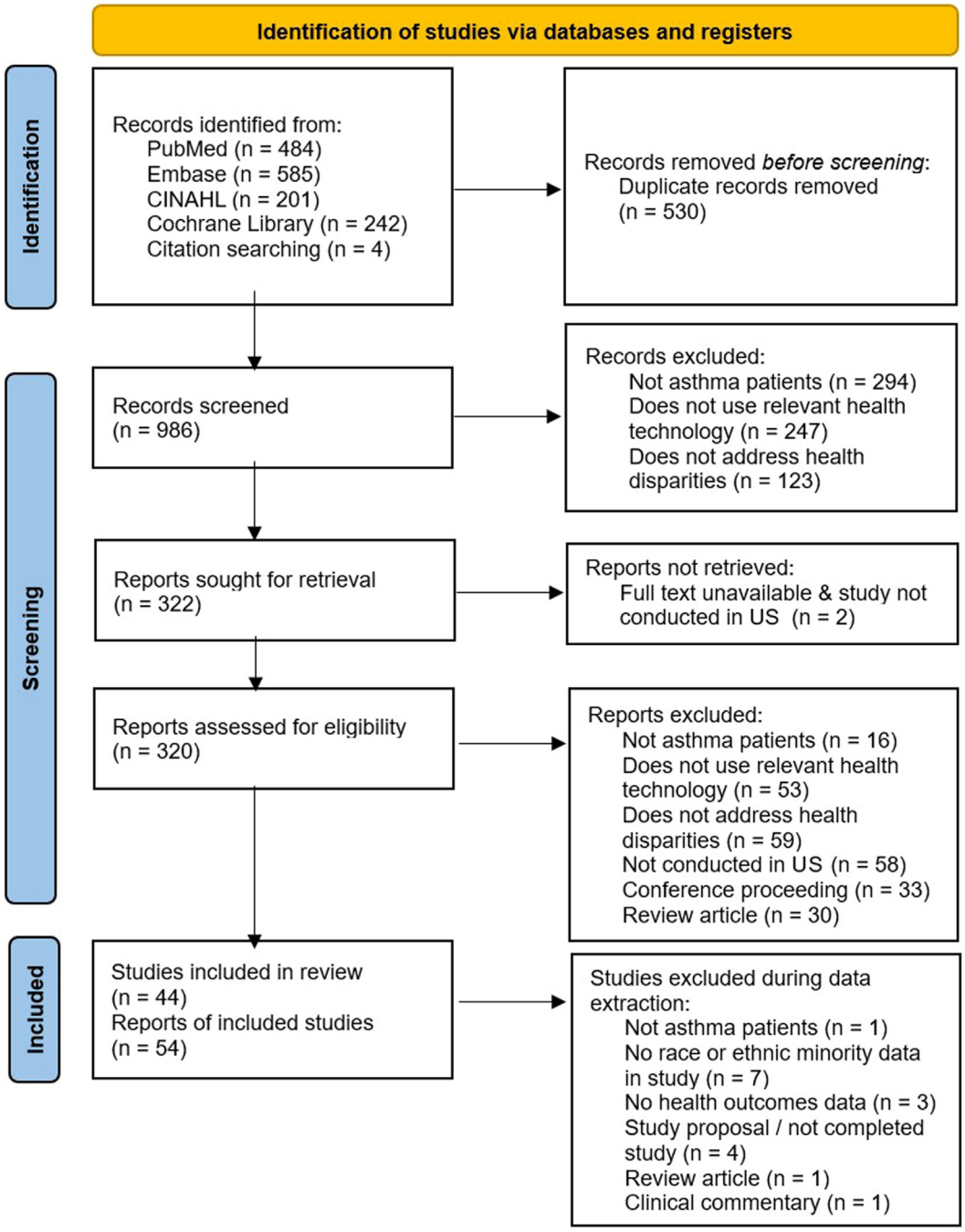

FIGURE 1. PRISMA diagram. *CINAHL*, Cumulative Index to Nursing and Allied Health Literature; *PRISMA*, Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

54), and duration ranged from 1 day to 1 year (median, 5 weeks). Nine studies had a majority Black population (90%), and 1 study had a majority Latino population (10%).

In 2 studies,[31,32] the directional flow of information was from the researchers to the participants. In the rest of the studies, the directional flow was from the participants to the researchers. Two studies[27,31] (20%) found a significant positive effect on asthma control. One of these studies also found a significant positive effect on asthma symptoms,[27] and the other found a significant positive effect on asthma quality of life.[31] No studies found a significant effect on medication adherence, with 1 study finding a nonsignificant positive effect.[27] No studies found a significant effect on health care utilization (Figure 2, *B*).

Bidirectional studies

There were 28 bidirectional studies included in the analysis. The most common electronic method was an electronic educational program used in 8 studies (29%). Examples of electronic educational programs included interactive computer modules and web-based computer educational games. The next most

TABLE I. List of included studies with study characteristics and outcome measures

Reference	Patient age group	n	Race or ethnicity	Intervention type	Study type	Study duration	Asthma adherence	Asthma control	Asthma symptoms	Asthma quality of life	Health care utilization
Generalized studies											
Kenyon et al,[18] 2019	Pediatric	32	85% Black, 15% Other, Not Hispanic 95%	Text messaging	RCT	30 d	—	NA	NA	NA	NA
Coker et al,[19] 2023	Adult	221	32% Latino, 19% non-Latino Black, 27% non-Latino White, 12% Other	Text messaging	RCT	12 mo	NA	NA	—	NA	—
Mosnaim et al,[20] 2008	Pediatric	28	100% Black	Text message plus additional	RCT	14 wk	NA	NA	NA	NA	NA
Mosnaim et al,[21] 2013	Pediatric	68	13% Hispanic/ Latino, 85% Black, 13%, Other	Audio/visual materials	RCT	10 wk	—	NA	NA	NA	NA
Riera et al,[22] 2017	Adult	20	100% Latino	Audio/visual materials	Interventional pre-post	1 d	NA	NA	NA	NA	NA
Teach et al,[23] 2021	Mixed	434	100% Black, 0.5% Latino	Text message plus additional	RCT	12 mo	—	++	++	—	—
Unidirectional studies											
Celano et al,[24] 2010	Pediatric	143	99% Black	Inhaler and non−inhaler device monitor	Nonrandomized trial	12 mo	NA	NA	NA	NA	NA
Dunton et al,[25] 2016	Pediatric	20	100% Latino	EMA	Nonrandomized trial	7 d	NA	NA	NA	NA	NA
Everhart et al,[26] 2018	Adult	59	90% Black	EMA	Nonrandomized trial	2 wk	NA	NA	NA	NA	NA
Kolmodin MacDonell et al,[27] 2016	Adult	49	100% Black	Two-way text messages	RCT	3 mo	±	++	++	NA	NA
MacDonell et al,[28] 2023	Adult	141	100% Black	Digital diary	Nonrandomized trial	7 d	NA	NA	NA	NA	NA
MacDonell et al,[29] 2012	Adult	13	100% Black	EMA	Nonrandomized trial	14 d	NA	NA	NA	NA	NA
Teufel et al,[30] 2018	Pediatric	14	93% Black	Inhaler device + EMA	Nonrandomized trial	2 mo	NA	NA	NA	NA	NA
Yarbrough et al,[31] 2016	Mixed	111	97.5% Black	Audio/visual materials	Nonrandomized trial	20 wk	NA	++	NA	++	NA
Apter et al,[32] 2011	Adult	333	68% Black, 7% Latino	Inhaler device + interventional counseling	RCT	6 mo	—	—	—	—	—
Vargas et al,[33] 2010	Adult	48	92% Latino	Electronic questionnaire	Interventional pre-post	1 d	NA	NA	NA	NA	NA
Bidirectional studies											
Bartlett et al,[34] 2002	Pediatric	15	100% Black	Inhaler device + feedback	Nonrandomized trial	4 wk	++	NA	NA	NA	NA
Nyenhuis et al,[35] 2021	Adult	53	100% Black	Non−inhaler device + feedback	RCT	24 wk	NA	±	NA	±	—
Bynum et al,[36] 2001	Pediatric	49	92% Black, 6% Other	Telehealth with nonphysician	RCT	4 wk	++	NA	NA	NA	NA
Kenyon et al,[37] 2016	Pediatric	14	100% Black	Inhaler device + feedback	Nonrandomized trial	3 mo	—	±	NA	NA	NA

Nyenhuis et al,[38] 2020	Adult	7	100% Black	Non−inhaler device + feedback	Nonrandomized trial	7 wk	NA	NA	NA	NA	NA
Patel et al,[39] 2017	Adult	422	100% Black	Telehealth with nonphysician	RCT	24 mo	NA	++	++	++	++
Perry et al,[40] 2018	Mixed	393	81% Black, 15% White	Electronic educational program	RCT	6 mo	++	—	—	—	—
Seid et al,[41] 2012	Pediatric	26	77% Black, 12% White, 12% Other	Interactive text messaging	RCT	3 mo	±	NA	±	±	NA
Warren et al,[42] 2016	Pediatric	12	92% Latino	Audio/visual materials	Nonrandomized trial	13 wk	NA	NA	++	±	NA
Joseph et al,[43] 2013	Pediatric	422	98% Black	Electronic educational program	RCT	12 mo	NA	NA	++	NA	—
Joseph et al,[44] 2007	Pediatric	314	98% Black	Electronic educational program	RCT	12 mo	±	NA	++	±	±
Finkelstein et al,[45] 2000	Adult	31	58% Latino, 16% Black, 23% White	Non−inhaler device + feedback	Nonrandomized trial	3 wk	NA	NA	NA	NA	NA
Mosquera et al,[46] 2021	Pediatric	63	59% Black, 30% Latino	Non−inhaler device + feedback	RCT	6 mo	—	—	NA	NA	Significant negative effect
Kenyon et al,[47] 2020	Pediatric	20	95% Black	Inhaler device + feedback	Nonrandomized trial	2 mo	++	NA	NA	NA	—
Lin et al,[48] 2020	Pediatric	21	74% Black, 21% White	Inhaler device + feedback	Nonrandomized trial	6 mo	++	++	++	NA	++
Otsuki et al,[49] 2009	Pediatric	250	98% Black	Inhaler device + feedback	RCT	18 mo	++	NA	—	NA	++
Arenas et al,[50] 2022	Mixed	26	69% Latino, 8% Black, 23% White	Interactive text messaging	Nonrandomized trial	8 mo	±	NA	++	NA	++
Arnold et al,[51] 2012	Pediatric	24	51% Latino, 36% Black	Electronic educational program	Nonrandomized trial	2-15 mo	NA	NA	++	NA	++
Gustafson et al,[52] 2012	Mixed	301	50% Black	Electronic educational program	RCT	12 mo	—	++	++	NA	NA
Joseph et al,[53] 2018	Pediatric	121	86% Black, 8% Latino	Electronic educational program	RCT	6 mo	±	NA	NA	NA	±
Mangan and Gerald,[54] 2006	Pediatric	42	100% Black	Electronic educational program	Nonrandomized trial	17 wk	NA	NA	NA	NA	NA
Speck et al,[55] 2016	Adult	44	100% Black	Electronic educational program	Nonrandomized trial	3 mo	NA	++	++	++	NA
Bian et al,[56] 2019	Pediatric	12,235	98% Black	Telehealth with physician	Nonrandomized trial	6 y	NA	NA	NA	NA	++

(continued)

TABLE I. *(Continued)*

Reference	Patient age group	n	Race or ethnicity	Intervention type	Study type	Study duration	Asthma adherence	Asthma control	Asthma symptoms	Asthma quality of life	Health care utilization
Finkelstein et al,[57] 1998	Adult	17	76% Latino, 12% Black, 12% White	Non−inhaler device + feedback	Nonrandomized trial	3 wk	NA	NA	NA	NA	NA
Freeman et al,[58] 2017	Pediatric	60	85% Black, 10% White	Audio/visual materials	Cross-sectional observational	1 d	NA	NA	NA	NA	NA
Halterman et al,[59] 2018	Pediatric	400	58% Black, 32% Latino	Telehealth with physician	RCT	9 mo	NA	NA	++	—	++
Van Houten et al,[60] 2021	Adult	60	75% Latino, 23% Black	Telehealth with physician	Nonrandomized trial	10 mo	NA	NA	NA	NA	±
Everhart et al,[61] 2017	Mixed	28	89% Black	EMA	RCT	4 mo	NA	NA	NA	++	NA

++, Significant positive effect; ±, nonsignificant positive effect; —, no effect; *EMA*, ecological momentary assessment; *NA*, not reported.
Race and ethnicity information provided to the extent as reported for each study and included non-Black or non-Latino information only if >5%.

common methods were inhaler device with individualized feedback (n = 5 [18%]) and noninhaler device with individualized feedback (n = 5 [18%]). The most common study designs were RCT with 13 studies (46%) followed by nonrandomized trial with 14 studies (50%). Study size ranged from 7 to 12,235 participants (median, 46.5), and duration ranged from 1 day to 6 years (median, 21 weeks). Twenty-two studies had a majority Black population (79%), and 6 studies had a majority Latino population (21%).

Regarding outcome measures, 12 studies (43%) reported on medication adherence, with 6 studies[34,36,40,47-49] (50%) showing a significant positive effect on adherence, 4 studies[41,44,50,53] (33%) showing a nonsignificant positive effect, and 2 studies[37,46] (16%) showing no effect. Eight studies (28%) reported on asthma control, with 4 studies[39,46,47,52] (50%) showing a significant positive effect, 2 studies[35,37] (25%) showing a nonsignificant positive effect, and 2 studies[40,46] (25%) showing no effect. Thirteen studies (45%) reported on asthma symptom burden, with 10 studies[31,39,43,44,48,50-52,55,59] (77%) showing a significant positive effect, 1 study[41] (8%) showing a nonsignificant positive effect, and 2 studies[40,49] (15%) showing no effect. Nine studies (31%) reported on asthma quality of life, with 3 studies[39,55,61] (33%) showing a significant positive effect, 4 studies[35,41,42,44] (44%) showing a nonsignificant positive effect, and 2 studies[40,59] (22%) showing no effect. Fifteen studies (52%) reported on health care utilization, with 7 studies[39,48-51,56,59] (46%) showing a significant positive effect (ie, decreased utilization), 3 studies[44,53,60] (20%) showing a nonsignificant positive effect, 4 studies[35,40,43,47] (27%) showing no effect, and 1 study[46] (7%) showing an unexpected negative impact of their intervention on health care utilization observing an increase in clinic telephone calls (Figure 2, *C*). Of note, the negative impact refers to the degree of health utilization, that is, increase in clinic telephone calls, and not a negative impact on asthma outcomes.

DISCUSSION

Our analysis found a total of 44 published studies examining the use of technology to improve asthma outcomes in historically marginalized patient populations. Demographic data revealed that most studies were conducted in a predominantly Black participant population, followed by Latino participant population. Identifying strategies to improve outcomes in such populations is a public health imperative because they experience the worst asthma disparities.[2,3] This review commissioned by the AAAAI Diversity, Equity, and Inclusion committee highlights strategies in historically marginalized populations with the most impact for key asthma outcome measures.

Most of the included studies were conducted among pediatric participants rather than adult participants. It may be that children and adolescents are perceived to be more adept and comfortable with technology as compared with adults and especially older adults.[63] Thus, researchers may more readily use technology-based interventions in younger populations. However, previous studies[64] have shown that older adults are likely to engage with technology if it is perceived by them to have a positive impact on their quality of life, providing an avenue for researchers and clinicians to use these methods in all age groups.

Most included studies were bidirectional, indicating at least some degree of reciprocity between study participants and

TABLE II. Summary of different intervention types

Study design	Intervention type
Generalized	• Text messaging: nonspecific text messaging, typically to remind patients to take medications • Text message plus additional: nonspecific text messaging paired with an additional intervention, such as focus groups • Audio/visual materials: nonspecific audio and/or visual medium
Unidirectional	• Inhaler device monitor: collecting data via participant's inhaler device without personalized feedback provided • Non−inhaler device monitor: collecting data via participant's non−inhaler device (such as activity monitor and automated pill box monitor) without personalized feedback provided • Ecological momentary assessment: self-report assessment tool where participant provides self-reported behavioral assessment in real time • Two-way text messaging: participant is prompted to respond to text message without individualized feedback based on their response • Digital diary: participants provided responses to prespecified prompts • Audio/visual materials: audio and/or visual medium with some aspect of participant-provided response • Electronic questionnaire
Bidirectional	• Inhaler device + feedback: collecting data via participant's inhaler device with personalized feedback provided • Telehealth with nonphysician provider • Non−inhaler device + feedback: collecting data via participant's non−inhaler device with personalized feedback provided • Electronic educational program: interactive internet or otherwise electronic-based program, including computer games • Interactive text messaging: bidirectional text messaging that includes individualized feedback for participant • Audio/visual materials: audio and/or visual medium with an aspect of participant response and feedback • Telehealth with physician

researchers. On the other end of the spectrum, there were only a handful of generalized studies, which involved no degree of personalized study information. As technology advances, the ability to efficiently obtain relevant data and deliver tailored health behavior or health education information increases. Accordingly, the bidirectional studies had a greater proportion of effect on the considered asthma outcome measures, followed by the unidirectional studies, and then the generalized studies. This would indicate that a greater degree of participant personalization is more likely to generate more impactful outcomes.

In general, there are limited conclusions that can be drawn from the generalized and unidirectional studies because most did not report on the predetermined outcome measures. In the single generalized study to show significant effect in any domain, the intervention involved individual and group wellness sessions paired with text messages that reinforced curriculum. The 2 studies that showed efficacy in the unidirectional grouping involved audio/visual material and 2-way text messaging. In this review, we specifically chose prespecified clinically relevant outcomes, such as asthma control, medication adherence, and health care utilization. A large majority of generalized and unidirectional studies did not report on these measures and therefore no association between these interventions and the predetermined asthma outcome measures used in this scoping review can be made.

In contrast, when specific outcome measures were reported in the bidirectional studies grouping, they were more likely to show a positive effect. Although there is always a risk of publication bias, this indicates that bidirectional interventions are more likely to be successful than generalized or unidirectional interventions for many asthma outcomes. The highest impact was found in decreasing asthma symptom burden, followed by improving asthma medication adherence. There was no particular modality that appeared as clearly more effective than others. However, inhaler devices with personalized feedback did appear particularly beneficial, especially in improving medication adherence. Electronic education programs were also generally effective. Overall, the application of personalized data with relevant actionable interventions appeared to be the prevailing factor related to the success of bidirectional interventions.

A further area requiring more dedicated research is digital equity among patients with asthma from historically marginalized populations. Although access to the internet grows each year, there is still a significant proportion of the United States without internet access, with some estimates identifying a quarter of the population.[65] There are disproportionately higher rates of those without internet access in Black, Latino, Native American, rural, and low-income populations.[66] There are also age-related differences, with older individuals less likely to have access to the internet and be more reliant on traditional technology, such as a home personal computer as compared with a smartphone.[67] Beyond internet access, studies should include consideration of additional aspects of digital equity, including internet and device affordability and digital literacy. These barriers lead to differences in health care delivery, because racial and ethnic minority patients are less likely to receive care via telemedicine.[68] Given that there is overlap between historically marginalized populations and immigrant populations, there is also the consideration of language barriers and cultural differences in the utilization of digital materials that should be considered in future studies. Most studies included in this review commented positively on the feasibility of the study in regard to the technical aspects of using the intervention technology, but few discussed potential implementation challenges from a public health perspective such as cost and insurance coverage considerations. There were limited data on whether participants could use technology services using their own devices or what technology access would look like after study completion.

Our study had several limitations. There is heterogeneity of the included studies. Many studies did not report on the predetermined outcomes of our analysis, whereas others included outcomes that we do not include, such as asthma knowledge. Thus, there were positive and negative effects on asthma care in individual studies that were not specifically reported by our study in an effort to standardize comparisons. In addition, specific statistical comparisons could be made between different study types, and therefore a direct cause and effect relationship between a greater degree of personalization and improved asthma outcomes cannot be definitely proven. The studies included in the

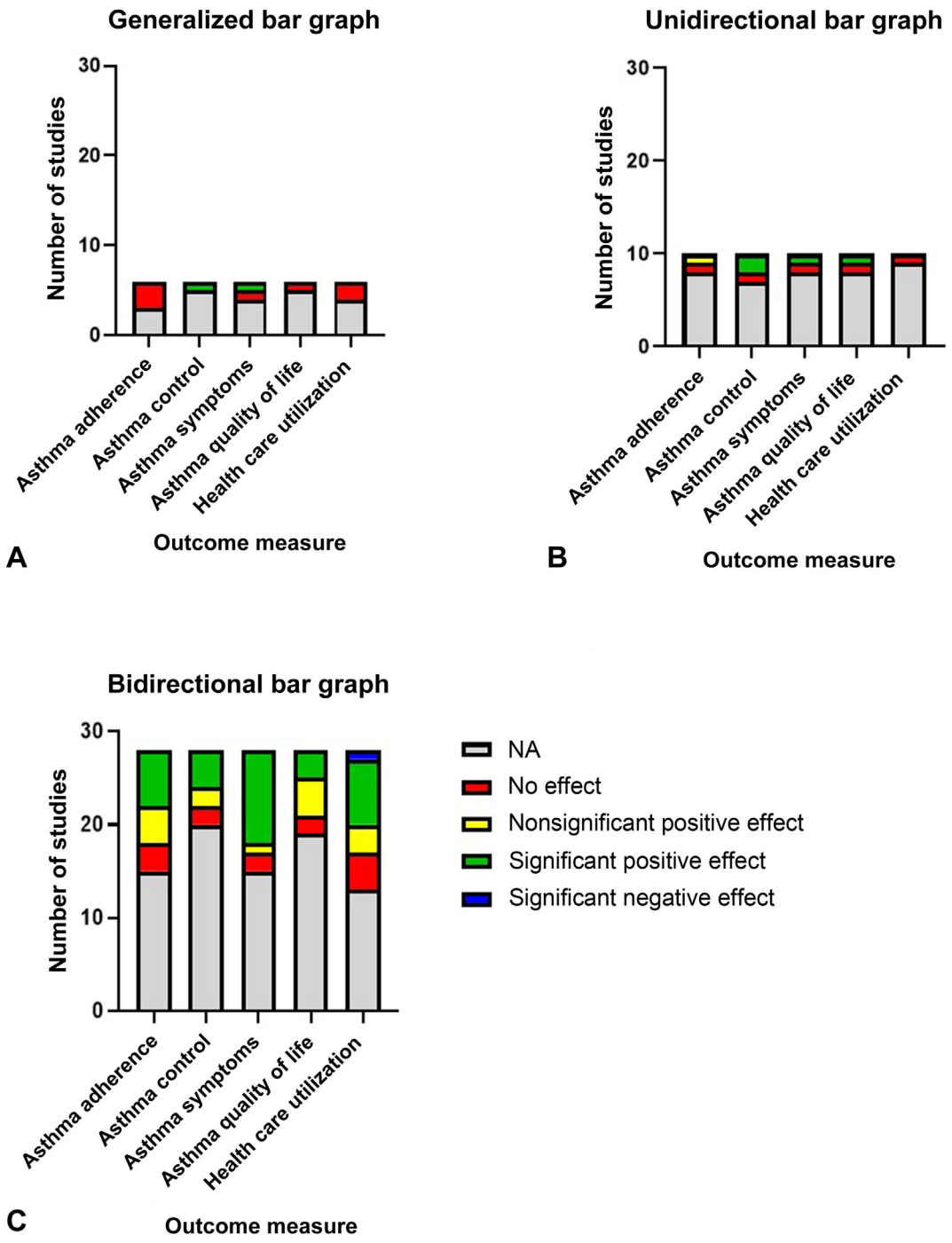

FIGURE 2. Summary of outcome measures by study type: (**A**) Generalized. (**B**) Undirectional. (**C**) Bidirectional. *NA*, Not applicable/available.

final analysis contained only 2 minority racial and ethnic participant populations, Black and Latino. Although this article helps to address the specific disparities in these populations, a lack of data on the use of technology in asthma in other racial and ethnic minority populations, such as Native Americans[69] and Arab Americans,[70] persists.

In conclusion, health care technology represents an increasingly important avenue in addressing asthma health disparities. Bidirectional interventions that collect patient-specific data and provide tailored recommendations, education, or treatment options are the most efficacious, and can improve asthma medication adherence, control, symptoms, quality of life, and health care utilization. Whether these interventions are more or less effective in historically marginalized populations is unknown and deserves further investigation, as technology offers the ability to potentially address specific problems and barriers that may be

otherwise overlooked. As technology continues to advance, including through use of artificial intelligence technology, there exists an even greater potential to improve care among all patients with asthma.

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