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Telemonitoring in patients with asthma: a systematic review

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ABSTRACT

Background: Monitoring and managing asthma using technology can help increase patient adherence and achieve better asthma control. This study aimed to evaluate the effectiveness of telemonitoring using smartphones and telephone communication compared to usual outpatient clinical evaluation in patients with asthma.

Data sources: This systematic review was conducted in 2023. Databases PubMed, Scopus, Web of Science, and the Google Scholar search engine, were searched from 2013 to 2022.

Data selection: The selected studies were randomized clinical trials that used telemonitoring in patients with asthma. The quality of the studies was evaluated using the JADAD scale. Data were collected using a data extraction form, and the findings were synthesized narratively. This systematic review was conducted following the PRISMA checklist.

Results: Initially, 4,147 articles were found, of which 14 were included in the study. The results showed that in some cases, telemonitoring using smartphones and telephone communication in patients with asthma is effective, while in other studies, its effectiveness was not observed.

Conclusions: Telemonitoring using smartphones and telephone communication in patients with asthma can be considered an appropriate strategy to reduce the use of healthcare resources and improve quality of life. However, further studies are recommended to investigate the effectiveness of each of these technologies and their specific outcomes.

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Telemonitoring; asthma; smartphones; telephone communication

Introduction

Asthma is a common, chronic, and multifaceted respiratory disease with varying severity that has a significant impact on healthcare costs, loss of work and school days, and mortality (1). Additionally, it is a global health problem in developed and developing societies, with increasing prevalence and treatment costs over the past decades (2). Patients with asthma require frequent medical visits, continuous monitoring, prescription of multiple drugs, and most of them experience various side effects (3). Study findings have shown that self-management in patients with asthma is often poor, with a majority of patients having poor adherence to disease management and treatment (4). Since common asthma care involves clinic visits, during the COVID-19 pandemic, access to healthcare services was severely restricted, and patients were unable to physically visit clinics, resulting in lower adherence rates (1).

Poor adherence jeopardizes treatment effectiveness and is the main factor in uncontrolled disease, life-threatening attacks, and increased use of healthcare resources (5).Empowering patients, which is an effective step toward achieving desirable asthma control, can be implemented using Electronic Health and Telemedicine technologies (3).

Previous studies have stated that Telemedicine is effective in monitoring, follow-up, treatment adherence, reducing respiratory symptoms, and improving the quality of life in patients with asthma (3). Telemonitoring is defined as an automated process for transferring patient health status data from home to healthcare centers and receiving feedback and reminders from service providers (6). This method can empower patients to actively participate in the management of their asthma, and clinical guidelines for asthma, have confirmed the potential for telemonitoring in disease management (4).

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This article has been corrected with minor changes. These changes do not impact the academic content of the article.

On the other hand, access to the internet and smartphones has increased and is available to a large number of patients in the community (4,7). People carry their smartphones with them almost all the time, and smartphone applications can be a useful tool in telemonitoring asthma (8).

The results of various studies have shown the positive effects of digital interventions and smartphone applications in improving medication adherence, asthma control, and quality of life in children and adolescents, although the effectiveness of these technologies depends on their features (9–11).

Since it is essential to examine the effectiveness of telemonitoring technology, this study was conducted to review the effectiveness of using smartphones and telephone communication compared to the usual outpatient clinical evaluation of patients with asthma.

Methods

This systematic review was conducted in 2023 following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist (12), involving several stages outlined below.

Search strategy

First, relevant keywords were identified using Medical Subject Headings (MeSH). To increase search sensitivity, a combination of search terms, synonyms, and OR and AND operators was employed. Relevant sources were then searched, including databases, grey literature, and other pertinent references based on the search strategy. The search was performed on PubMed, Scopus, Web of Science, and Google Scholar search engines. The search was limited to English-language articles published between 2013 and 2022. The search strategy was tailored to meet the requirements of each database, and the search strategy for each database is provided in appendix 1. An example of the search strategy is provided below:

Inclusion and exclusion criteria

The inclusion and exclusion criteria for the articles were based on PICO criteria and the study type, as follows:

Population

The study included clinical trials involving individuals of any age group with asthma. Patients with coexisting diseases such as COPD, allergic rhinitis, atopic dermatitis, food allergy, etc., were excluded. Additionally, studies related to parents of patients with asthma or asthma during pregnancy were also excluded. Protocols and other study types such as retrospective studies, cohort studies, and review studies were excluded, although references from review studies were examined. Furthermore, studies with duplicate authors were also excluded.

Intervention

The study included clinical trials that employed telemonitoring *via* smartphones and telephone communication.

Comparison

The study encompassed clinical trials that compared telemonitoring *via* smartphones and telephone communication with usual inpatient and outpatient clinical evaluation.

Outcome

All clinical and non-clinical outcomes related to the intervention's effectiveness, as well as any outcomes mentioned in the studies, were considered.

Screening and data extraction

After conducting the search, resource management was performed using EndNote software version 18, and duplicate references were removed. The screening of studies was carried out in three separate phases based on the title, abstract, and full text of the articles. The reviews were conducted by two researchers (F.V) and (M.S), and disagreements in references were resolved by a third researcher (L.F). Once the final articles were determined, a data extraction form was designed, including the author's name, year of publication, country of study, study objective, study method, study population, telemonitoring system, intervention group, control group, and outcome.

Quality assessment

After data extraction from the final articles, the quality of the selected studies was assessed using the Jadad scale (13,14). This scale consists of an eight-item checklist that scores the quality of randomized clinical trials from zero to one point. To prevent bias during the quality assessment of the articles, the researcher was unaware of the primary information of the article, such as the author's name, country, and year of

publication. It should be noted that studies were not excluded based on quality criteria.

Data synthesis and analysis

Following data extraction and quality assessment, data summaries were created using data extraction tables. Due to the lack of homogeneity in age groups and reported outcomes, a meta-analysis was not feasible. Consequently, the evidence synthesis and results were presented in a narrative form.

Results

The initial search of databases resulted in 4,147 articles. After removing duplicates, 2,052 articles were examined. Upon reviewing the titles, 110 articles were left for further analysis. Finally, after reviewing the abstracts, only 34 articles were considered. The full text of these 34 articles was examined, but 20 articles were excluded based on the inclusion and exclusion criteria (Figure 1).

Out of these 20 articles, study population in six studies (15–20), intervention group in six studies (21–26), control group in three studies (27–29), and outcome in one study (30) did not meet the inclusion and exclusion criteria and were therefore excluded.

Additionally, two studies were not clinical trials (6,31), and two studies were duplicates (32,33). Finally, based on the inclusion and exclusion criteria, 14 articles were selected for further review.

The quality of the 14 selected articles varied, as indicated by the Jadad scale assessment (Table 1). After quality assessment, data from the articles were extracted using the data extraction form and presented in tables (Table 2). Out of the 14 articles, seven were from the United States (34–40) and one was from each of the following countries: Canada (41), Netherlands (42), Australia (43), Slovenia (44), Korea (8), Singapore (45), and China (46).

The findings showed that due to the diversity of the study population, which included children, adolescents, adults, and the elderly, telemonitoring using smartphones and telephone communication for monitoring patients with asthma was performed in various ways, and the method of giving feedback to the patient differed. Moreover, these interventions differed in many aspects, such as intervention goals, number of sessions and intervention duration, and system components for asthma patients. Therefore, due to the heterogeneity between the studies, meta-analysis was not possible, and the results were reported narratively. On the other hand, the diversity of reported outcomes made it challenging to compare results across studies. Some studies only evaluated patient outcomes, while others also included parameters such as feasibility. The summary of study outcomes are presented in Table 2.

Telemonitoring through smartphone applications and phone calls with doctors for patients with uncontrolled asthma, in order to remind and provide feedback about the use of inhaled corticosteroids (ICS) and Short-Acting Beta-Agonists (SABA), showed that the intervention group had a statistically significant increase ($p < .01$) in the percentage of SABA-free days, while there was no significant increase in the control group ($p < .18$) (34). Adherence to ICS changed minimally in the intervention group ($p = 0.40$), but there was a significant decrease in the control group ($p < .01$). Furthermore, telemonitoring through smartphone applications with six modules and telephone follow-ups for children showed that the intervention group had higher adherence and C-ACT scores compared to the control group. During the follow-up period, the average number of school absences and parents missing work were lower in the intervention group, and the diagnosed respiratory infections were lower compared to the control group. Medical costs were also significantly reduced in the intervention group compared to the control group (931 versus 1179 Yuan) (46).

Telemonitoring, which involves the use of email, phone calls, or text messages, did not yield any significant differences in medication adherence ($p = 0.55$) or asthma exacerbations ($p = 0.61$) among adult patients with persistent asthma during the one-year follow-up period (35). Furthermore, there were no notable variations between the intervention and control groups in terms of proportion of days covered ($p = 0.21$), asthma exacerbations ($p = 0.77$), and asthma medication ratio ($p = 0.81$) (35).

A web-based application utilizing OpenEHR, automated text message reminders, as well as weekly Peak Expiratory Flow (PEF) and monthly Asthma Control Test (ACT) reminders, coupled with additional follow-up *via* phone or in-person as needed, displayed a slight increase in PEF, forced expiratory volume in 1 s (FEV1), and vital capacity within the intervention group compared to the control group. Nevertheless, these differences were not statistically significant. Additionally, 40 patients (78.4%) reported experiencing at least one positive effect of telemonitoring on their asthma management, and 41 patients (80.4%) expressed interest in continuing the program (44).

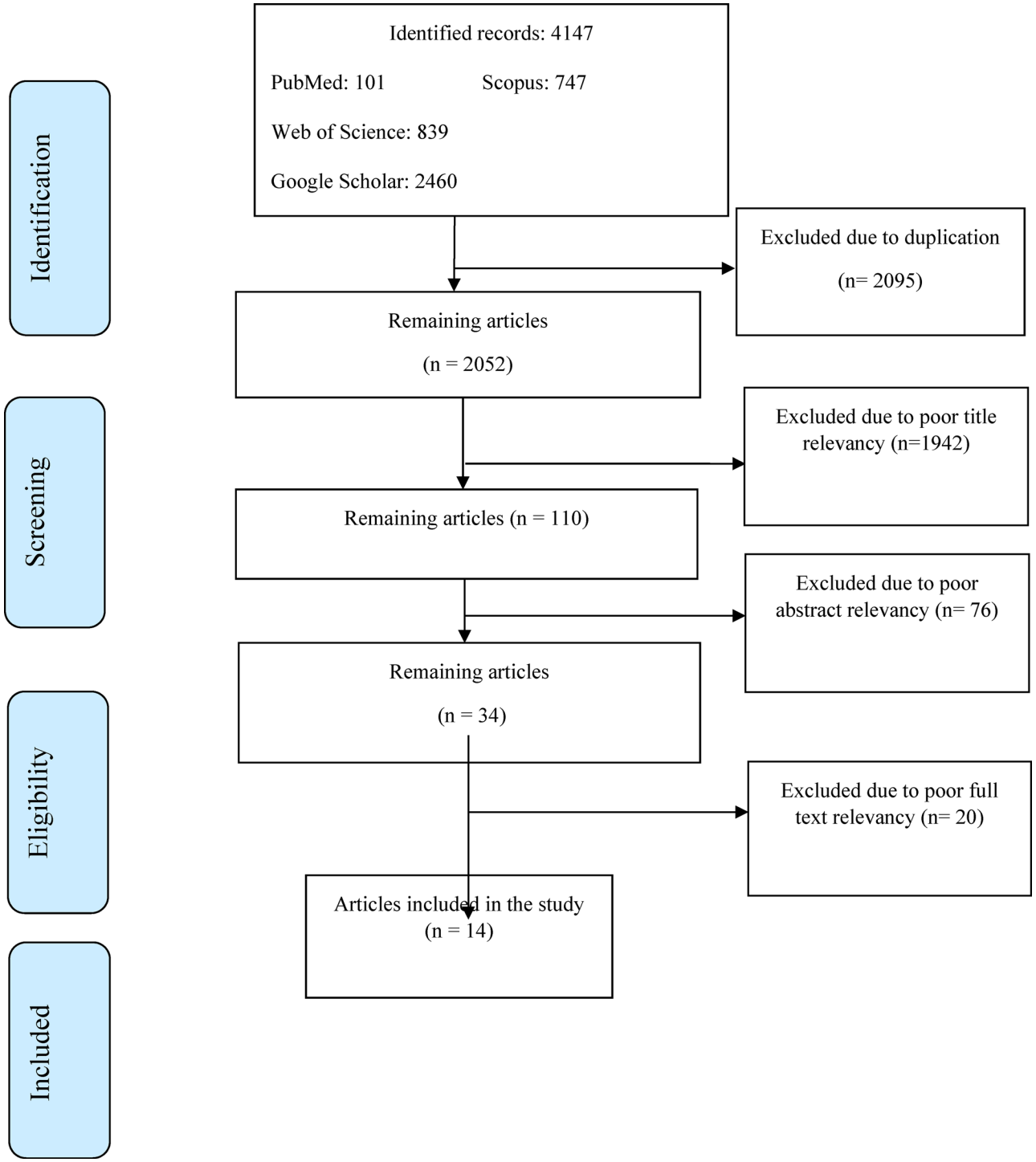

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

Telemonitoring involving the integration of an inhaler with an electronic monitoring sensor, accompanied by daily text message reminders for using inhaled corticosteroids (ICS) and data transmission *via* a smartphone application, did not result in any significant differences in average adherence between the intervention and control groups ($p = 0.73$). Moreover, the average change in cACT score during the 30-day intervention did not exhibit a statistically significant difference between the intervention and control groups ($p = 0.16$) (37).

In the case of telemonitoring through Short Message Service (SMS), a statistically significant difference ($p = 0.0001$) was observed between the intervention and control groups in terms of the ratio of participants who underwent spirometry during the follow-up

Table 1. Quality assessment table.

Author Year	Was the research described as randomized?	Was the approach of randomization appropriate?	Was the research described as blinding?	Was the approach of blinding appropriate?	Was there a presentation of withdrawals and dropouts?	Was there a presentation of the inclusion/exclusion criteria?	Was the approach used to assess adverse effects described?	Was the approach of statistical analysis described?	Total
Nemanic et al. (44)	1	1	0	0	1	1	0	1	5
Baptist et al. (40)	1	1	1	1	1	1	0	1	7
Lv et al. (46)	1	1	0	0	1	1	0	1	5
Patel et al. (36)	1	1	0	0	1	1	1	1	6
Coiera et al. (43)	1	1	1	1	1	1	1	1	8
Johnson et al. (39)	1	1	0	0	1	1	1	1	6
Vasbinder et al. (42)	1	1	1	1	1	1	1	1	8
Prabhakaran and Wei (45)	1	1	0	0	1	1	1	1	6
Kenyon (37)	1	1	0	0	1	1	0	1	5
Cvietusa et al. (35)	1	0	0	0	1	1	0	1	4
Merchant et al. (38)	1	1	0	0	1	1	0	1	5
Ahmed et al. (41)	1	1	0	0	1	1	0	1	5
Kim et al. (8)	1	0	0	0	0	1	0	1	3
Mosnaim et al. (34)	1	1	0	0	1	1	0	1	5

1 stands for the answer "yes", and 0 stands for the answer "no".

period. The intervention group (37/79) had a higher number of registered spirometry cases per patient compared to the control group (8/59) (43). In another study, telemonitoring *via* the eCARE system to monitor patients' asthma symptoms and send medication reminders through SMS did not yield any significant differences between the intervention and control groups in terms of the ratio of patients who had emergency department visits related to asthma or hospitalization ($p = 0.85$ and $p = 0.79$, respectively) (45).

In telemonitoring *via* telephone counseling sessions for women, the results showed that those who completed the intervention (six sessions) experienced significant improvements in self-regulation of asthma ($p < 0.01$) and quality of life ($p < 0.01$). Furthermore, after completing the intervention, women in the intervention group had a significant reduction in daily symptoms ($p < 0.05$), asthma control ($p < 0.01$), unplanned physician visits ($p < 0.05$), and planned physician visits ($p < 0.01$) during the 24-month follow-up period (36).

Similarly, in telemonitoring *via* a self-regulation process with telephone sessions for the elderly, the intervention group showed significantly higher scores on the Mini-Asthma Quality of Life Questionnaire (mAQLQ) in the first month ($p < 0.001$), sixth month ($p = 0.031$), and twelfth month ($p = 0.045$) compared to the control group. Additionally, the Asthma Control Questionnaire (ACQ) scores in the intervention group were better than those in the control group in the first month ($p < 0.001$), sixth month ($p = 0.06$), and twelfth month ($p = 0.07$). Moreover, the use of healthcare services was lower in the intervention group, and there was no significant difference in fractional exhaled nitric oxide (FeNO) levels in the sixth month ($p = 0.50$) and twelfth month ($p = 0.90$), as well as predicted forced expiratory volume in one second (FEV1%) in the sixth month ($p = 0.33$) and twelfth month ($p = 0.17$) (40).

In telemonitoring using the Propeller Health Asthma Platform, which is connected to inhaler sprays and synchronized with smartphones, the results indicated a decrease in the average daily use of Short-Acting Beta-Agonist (SABA) per person in the intervention group compared to the control group ($p < 0.001$). Additionally, the intervention group showed an increased ratio of days without using SABA ($p < 0.01$). However, there was no significant difference in the Asthma Control Test (ACT) scores between the two groups in the total study population. Nevertheless, for adults with uncontrolled ACT scores at the beginning of the study, there was a significant improvement ($p < 0.05$) (38).

Telemonitoring through smartphone applications such as snuCare, which are based on self-management guidelines and provide daily signals to users about their asthma control status, demonstrated good feasibility results. There was a high adherence to the program, with a total of 2,226 signals produced over eight weeks (an average of 1.8 signals per day per patient), indicating proper adherence to snuCare. User satisfaction ratings were also favorable, with an average score of 4 out of 5. Initially, adherence in both groups was similar, but during the study, adherence in the intervention group improved compared to the

Table 2. Data extracted from articles related to telemonitoring of asthma.

No	Author	Country/ year	Objective	Study design	Sample	Type of telemonitoring	Intervention group	Control group	Outcome
1	Mosnaim et al. (34)	USA 2021	To assess whether patient self-monitoring *via* electronic medication monitoring and smartphone application plus remote clinician feedback influences ICS and SABA use	randomized controlled trial (12 months)	101 patients with uncontrolled asthma (age 25 to 65 years)	Inhalers with electronic medication monitoring and feedback on ICS and SABA use *via* a smartphone application and clinician phone calls	feedback on ICS and SABA use *via* a smartphone application and clinician phone calls	routine care	The percentage of SABA-free days increased significantly in the treatment group ($p < .01$) and nonsignificantly in the control group ($p = .18$). ICS adherence changed minimally in the treatment group ($p = .40$) but decreased significantly ($p < .01$) in the control group.
2	Cvietusa et al. (35)	USA 2020	To examine whether giving patients some control over the type of digital communication technology (DCT) used to communicate with them would improve inhaled corticosteroid (ICS) adherence.	pragmatic, randomized controlled trial (1-year)	7522 adult patients with persistent asthma (ages 18 years and older)	a reminder system sends text or phone reminders	reminder by text or automated call	usual care	Among the patients who did provide a DCT preference and stratified by the type of reminder preferred (email, phone, or text), no differences emerged over the 1-year observation period in either medication adherence ($p = 0.55$) or asthma exacerbations ($p = 0.61$) . Also, There was no difference in asthma outcomes between the intervention and control groups in the proportion of days covered($p = 0.21$), Asthma medication ratio ($p = 0.81$), and Asthma exacerbations ($p = 0.77$).
3	Kenyon et al. (37)	USA 2019	To assess the feasibility of a mobile health, inhaled corticosteroid (ICS) adherence reminder intervention and to characterize adherence in children with persistent asthma	pilot randomized controlled trial (30-day)	41 Children with persistent asthma (aged 2–13)	electronic monitoring sensor with daily text message reminders	daily text message reminders for 30 days and both arms received electronic sensors to measure ICS use	Usual care	Analyses demonstrated similar average daily adherence between groups ($p = 0.73$). Also, mean change in cACT score over the 30 days of the intervention was not statistically significantly different between controls and intervention ($p = 0.16$).
4	Coiera et al. (43)	Australia 2019	To evaluate whether targeted SMS reminders to attend an asthma review could improve an asthma action plan	Randomized controlled trial (three-month follow-up)	138 Adults (age ≥18 years)	SMS reminders	SMS reminders after 1 and 2 month	Usual care	There were more recorded instances of spirometry per patient performed during the follow-up period for intervention (37/79), compared with usual care (8/59; $p < 0.0001$).
5	Nemanic et al. (44)	Slovenia 2019	To test the applicability and potential effects of a telemonitoring of patients with asthma (12-months)	Single-centre prospective randomized controlled clinical	100 patients with asthma, aged 18-75	A Web-based application for patients with asthma based on OpenEHR	To receive a reminder *via* an automated SMS to send in PEF values once per week and ACT scores once per month	Control groups had their ongoing asthma care from their pulmonologist, had regular appointments every 3 to 6 months, and were instructed to measure PEF daily and ACT monthly.	The compliance of reporting PEF and ACT values through a 12-month period was good and was higher than 80% in 49 of 51 patients. Also, to detect a higher increase in PEF, FEV1 and VC values in the interventional group than in the control group, but it did not reach statistical significance.

(*Continued*)

Table 2. Continued.

No	Author	Country/ year	Objective	Study design	Sample	Type of telemonitoring	Intervention group	Control group	Outcome
6	Lv et al. (46)	China 2019	To evaluate the effectiveness of a mobile application-assisted nurse-led management model in children with asthma	Multi-centre randomized clinical trial	152 children (6 to 11.9 years old)	computer software for use in desktop computers and on Android smartphones. The software included: (medication reminder, adherence man- agement, alert of acute asthma exacerbations, assessment of ex- acerbation severity, treatment recommendation, keeping a health diary, instant communication with healthcare providers and health education)	smartphone application and nurse-led with phone call follow-ups and answered questions *via* the software application every day	Asthma care provided by specially trained asthma nurses (nurse-led asthma care)	The frequency of asthma exacerbations significantly decreased in the two groups with a more significant decrease observed in the experimental group ($p < 0.001$). Median days of school absence and parental work loss in the experimental group were lower than those in the control group. Medical expenses decreased significantly in the experimental group compared with those in the control group (931 vs 1179 Yuan).
7	Prabhakaran and Wei (45)	Singapore 2018	To evaluate the effectiveness of the upgraded eCARE monitoring system on asthma control in discharged emergency department (ED) patients	Multicentre randomized controlled trial (3-month follow-up)	424 patients (21 years and above)	The eCARE system to monitor patients' asthma symptoms and remind SMS them to take medication.	SMS monitoring (daily for 1–2 wk, then weekly for 3 wk)	Routine care	There is no statistical difference between the proportion of patients who had asthma-related ED visits or hospital admissions between the eCARE and routine care groups ($p = 0.856$ and $p = 0.797$, respectively). Approximately 95% of patients under the eCARE programme were satisfied with the SMS service.
8	Patel et al. (36)	USA 2017	To evaluate a telephone-based self-regulation intervention that emphasized African American women's management of asthma in a series of 6 sessions.	Randomized clinical trial (24-month follow-up)	422 African American women with persistent asthma 18 or older	Telephone counseling sessions	A series of 6 telephone counseling sessions (30–45 min in duration, 2 wk apart)	Usual care (treatment and education within health care settings at the time of clinic visits based on National Asthma Education Prevention Program (NAEPP) Guidelines for the Diagnosis and Management of Asthma)	Women who completed the intervention reported greater self-regulation ($p < .01$) and improved quality of life ($p < .01$). Also, daytime symptoms ($p < .05$), asthma control ($p < .01$), unscheduled physician visits ($p < .05$), and scheduled physician visits ($p < .01$).

(*Continued*)

Table 2. Continued.

No	Author	Country/ year	Objective	Study design	Sample	Type of telemonitoring	Intervention group	Control group	Outcome
9	Johnson et al. (39)	USA 2016	To assess the impact of MyMediHealth (MMH) – a website and a short messaging service (SMS)- based reminder system	Randomized controlled study (3 wk)	98 adolescents with asthma aged 12–17 years	MyMediHealth (MMH) – a website and a short messaging service (SMS)- based reminder system – on medication adherence and perceived self-efficacy in adolescents with asthma	A website and a short messaging service (SMS)- based reminder system	Usual care	Improvements in self-reported medication adherence (p=.011), quality of life (p=.037), and self-efficacy (p=.016) and reported high satisfaction with MMH .
10	Kim et al. (8)	Korea 2016	To evaluate the feasibility of the ubiquitous healthcare system of asthma care using a smartphone application (snuCare) based on the self-management guideline or action plan.	randomly to two group (8 wk)	44 patients including fragile Asthmatics (over 19 years old)	smartphone application (snuCare)	smartphone application (snuCare) based on the self-management guideline and daily signals to the users about their asthma control status	routine care	Feasibility snuCare indicated 2,226 signals generated by 22 patients during 8-week trials (average 1.8 signal generation per day in each patient), indicating a fair adherence to the snuCare program. The adherence was similar in both groups at baseline however, the adherence became better in the intervention group compared with the control group ($p = 0.01$). Changes in QLQAKA in the intervention group were significant ($p = 0.027$), but were not significant in the control group ($p = 0.139$).
11	Vasbinder et al. (42)	Netherlands 2016	To study the effects of Real-time medication monitoring (RTMM) with short message service (SMS) reminders on adherence to ICS, asthma control, asthma-specific quality of life and asthma exacerbation rate, and cost-effectiveness	multicentre, randomized controlled trial (12 months)	209 children (aged 4–11 years)	Real-time medication monitoring (RTMM) with short message service (SMS) reminders	Tailoring SMS reminders with the use of real-time medication monitoring (RTMM)	Usual care	Mean adherence was higher in the intervention group: 69.3% versus 57.3% (difference 12.0%, 95% CI 6.7%–17.7%). No differences were found for asthma control ($p = 0.203$), quality of life (0.659 P=) or asthma exacerbations($p = 0.432$). Also, Costs were higher in the intervention group, but this difference was not statistically significant.

(*Continued*)

Table 2. Continued.

No	Author	Country/ year	Objective	Study design	Sample	Type of telemonitoring	Intervention group	Control group	Outcome
12	Merchant et al. (38)	USA 2016	To evaluate the effectiveness of the Propeller Health Platform for asthma management in a real-world outpatient clinic setting	Randomized Clinical Trial (12 months)	495 participants (ages 5 years and older)	Propeller Health Asthma Platform	Connecting the sensor to the SABA spray and pairing it with the smartphone and web applications and accessing the Propeller Health platform and receiving feedback through it	routine care	The daily mean number of SABA uses per person decreased between the first week and the remainder of the study period (p<.001). Similarly, the proportion of SABAfree days increased for the IG (p < .01). Also, asthma Control Test (ACT) scores were not significantly different between arms in the entire study population, but adults with initially uncontrolled ACT scores showed a significantly larger improvement in the proportion with controlled asthma in IG p < .05).
13	Ahmed et al. (41)	Canada 2016	To compare the impact of access to a Web-based asthma self-management patient portal linked to a case-management system (MAP) over 6 months compared with usual care on quality of life	multicenter, parallel, 2-arm, pilot, randomized controlled trial (9-month)	100 participants (aged between 18 and 69 years)	customized personal Web-based self-management support systems linked to a case-management system	To use my asthma portal My Asthma Portal (MAP) and monitor and receive feedback regarding current self-management practices	Usual Care	Compared with usual care, participants in the intervention group reported significantly higher asthma quality of life (mean change 0.61), and the change in asthma quality of life for the intervention group between baseline and 3 months (mean change 0.66) was not seen in the control group. No significant differences in asthma quality of life were found between the intervention and control groups at 6 (mean change 0.46) and 9 months (mean change 0.39).For all self-reported measures, the intervention group had a significantly higher proportion of individuals, demonstrating a minimal clinically meaningful improvement compared with the usual care group.
14	Baptist et al. (40)	USA 2013	To evaluate an asthma self-regulation intervention for older adults, specifically observing the effects on asthma quality of life (QoL) and asthma control	A randomized, double-blind, controlled trial	70 older adults aged 65 and older with persistent asthma	A self-regulation process with telephone sessions	The personalized intervention followed a self-regulation process with three one-on-one telephone sessions and three in-person group sessions	Routine care	The mAQLQ score was significantly higher in the intervention group at 1, 6, and 12 months. The ACQ was better in the intervention group than in the control group at 1, 6, and 12 months. Healthcare utilization was lower in the intervention group, although no difference was observed in FENO or predicted FEV1%.

control group ($p = 0.01$). Additionally, changes in the Quality of Life Questionnaire for Adult Korean Asthmatics (QLQAKA) were significant in the intervention group ($p = 0.02$), but not significant in the control group ($p = 0.13$).

Telemonitoring through Real-Time Medication Monitoring (RTMM) with short message service (SMS) reminders demonstrated higher average adherence in the intervention group (69.3% versus 57.3%). However, there were no significant differences in the adjusted means of Childhood Asthma Control Test (c-ACT) scores ($p = 0.20$), Pediatric Asthma Quality of Life Questionnaire (PAQLQ) scores ($p = 0.65$), and asthma exacerbations ($p = 0.43$) between the intervention and control groups at the end of the follow-up period. Moreover, the total costs, including the expenses for text messages, medication, physicians, hospitals, and parents' work absence due to illness, were higher in the intervention group from both healthcare (731 euros versus 636 euros) and societal perspectives (1043 euros versus 764 euros), although these differences were not statistically significant (42).

Telemonitoring through the asthma portal My Asthma Portal (MAP) and receiving feedback on current self-management practices revealed no significant difference in the quality of life for individuals with asthma between the intervention and control groups during the three-month (mean change = 0.61), six-month (mean change = 0.46), and nine-month (mean change = 0.39) follow-up period (41).

A study on telemonitoring using MyMediHealth (MMH) – a website and a short messaging service (SMS)-based reminder system – to enhance medication adherence and perceived self-efficacy in adolescents with asthma indicated that the intervention group reported improved self-reported medication adherence ($p = 0.01$), quality of life ($p = 0.03$), and self-efficacy ($p = 0.01$) compared to the control group. The intervention group expressed high satisfaction; however, African American patients had lower usage rates (39).

Discussion

Results of this study indicated that telemonitoring through smartphones and telephone communication in patients with asthma employed various methods, ranging from simple approaches such as telephone calls and text messages (35,36,40,43) to more advanced techniques like smartphone applications (34,42,45,46), web-based portals (39,41,44), and the utilization of sensors connected to inhalers, synchronized with smartphones (8,37,38). The effectiveness of these interventions was assessed using diverse methods. While some studies demonstrated effectiveness and positive outcomes, others did not observe such effects.

The findings from some studies demonstrated that telemonitoring in patients with asthma, utilizing smartphones and telephone communication, resulted in an increased number of days without Short-Acting Beta-Agonists (SABAs) and a reduction in the average daily SABA use per person (34,38). These results were consistent with the findings of Chan et al., which exhibited a significant increase in the percentage of days without SABA in the intervention group (47). Additionally, the findings indicated that older adults exhibited improved asthma control questionnaire scores and required less healthcare when provided with three follow-ups at different time intervals (40). Similarly, the results of Farzandipour et al. demonstrated that self-management of asthma patients using health apps improved asthma control, lung function, and quality of life (48).

Furthermore, the results demonstrated that telemonitoring in patients with asthma, employing smartphones and telephone communication, led to better control of asthma including reduced daily symptoms, decreased unscheduled and scheduled physician visits, improved quality of life, and enhanced patient satisfaction among adolescents and African American women (36,39). These findings align with the results reported by Alquran et al., who found that smartphone applications improved asthma control, medication adherence, and self-efficacy, suggesting that such applications can be effective tools for asthma management, particularly among adolescents, who are the primary users of smartphones (10).

The results of the current study highlight the effectiveness of telemonitoring in treatment adherence outcomes and C-ACT scores in reducing school absences, parental work loss, and diagnosed respiratory infections in the pediatric age group. Additionally, this intervention led to a decrease in medical expenses (46). These results are consistent with those of Ramsey et al., who discovered that digital interventions improved adherence and health outcomes, such as enhanced asthma control, improved quality of life, and reduced healthcare service utilization in children. Thus, telemonitoring holds promise for improving asthma management in children (9).

However, some studies have shown that telemonitoring interventions in patients with asthma using smartphones and telephone communication may not be effective compared to common care in some outcomes and age groups. For instance, several studies indicate that telemonitoring interventions in adults

with asthma using smartphones and telephone communication had no effect on peak expiratory flow (PEF), forced expiratory volume in one second (FEV1), and vital capacity (VC). These interventions also did not affect scores on the Childhood Asthma Control Test (c-ACT) and the Pediatric Asthma Quality of Life Questionnaire (PAQLQ) in children (37,42,44). Additionally, they were not effective in reducing emergency department visits or hospitalizations related to asthma (45). Similarly, a study by Stukus et al. demonstrated that mobile health had no impact on emergency department visits, urgent care, or hospitalization in patients with asthma (19).

It appears that the effectiveness of telemonitoring technologies used in patients with asthma through smartphones and phone communication is influenced by their features. For example, text message reminders are the most widely accepted form of technology-based medication reminders and can be relatively easy to implement and support (35). Using text message reminders to commit patients to an action plan in remote and rural areas where asthma care is not easily accessible can be effective (43). However, reminders *via* text messages alone may not be sufficient for prompt action, which could be particularly important for high-risk pediatric populations and minority groups (37). It may be argued that the use of text message services alone cannot replace common methods of assessing and monitoring patients with asthma and is only effective for patients who forget to take their medication, as it essentially functions as a reminder system (45).

While text messages are considered a useful technology for addressing healthcare disparities, their integration and web-based nature may limit access for some families, particularly those from racial and ethnic minority groups (39).On the other hand, if a smartphone and web-based application are simple and require no additional knowledge, they can encourage patients to regularly monitor their condition.

A simple structured graphical overview of the patient's condition can be a useful tool for continuous patient monitoring. Furthermore, regular feedback and treatment recommendations from healthcare professionals, particularly in cases of asthma exacerbation and when the patient is most vulnerable, are particularly important (44). Creating solutions to engage patients in using such systems and integrating them into their daily activities is crucial (41). For example, in the adolescent age group, the use of tools or system designs that increase motivation, self-efficacy, social support, and skill development can be effective (39).

Limitations

Since all the studies were conducted in developed countries, the findings of this study cannot be generalized to developing countries where electronic infrastructure, communication facilities, access to smartphones, and the level of digital literacy vary. Due to the heterogeneity of the study population and outcomes, a meta-analysis was not feasible, and the results were reported narratively. However, efforts were made to accurately report the clinical results from the studies.

Conclusion

It seems that telemonitoring systems using smartphones and telephone communication and providing feedback can be considered a promising strategy for monitoring, managing, and treating patients with asthma. Nevertheless, it is crucial to ensure that these technologies are accessible and applicable to individuals of all races, age groups, genders, socioeconomic backgrounds, and levels of literacy. Moreover, conducting more high-quality studies and performing separate meta-analyses for each outcome are recommended.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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