Review Article

ISSN: 1735-0344 *Tanaffos 2022; 21(2): 132-145*

TANAFFOS

Efficacy of Telemedicine for the Management of Asthma: A Systematic Review

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Received: 31 August 2021
Accepted: 15 November 2021

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Background: Considering the increased prevalence of asthma and its consequences for individuals and society, its effective management and close monitoring is essential. Awareness of the effects of telemedicine can improve asthma management. The present study aimed to systematically review articles examining the effect of telemedicine on the management of asthma, including control of the symptom, patients' quality of life, costs, and adherence to treatment programs.

Materials and Methods: A systematic search was performed on four databases: PubMed, Web of Science, Embase, and Scopus. English language clinical trials investigating the effectiveness of telemedicine in asthma management published from 2005 to 2018 were selected and retrieved. The present study was designed and conducted based on the PRISMA guidelines.

Results: Out of 33 articles included in this research, telemedicine was employed by 23 studies for the promotion of patient adherence to treatment in the form of reminders and feedback, by 18 for telemonitoring and communicating with healthcare providers, by six for offering remote patient education, and by five for counseling. The most frequently used telemedicine approach was asynchronous (used in 21 articles), and the most commonly utilized tool was Web-based (utilized in 11 articles).

Conclusion: Telemedicine can improve symptom control, patients' quality of life, and adherence to treatment programs. However, little evidence exists confirming the effectiveness of telemedicine in decreasing costs.

Key words: Asthma; Telemedicine; eHealth; Systematic review

INTRODUCTION

Asthma is a chronic disease inflicting 300 million people of different age groups worldwide. It is predicted that 33% of the world's population will be affected by this disease by 2025. Every year, 250,000 deaths occur due to asthma (1,2). This disease also imposes enormous financial burdens on all age groups in the form of mortality, disability, decreased quality of life, and healthcare costs (3,4).

Implementing targeted strategies for timely asthma diagnosis and providing access to appropriate treatment services can effectively decrease the burden of this disease (5). According to the national asthma prevention and management clinical guidelines, asthma management includes symptom monitoring, encouragement for taking medications, treatment adherence, controlling environmental factors, preventing asthma-inducing factors, patient education, and establishment of rapport between patients and healthcare providers to increase the

quality of life and decrease the costs (6). Furthermore, effective asthma management requires continuous monitoring and interaction between patients and healthcare professionals through a collaborative approach (7). The main challenges of asthma management include adherence to treatment, symptom control, improvement of the quality of life, and healthcare costs. For instance, adherence to treatment in asthma is generally poor due to missed doses and poor adherence, which leads to poor asthma control and exacerbation of the symptoms (8,9). As a result, poor adherence negatively impacts the dimensions of the quality of life, especially in children, and directly and indirectly increases treatment costs in patients with asthma (4,10,11). Moreover, in asthma management, there are challenges in terms of prevention (e.g., education), diagnosis (e.g., scarcity of specialists), treatment (e.g., social and therapeutic costs), and follow-up (e.g., communication with healthcare providers and symptom monitoring) (12,13).

Similar to other fields, many healthcare challenges have been considerably overcome by using information and communication technology (14,15). Today, electronic health (eHealth) is widely employed to effectively manage different diseases and improve healthcare provision (16-18).

According to the definition proposed by the World Health Organization (WHO), telemedicine refers to providing healthcare services using information and communication technology where distance is a concern (19,20). There are two types of telemedicine. Synchronous telemedicine refers to the provision of health information in real-time and facilitates live discussion between patients and providers for medical services and advice. Asynchronous telemedicine is a "store-and-forward" approach where the patient shares info through a patient portal and the provider reviews it later (21,22).

eHealth solutions can enhance healthcare quality and reduce costs (23). As one form of eHealth, telemedicine facilitates access to healthcare, improves health outcomes, reduces medical costs, enhances the use of resources, expands educational opportunities, and promotes cooperation between patients and physicians (24). Similarly, in the case of asthma, it has been reported that telemedicine can overcome challenges such as supervision and monitoring, adherence to treatment, facilitating avoidance of exacerbating factors, and timely access to healthcare advice (25,26). A review of the literature showed that hitherto, several studies have examined the effects of telemedicine on asthma, some reporting positive and others noticing adverse effects (25-28). Therefore, in the present study, the researchers attempted to increase the search duration and employ a more sensitive search strategy to examine the effects of telemedicine on asthma symptom control, patients' quality of life, costs, and patient adherence to treatment programs. Accordingly, the following research questions were posed:

What are the benefits of telemedicine interventions in asthma management?

What is the effect of using telemedicine on asthma symptom control?

What is the effect of using telemedicine on the adherence of patients with asthma to treatment programs?

What are the effects of telemedicine on costs imposed on patients with asthma?

What are the effects of telemedicine on the patient's quality of life?

MATERIALS AND METHODS

The present systematic review was designed based on the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (29) (Figure 1).

Data Sources and Search Strategy

Articles written in English and published from 2005 to 2018 were searched on four databases: PubMed, Web of Science, Embase, and Scopus. The search strategy comprised MeSH terms, Emtree, and keywords related to asthma and telemedicine, which were also combined using Boolean AND/OR operators. Published articles were identified and retrieved using a search strategy developed by the authors (Table 1).

Inclusion and Exclusion Criteria

Articles were included in this study if: 1) they were randomized clinical trials in English; 2) employed intervention tools including all solutions based on telemedicine and information and communication technology for the diagnosis and management of asthma; 3) included any age group (children and adults) diagnosed with asthma in the target population; and 4) the results of interventions were related to the effects of telemedicine on asthma management, symptom control, quality of life, costs, and adherence to the treatment program.

All clinical trials exploring the effects of telemedicine on asthma management, symptom control, quality of life, costs, and adherence to the treatment programs were included in the present study. First, the titles and abstracts of the articles were examined, and, subsequently, the full texts were selected, retrieved, and independently reviewed by two researchers. Any disagreement was resolved through consultation with a third researcher.

Data Extraction

For each article included in this study, the name of the first author, publication year, location, participants, type of telemedicine and tools used, duration of the interventions and outcomes, as well as data required for evaluating the quality of the articles were extracted (Table 2). To facilitate reporting, the telemedicine approaches used in the articles were divided into two types of synchronous and asynchronous (21,22). The functions used in telemedicine interventions are presented in a separate table based on the study's goals. In this study, telemedicine functions for patients with asthma were divided into five categories: consultation, communication, education, monitoring, and reminder. Similar studies have also adopted this categorization (Table 3) (30-33).

Table 1. Search strategy

No.	Concept	Search strategy
1	Telemedicine	Telemedicine OR tele* OR ehealth* OR e-health* OR "electronic health*" OR remote OR "remote consultation" OR "Reminder Systems" OR distance OR mhealth* OR "Mobile Applications" OR mobile OR "mobile health" OR "mobile technolog*" OR "mobile care" OR apps OR "Smartphone" OR *phone OR "Cell Phone" OR *phones OR pda OR *computer* OR "Computers, Handheld" OR handheld OR tablet* OR "Wireless Technology" OR Internet OR internet* OR web* OR internet-delivered OR internet-based OR "Patient Portals" OR portal* OR palmtop* OR digital OR Electronic Prescribing OR Electronic Prescribing OR e-therapy OR podcast* OR online OR virtual OR "Remote Sensing Technology" OR "Home Care Services, Hospital-Based" OR "Electronic Mail" OR email* OR e-mail* OR teleconference* OR "Videoconferencing" OR "Text Messaging" OR message* OR texting OR "short messaging service" OR "Mass Media" OR "social media" OR "Social Media"
2	Asthma	asthma OR "Asthma*"

Table 2. Characteristics of included studies

Author(publication year)	Study location	Age Group and Sample Size	Type of telemedicine(tools)	Outcome category	Duration of intervention	Results
Stukus et al (2018) (34).	USA	Patients aged (6 months to 21 years) IG (n = 98) UC (n = 95)	Synchronous (mobile application)	Cost	6 months	Effect of neutral of telemedicine on cost
Perry et al (2018) (35).	USA	Patients aged (7 to 14 years) IG (n=180) UC (n=183)	Synchronous (live interactive video)	Symptoms control Medications adherence Quality of life	6 months	Positive effect of telemedicine on medications adherence Effect of neutral of telemedicine on symptoms control and quality of life
Halterman et al (2018) (36).	USA	Patients aged (3 to 10 years) IG (n = 199) UC (n = 196)	Synchronous (video conferencing)	Symptoms control Cost Quality of life	12 months	Positive effect of telemedicine on symptoms control, cost, and quality of life
Fedele et al (2018) (37).	USA	Patients aged (12 to15 years) IG (n = 25)	Synchronous (mobile application)	Medication adherence Asthma control Quality of life	4 months	Positive effect of Telemedicine on asthma control, medication adherence, and quality of life

		UC (n = 25)				
Perry et al (2017) (38).	USA	Patients aged (12 to 17 years) IG (n = 17) UC(n = 17)	Asynchronous (mobile application)	Asthma control	6 months	Positive effect of telemedicine on asthma control.
Britto et al (2017) (39).	USA	Patients aged (12 to 22 years) IG (n = 31) UC(n = 34)	Asynchronous (text messaging system with mobile)	Asthma control Quality of life Medication adherence	6 months	Positive effect of telemedicine on asthma control, quality of life, and medication adherence.
Johnson et al (2016) (40).	USA	Patients aged (12 to 17 years) IG (n = 53) UC (n = 45)	Asynchronous (short messaging service -based reminder system)	Medication adherence Quality of life	1 months	Positive effect of telemedicine on medication adherence , and quality of life
Bender et al (2015) (41).	USA	Patients age (3 to 12 years) IG (n = 590) UC (n = 597)	Asynchronous (speech recognition (SR) software and electronic health records (EHRs))	Medication adherence	24 months	Positive effect of telemedicine on medication adherence.
Joseph et al (2013) (42).	USA	Patients aged (≥ 12 years) IG (n = 204) UC (n = 218)	Asynchronous (web-based)	Symptom control	12 months	Positive effect of telemedicine on symptom control
Gustafson et al (2012) (43).	USA	Patients aged (4 to 12 years) IG (n = 148) UC (n = 153)	Asynchronous (telephone with Web-Based)	Medication adherence Asthma control	12 months	Positive effect of telemedicine on asthma control. Effect of neutral of telemedicine on medication adherence.
Bender et al (2010) (44).	USA	Patients aged (18 to 65 years) IG (n = 50) UC (n = 50)	Synchronous (interactive voice response system)	Medication adherence Asthma control Quality of life	3 months	Positive effect of telemedicine on medication adherence. Effect of neutral of telemedicine on asthma control, and quality of Life.
Patel et al (2009) (45).	USA	Patients aged (≥65 years) IG (n = 25) UC (n = 23)	Synchronous (telephone)	Medication adherence	12 months	Positive effect of telemedicine on medication adherence.
Van den wijngaart et al (2017) (46).	Netherlands	Patients aged (6 to 16 years) IG (n = 105) UC (n = 105)	Synchronous (web-based monitoring)	Asthma control Symptoms control	16 months	Positive effect of telemedicine on asthma control, and symptoms control.
Vasbinde et al (2016) (47).	Netherlands	Patients aged (4 to 11 years) IG (n=108) UC (n = 111)	Asynchronous (short message service reminders)	Asthma control Quality of life Cost Medication adherence	12 months	Positive effect of telemedicine on medication adherence. Effect of neutral of telemedicine on asthma control, and quality of life. Negative effect of telemedicine on cost.
Bergen et al (2015) (48).	Netherlands	Patients aged (4 to 18 years) UC (n=89) IG (n=91)	Asynchronous (web-based monitoring)	Cost	12 months	Positive effect of telemedicine on cost.
Van gaalen et al (2013) (49).	Netherlands	Patients aged (18 to 50 years) IG=47 UC=60	Asynchronous (web-based)	Asthma Control Quality of life	12 months	Positive effect of telemedicine on asthma control, and quality of life.
Rikkers-Mutsaerts et al (2012) (50).	Netherlands	Patients aged (12 to 18 years) IG (n = 46) UC (n = 44)	Asynchronous (web-based)	Quality of life Asthma control	12 months	Positive effect of telemedicine on asthma control, and quality of life.
van der Meer et al (2011) (51).	Netherlands	Patient (18 to 50 year) IG (n = 101) UC (n = 99)	Synchronous (web-based)	Cost	12 months	Positive effect of telemedicine on cost.
Hashimoto et al (2011) (52).	Netherlands	Patients aged (18 to 75 year)	Synchronous (web-based)	Quality of life Asthma control	6 months	Effect of neutral of telemedicine on asthma control, and quality of

		IC (n = 52) UC (n = 43)				life.
van der Meer et al(2009) (53).	Netherlands	Patients aged (18 to 50years) IG (n = 101) UC (n = 99)	Asynchronous (web-based)	Asthma control Quality of life	12 months	Positive effect of telemedicine on asthma control. Effect of neutral of telemedicine on quality of life.
Willems et al (2008) (54).	Netherlands	Patients aged (7 years and older) IG (n=55) UC (n=54)	Asynchronous (electronic asthma monitor)	Quality of life Medication adherence Symptoms control	12 months	Effect of neutral of telemedicine on quality of life, and medication adherence.
Chan et al (2017) (55).	New Zealand	Patients aged (6 to 15 years) IG (n =110) UC (n = 110)	Asynchronous (smart Track electronic monitoring device)	Asthma control Medication adherence	6 months	Positive effect of telemedicine on asthma control, and medication adherence.
Chan et al (2015) (56).	New Zealand	Patients aged (6 to 15 years) IG (n = 110) UC (n = 110)	Asynchronous (smart Track electronic monitoring device)	Asthma control Medication adherence	6 months	Positive effect of telemedicine on asthma control, and medication adherence.
Petrie et al (2012) (57).	New Zealand	Patients aged (16 to 45years) IG (n = 204) UC (n = 218)	Asynchronous (text message programe)	medication adherence	4 months	Positive effect of telemedicine on medication adherence.
Zairina et al (2016) (58).	Australia	Patients aged (≥18 years) IG (n = 36) UC (n = 36)	Asynchronous (mobile application)	Asthma Control Quality-of-life	6 months	Positive effect of telemedicine on asthma control, and quality of life.
Lau et al (2015) (59).	Australia	Patients aged (18 years and older) IG (n=154) UC (n=176)	Asynchronous (web-based personal health record)	Asthma control	12 months	Effect of neutral of Telemedicine on asthma control.
Lv et al (2012) (60).	China	Patients aged (12 to 18 years) IG (n = 50) UC (n = 50)	Asynchronous (mobile phone short message service)	Quality of Life Asthma control	12 months	Positive effect of telemedicine on asthma control, and quality of life
Takita et al (2017) (61).	Japan	Patients aged (38 to 88 years) IG (n = 17) UC (n = 16)	Asynchronous (DVD)	Asthma control	1 months	Positive effect of telemedicine on asthma control.
Koufopoulos et al (2016) (62).	United Kingdom	Patients aged (18 to 64 years) IG (n = 99) UC (n = 117)	Synchronous (web-based and mobile application)	Medication adherence	3 months	Effect of neutral of telemedicine on medication adherence.
Strandbygaard et al (2010) (63).	Denmark	Patients aged (18 to 45 years) IG (n = 12) UC (n = 14)	Asynchronous (short message service)	Medication adherence	12 months	Positive effect of telemedicine on medication adherence
Prabhakaran et al (2010) (64).	Singapore	Patients aged (21 years or above) IG (n = 60) UC (n = 60)	Asynchronous (short message service)	Asthma control	3 months	Positive effect of telemedicine on asthma control.
Jan et al (2007) (65).	Taiwan	Patients aged (8 to 12 years) IG (n=88) UC (n=76)	Synchronous (web-based)	Quality of life Medication adherence	12 months	Positive effect of telemedicine on quality of life, and medication adherence.
Sundberg et al (2005) (66).	Sweden	Patients aged (18 to 25 years) IG (n=48) UC(n=49)	Asynchronous (computer program)	Quality of life Asthma control	12 months	Effect of neutral of telemedicine on asthma control, and quality of life.

IG: Intervention group, CU: Control group

Table 3. Functions used in telemedicine

Outcome category	Functionality
Symptom/ asthma control	Communication, consultation and education (29)
	Monitoring, communication and reminder (38,46,58)
	Education (42,61)
	Communication and monitoring (37)
	Reminder (39,55,56)
	Education, reminder and monitoring (49,50)
	Education and reminder (60)
	Reminder, education, monitoring, communication, consultation (43)
	Communication, consultation and education (35)
	Communication and monitoring (34)
	Reminder (39,45,55-57,63)
	Monitoring and reminder (47)
	Monitoring, communication and reminder (41)
Medication adherence	Education, communication, monitoring and reminder (44)
	Monitoring, communication and education (65)
Cost	Monitoring, communication and reminder (36)
	Communication, consultation and monitoring (48)
	Communication and monitoring (37)
	Monitoring, communication and reminder (36)
	Education, reminder and monitoring (49,50)
Patients' quality of life	Reminder (39)
	Monitoring, communication and reminder (58)
	Education and reminder (60)
	Reminder and monitoring (40)
	Monitoring, communication and education (65)

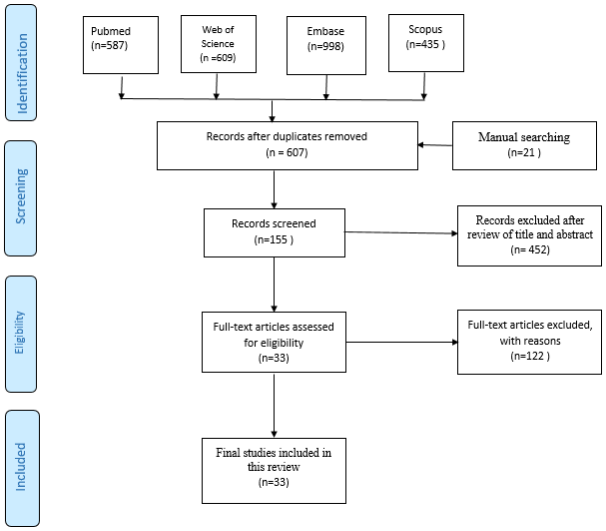

Figure 1. PRISMA flow diagram of literature search and selection.

RESULTS

Based on the search strategy results, 2629 articles were retrieved, including 2046 duplicates. After the removal of the duplicates, 583 articles remained. At this stage, upon a manual search, journals related to medical informatics (Journal of Medical Internet Research, Journal of Telemedicine and Telecare, Journal of the American Medical Informatics Association) were searched, and 24 articles were added. Thus, 607 articles remained for screening. In the next stage, the authors examined the titles and abstracts of the remaining articles, and 452 articles were removed. Therefore, 155 articles remained at this stage. Subsequently, the full texts of the articles were examined by the authors. Irrelevant articles (19 articles due to the absence of telemedicine as the intervention method, 32 articles had not examined the goals of this study, six articles had investigated other diseases such as allergies and chronic obstructive pulmonary disease, 48 articles due to lack of access to full texts, 13 articles were duplicate and overlapping, three articles were a letter to the editor, and 1 article was a review study) were eliminated based on inclusion and exclusion criteria. Finally, 33 articles compatible with the objectives and inclusion criteria of the present study remained for review.

Characteristics of Studies

Twelve articles were conducted in the US (34-45), nine in the Netherlands (46-54), three in New Zealand (55-57), two in Australia (58,59), and one in China (60), Japan (61), England (62), Denmark (63), Singapore (64), Taiwan (65), and Sweden (66). The number of patients equaled 3565 and 3365 in the experimental and control groups, respectively, and their ages ranged from six months to 88 years. The type of telemedicine was asynchronous in 21 articles (38-43,47-50,53-61,63,64,66) and synchronous in 11 articles (34-37,44-46,51,52,62,65). In general, the most frequently used types of instruments were Web-based in 11 articles (38,42,46,48-52,59,62,65), short message service (SMS) or telephone in seven articles (39,40,47,57,60,63,64), and mobile applications in four articles (34,37,38,58). In the asynchronous type, the most frequently used tool was SMS or telephone (39,40,47,57,60,63,64) and Web-based (38,42,48-50,59), while in the synchronous form the most frequent tool was Web-based (46,51,52,62,65). The duration of the intervention was between three weeks to 24 months.

Functions used in telemedicine interventions

The major functions of telemedicine referred to in the studies can be categorized into five groups. The most frequent function was related to reminders. In 23 (34, 38-41,43-50,52-60,63,64) out of 33 articles, the application of this function of telemedicine was studied. This was followed by remote monitoring (n=18) (34,37,38,40,44,46,47,49-54,58,59,64,65), communication (n=18) (34-38,41,43,44,46,51-54,58-60,65), remote education (n=16) (35,36,42-44,49-53,59-62,64-66), and remote counseling (n=5) (35,36,41,43,51). It is noteworthy that some studies employed a combination of these functions; in 21 articles (37,38,41,43,44,46,48-50,58,65), the interventions utilized more than one function. The majority of the combined functions used by the studies were observed in six studies (34,38,46,54,58,64). The main functions of telemedicine interventions included alarms and feedback, setting alarms for taking medications, alarms in case of wrong doses, encouraging messages for taking the right dose and reducing asthma symptoms, sending messages in case of incomplete information, and reminding the time of visits (34,38-41,43-50,52-60,63,64).

The main functions of telemedicine interventions in terms of remote monitoring included online asthma control, respiratory functions, entering data about asthma symptoms and physical examination information (i.e., images, respiratory volume, and height and weight data), data on the dose of medications and monitoring the doses by healthcare providers, and recording the progress of the disease (34,37,38,40,44,46,47,49-54,58,59,64,65).

The main functions of telemedicine interventions in terms of counseling included a conversation with parents about their children's asthma and the implementation of treatment programs for children and their education (35,36,41,43,51).

The significant functions of telemedicine interventions in terms of communicating with healthcare providers included sending symptom information to healthcare providers, requesting communication with them in case of severe and persistent symptoms, monitoring adherence to the treatment programs, and regular intake of medications with appropriate graphical formats, and common questions about asthma (34-38,41,43,44,46,51-54,58-60,65).

The main functions of telemedicine interventions in terms of education included information on asthma, anatomy of the lungs, common symptoms of asthma, appropriate use of asthma control medications, how to follow treatment programs, different types of factors exacerbating asthma, management of acute asthma attacks, proper use of inhalers, peak flow meters, spacers, and telemedicine tools (35,36,42-44,49-53,59-62,64-66).

Asthma control and symptoms

Twenty-four articles were found on the effects of using telemedicine for controlling asthma and its symptoms. In these articles, five telemedicine functions (monitoring, education, feedback, alarms, and communication) were used separately or in combination to control asthma symptoms. Most functions included alarms and reminders, followed by remote education and symptom monitoring.

In terms of the effects of utilizing telemedicine for controlling asthma and its symptoms, 17 articles reported positive results; three articles (36,37,46) used the synchronous method, with one article utilizing Web-based tools (46), one article employing mobile application (37), and one article using video conferencing (36). Moreover, 14 articles (38,39,42,43,46,49,50,53,55,56,58,60,61,64) utilized the asynchronous method, in which the most frequent tool was Web-based in seven articles (38,42,43,46,49,50,53). In addition, in seven articles (35,44,47,52,54,58,66), telemedicine had no effect on controlling asthma and its symptoms. Four articles (47,54,58,66) employed asynchronous telemedicine, one article via a mobile application (58), one using SMS (47), one using an electronic asthma monitor (54), and one employing computer programs (66).

In addition, three articles (35,44,52) used the synchronous method, with one article utilizing a live interactive video (35), one article utilizing Web-based tools (62), and one article using an interactive voice response (IVR) system (44).

Medication adherence

Sixteen articles were found on the effect of telemedicine on adherence to treatment. The most frequent function employed in telemedicine interventions was reminders and alarms. This was followed by communication with healthcare providers and monitoring.

Based on the results of 13 articles, telemedicine improved adherence to treatment in the intervention groups compared to the control groups (35,37,39-41,44,45,47,5557,63,65). Most articles (n=8) (35,37,39-41,44,45,47,55-57,63,65) utilized the asynchronous method, in which the most frequent tool was SMS (39,40,47,57,63).

Three studies reported that the incorporation of telemedicine did not affect adherence to treatment in the experimental groups (43,54,62). Two studies used the asynchronous method, including Web-based tools and mobile applications (43,62), while one used the synchronous method, including the electronic asthma monitor (54).

Cost

Five articles were found on the effect of telemedicine on costs. Monitoring and communication with healthcare providers were the most important functions used in telemedicine interventions. Both social (commuting, SMS, and time costs) and healthcare costs (visits, counseling, medication, visiting the emergency department, and hospital admission costs) were measured in the studies.

In two articles, the costs were reduced in the experimental group compared to the control group (36,48). In one article, the synchronous method and video conferencing (36), and in another study, the asynchronous method and Web-based tools (48) were incorporated. Moreover, in one study, the costs were higher in the experimental group, but the difference was not statistically significant (47). Also, in two articles, the experimental and control groups did not differ (34,51). In addition, synchronous telemedicine was used in both studies, with one article utilizing a mobile application (34) and the other employing a Web-based tool (51).

Patient's quality of life

Sixteen articles were found on the effect of telemedicine on the quality of life. The most frequent function used in telemedicine interventions was reminders and alarms, followed by monitoring. In nine articles, the results revealed that telemedicine improves the quality of life in the experimental groups (36,37,39,40,49,50,58,60,65). Six articles (39,40,49,50,58,60) employed the asynchronous method, with the majority of the studies using SMS (39,40,60). In contrast, three articles used the synchronous method (36,37,65), with one article using video conferencing (36), one utilizing a mobile application (37), and one employing Web-based tools (65).

In seven studies, the use of telemedicine led to no difference between the experimental and control groups (35,44,47,52-54,66). Four studies (47,53,54,66) utilized the asynchronous method, with one study using Web-based tools (53), one utilizing SMS (47), one employing an electronic asthma monitor (54), and one using computer programs (66). Moreover, three articles (35,44,52) used the synchronous method, with one article utilizing live interactive video (35), one article using Web-based tools (52), and one article (44) using the interactive voice response system.

DISCUSSION

The aim of this study was to investigate the role of telemedicine in the management of asthma. Studies demonstrated that the use of technology plays a vital role in the management of the disease (67,68). Examination of the functions incorporated in the telemedicine interventions demonstrated that the most frequently used functions were reminders and alarms, followed by monitoring of the control of asthma symptoms and adherence to the treatment programs. Similar studies have reported the effective use of SMS for monitoring and management of asthma medications (69-71).

In most studies, multiple functions were used in telemedicine interventions. Results showed that using combination features of reminders, monitoring, and

communication with healthcare providers leads to more diverse services offered to patients with asthma. According to review studies, using a combination approach further improves asthma control and the quality of life compared to the control groups (25). Moreover, in another study, multiple telemedicine functions have been reported to positively affect hemoglobin control in adults with type 1 diabetes (72). Furthermore, examination of the functions used in telemedicine interventions demonstrated that the most frequently used functions were reminders and alarms, followed by monitoring the control of asthma symptoms and adherence to the treatment programs. Similar studies have reported that SMS is an effective tool for control and management of medications in patients with asthma (69-71).

Regarding controlling asthma and its symptoms, the majority of studies included in the present review revealed that telemedicine is effective for this purpose. Similar studies have reported the positive effect of using telemedicine on controlling asthma and its symptoms (25,73,74). Findings of the reviewed studies suggested that the asynchronous form of telemedicine, mainly utilizing Web-based tools, has positive effects on controlling asthma and its symptoms. Based on the findings of review studies, using Web-based interventions leads to better management of chronic conditions, especially asthma (75,76).

In terms of treatment adherence, the majority of the reviewed studies approved the effectiveness of telemedicine interventions in adherence to treatment. Most studies examined here employed asynchronous telemedicine, e.g., SMS and alarms, for reminding the consumption of medications. In similar review studies, eHealth tools have been regarded as acceptable and effective in adherence to treatment and medication use in patients with asthma (77,78). The use of tools such as SMS and alarms for timely medication intake has been demonstrated to enhance adherence to treatment programs (69,79).

Some studies reported that telemedicine effectively controls costs (36,48), whereas others observed no difference between the experimental and control groups (34,51). One study even reported a negative effect of telemedicine on the costs in the experimental group, but this result was not statistically significant (47). Some similar review studies revealed that, in general, the number of visits, admission, and hospitalization was improved in economic terms, while no significant improvement has been reported in some others (80). Moreover, in the study by Hui et al., no significant improvement was observed in terms of admissions and visits to emergency departments (81).

Furthermore, according to the majority of reviewed studies, telemedicine improved the experimental groups' quality of life. Similar review studies have also demonstrated the effectiveness of telemedicine interventions, e.g., mobile Health, for improving the quality of life in patients with asthma (31,82,83).

Overall, most reviewed studies showed that telemedicine was effective in asthma management. This finding was confirmed by other systematic reviews (25,27,74). In addition, it was found that the short duration of interventions (66), poor participation of healthcare providers and patients (58,66) especially in management programs for children with asthma (35,47,54), and patient's lack of understanding of the advantages of telemedicine for asthma management (44), distance barriers and inadequate access to asthma providers in rural regions (35) are the most important factors preventing the effectiveness of telemedicine for asthma management.

Based on various sources, influential factors in the success of chronic disease management programs include sharing the program objectives with the participants, fostering teamwork, using motivational methods, explaining the advantages of the programs to the patients and healthcare providers, and following asthma care guidelines (84,85). Also, according to some studies on management programs for children with asthma (34-36,43,47,48,54), parents play a vital role in implementing asthma management programs (86). The use of widespread technologies such as computer games for education and

smartphones also play a detrimental role in enhancing control and adherence to the treatment program for children with asthma (87-91).

Strengths and Limitations of the Study

The limitations of this study included the unavailability of the full texts of some articles, which led to their exclusion from the study. Moreover, articles written in languages other than English were excluded.

One of the strengths of the present study was the assessment of several domains related to asthma management. In this study, the effects of telemedicine on asthma management (in four domains of controlling asthma and its symptoms, adherence to treatment, quality of life, and costs) were investigated. Compared to similar studies (25,78), this study investigated more domains and covered more extended periods. Moreover, the comprehensive search strategy included many keywords and extended periods in the present study and included more studies.

CONCLUSION

The most frequently used function in asthma management was reminders and alarms. It was demonstrated that combining different intervention features and functions improves asthma management significantly compared to using a single feature. Overall, the use of telemedicine positively affects asthma management by improving symptom control, patients' quality of life, and adherence to the treatment program. Nevertheless, little evidence is available on its effectiveness in reducing costs.

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