Effectiveness of Telemedicine Consultation Among Asthmatic Adults and Children: A Meta-Analysis

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Background: The circumstances surrounding the current COVID-19 pandemic has necessitated the employment of telemedicine for administering care to patients and families. There is difficulty of seeking medical help among those with chronic and recurrent illness like asthma. The authors conducted a metanalysis to determine whether telemedicine for asthma management is effective.
Objective: This study aimed to systematically review the effectiveness of telemedicine consultation among asthmatic adults and children in terms of: a) asthma control, b) quality of life, c) cost effectiveness, d) lung function and e) exacerbations.
Methods: A comprehensive search of randomized controlled trials was performed using the MEDLINE (PubMed), EMBASE, The Cochrane Library, Google Scholar, clinical trial registries (e.g., clinicaltrials.gov, clinicaltrialregister.eu) and relevant websites. The authors were interested in studies that measured these outcomes: asthma control, quality of life, cost effectiveness, lung function and exacerbations. Three reviewers identified studies for inclusion in this meta-analysis. They extracted data then used fixed effect and random effect modelling.
Results: The authors identified 15 RCTs with total of 3,015 enrolled patients. A variety of telemedicine interventions were incorporated: telephone and Internet-based models of care. Most control used was the conventional face-to-face. Meta-analysis did not show a clinically important improvement in patients' asthma control and lung function, there was no significant reduction in the number of hospital admission and visits to the emergency department over 12 months and not significantly cost effective. However, there was a significant improvement in the quality of life (95% CI [0.05, 0.29], $p = 0.006$).
Conclusion: Although nothing beats the advantage of physically seeing patients face-to-face, this study just supports the knowledge that telemedicine offers promising alternative to promote good communication between patients and caregivers, resulting in adherence to asthma management, which leads to better asthma control, improvement of patients' quality of life, lung function, better cost-effectiveness and decrease in ER visits and exacerbation.

Key words: telemedicine, telehealthcare, asthma

Introduction

Introduction of health information technology undeniably offers unique and new opportunities to change the way healthcare is organized from a pen and paper system to a more modern monitoring systems that capitalize on the conveniences of the internet, smart phones and other gadgets. It facilitates integrated self-management support in asthmatic patients by enabling remote delivery of care in a time when healthcare systems are already overburdened and more frequent routine visits are not desirable such as during pandemics. In general, providing patients with long-term conditions timely access to health actions when needed, medication concordance and health education additionally empower individuals to self-manage more effectively their condition by facilitating and reinforcing health behaviour change. The trend of its prevalence is increasing although some countries have seen a decline in hospitalizations and death. But due to the episodic nature of asthma symptoms and exacerbations affecting patient's quality of life, constant monitoring with a physician and effective self-management of the condition are necessary. Indeed, asthma still imposes a significant burden on the individual patient, the health care systems, and on society through loss of productivity in school or workplace and even disruption to the family dynamics.[1]

A study done in Canada by FitzGerald, et al. that investigated the effectiveness of using computer technology in asthma control to deliver patient self-management programs found that there was insufficient evidence to determine whether computer-enabled

interventions were effective compared with no intervention or usual care.[2] Although the results have been inconsistent, a systematic review on telemedicine by Morrison et al supported that these interventions may be effective in improving knowledge, reducing activity limitations, improving markers of self-management, quality of life, and optimizing medication use.[3]

In general, the level of intervention may vary in telehealthcare. The benefits are mediated by education, an enhanced therapeutic relationship, more intensive monitoring of the patient and feedback. The precise mixture of these elements has not been measured by different studies done previously; however, these elements are important and they should be studied further for complex interventions. Only few studies were also able to assess the effect of telehealthcare on hospital admission because studies were too small or the follow-up period was too short, or because the studies included only patients with mild asthma and there were no admissions at all.[4] While previous studies have included Web-based monitoring, most do not provide a comprehensive evaluation of asthma-related behaviors such as adherence to asthma treatment which limited its ability to evaluate the impact of the intervention on adherence as an intermediate effect to improve asthma control. The number of participants lost to follow-up and missing data resulted in a relatively small sample size. Additionally, these interventions seem to be most successful in patients with more severe illness or uncontrolled disease who have most to gain. However, it is still unclear which patients might benefit most.[5] More research is also needed to investigate the cost effectiveness of telehealthcare-centred models of care.

In the Philippines where its citizens are currently experiencing a global pandemic of Coronovirus Disease 2019 (COVID-19) and cases are still rising, they are facing an even greater challenge. There is difficulty of seeking medical help especially among those with chronic and recurrent illness like asthma. This imposes a heavier burden to patients, family and the community at large. Therefore, asthma's high burden of disease requires improvements and alternative in access to treatments.[6] Although this may be a relatively new concept in our country, Telemedicine, has been practiced as early as the 1970s, which literally means "healing at a distance".[7] It signifies the use of information and communication technologies (ICT) to improve patient outcomes by increasing access to care and medical information. ICTs offer great potential to address some of the challenges faced by both developed and developing countries in providing accessible, cost-effective, high-quality health care services. This is also particularly beneficial for groups that traditionally suffer from lack of access to health care such as rural and underserved communities in developing countries such as the Philippines. Hence, ICT in telemedicine is widely believed to play a vital role now more than ever. The outcomes of the study provide necessary information to assess these interventions on longer-term outcomes, less influenced by daily fluctuations in symptoms, and address the impact of disease on individuals' consumption of health care services and related costs.

This study aimed to systematically review the effectiveness of telemedicine consultation among adults and children with asthma in terms of: asthma control, quality of life, cost effectiveness, lung function and exacerbations.

Methods

This research paper was presented and approved by the Research Committee of the Department of Family and Community Medicine of DOPMC. Furthermore, this research paper was submitted and approved by the Chairman of the Research Committee of PAFP. The research followed good ethical and clinical practice standards and exempted from ethical review.

Criteria for Considering Studies for This Review

Types of Studies

In this meta-analysis, all randomized controlled trials were included.

Types of Participants

Studies involved patients who had received a diagnosis of asthma from a physician regardless of age, sex, race, ethnic origin, language spoken, and disease severity. Participants recruited in both outpatient clinics and hospital settings were included. Participants must have a device (mobile phone, telephone, computer, tablet) with or without internet access. Studies involving participants with chronic obstructive pulmonary disease, other serious medical diagnoses (e.g. severe psychiatric, neurological, oncologic, or immunologic disease) and those with severe mobility limitations were excluded.

Types of Interventions

The conceptual definition of telemedicine or telehealthcare, as adapted from Miller is "the provision of personalized healthcare at a distance." This constitutes the following three factors: information obtained from the patient, whether by conversation, video, chest x-ray, oxygen saturation, etc., that pertains to the patient's condition; electronic transfer of this information to a health care professional over a distance; and personalized feedback tailored to the patient and provided by a health care professional who exercises clinical skills and judgement.[8]

"At a distance" refers to health care that uses a tool of distance communication that works without the simultaneous physical presence of the participants in the interaction. According to this definition, the technology used might be telephone, e-mail, short message service (SMS), chats, internet or any other device. The novelty or sophistication of the technology is irrelevant. Feedback from the health care professional to the patient could be synchronous or asynchronous (i.e., by store-and-forward technology, in which a patient's data are kept in an electronic repository and forwarded to a health care professional on request). The health care professional should provide advice tailored to the consulting patient. In most studies, telemedicine was compared with face-to-face usual care.

Types of Outcome Measures

Primary Outcomes

The primary outcomes include a reduction in asthma impairment measured as improvement in asthma control and in asthma-related quality of life, and a reduction in asthma risk measured as a decrease in urgent care events and hospitalization.

The clinical goals of asthma management as measured by Asthma Control Questionnaire (ACQ)[9] assess the level of asthma control that includes interference with activity, shortness of breath, nocturnal symptoms, rescue medication use, and hospital admissions; forced expiratory volume after 1 minute (FEV1); patient's physical/ emotional impact of asthma is measured using Asthma Quality of Life Questionnaire (AQLQ).[10]

Secondary Outcomes

The secondary outcomes explored are the evaluation of cost-effectiveness of tele-asthma care and the lung function of the asthmatic patients.

Search Methods for Identification of Studies

A comprehensive search of randomized controlled trials was performed using the MEDLINE (PubMed), EMBASE, The Cochrane Library, Google Scholar, China National Knowledge Infrastructure (CNKI), China Science and Technology Journal Database (VIP). Manual searches of respiratory journals and abstracts from meetings also contribute to the Cochrane Airways Group Specialised Register of Trials.

The reference lists of relevant trial publications were checked for any unidentified randomized clinical trials. To identify unpublished trials, we searched clinical trial registries (e.g., clinicaltrials.gov, clinicaltrialregister.eu, who.int/ictrp, chictr.org.cn) of Europe, USA, and China, and websites of pharmaceutical companies, websites of US Food and Drug Administration (FDA) and European Medicines Agency (EMA). We included unpublished and grey literature trials and assessed relevant retraction statements and errata for included trials.

Electronic Searches

The search strategy consisting of patient relevant terms ("asthma") and intervention relevant terms ("telemedicine", "telehealthcare", "teleconsultation," "telemanagement", "e-Health", "e-Care") was applied both in Medical Subject Headings (MeSH) and free text. The comprehensive search syntax is available in Figures 1 and 2.

Selection of Studies

We searched all databases and then selected randomized control trials with free full text available published from 2010 and until October 2020. Trials were included irrespective of language and publication type, however, protocols and on-going studies with partial results were excluded.

Data Collection and Data Extraction

Necessary data from all the articles that were collected were extracted by one author using a standardized data collection form to avoid discrepancies. A second author checked for validation. Any case of discrepancy was resolved through discussion, or if required, through discussion with a third author. We contacted all trial authors if relevant data were unclear or missing. The following data were extracted: study characteristics (author; year of publication; country and setting; the design of the study; the number of participants), population characteristics (their mean ages and the range of ages); a description of the intervention being investigated and of how the control group was managed; and outcomes (measures of symptoms; quality of life; use of the health care system, such as visits to the emergency department or admissions to hospital; cost data; monitoring of patient's forced expiratory volume in one second; and patient withdrawal from the study).

Data Synthesis and Statistical Analysis

The authors calculated summary statistics for their primary outcomes: risk ratios (RRs) for the dichotomous variables with 95% confidence intervals (CI); and continuous variable such as asthma-related quality of life score was calculated as mean difference with 95% CI. They directly retrieved from the published data of the articles.

RevMan 5.3.5 downloaded from the Cochrane Collaboration was used for statistical analysis. To create forest plots, data have to be compatible across studies. For example, for quality of life, they included only studies that reported using the Asthma Quality of Life Questionnaire (AQLQ) by Juniper; for cost-effectiveness, we included only studies that present the actual cost in the same currency; for visits to the emergency department, they included only studies with results that could be summarized into the variable of the number of patients with one or more visits to the emergency department over 12 months of follow-up. In this way, they produced meaningful comparative data across studies.

Measures of Treatment Effect

The mean differences and mean standard deviation for each outcome (asthma control and in asthma-related quality of life, and a reduction in asthma risk measured as a decrease in urgent care events) were directly retrieved from the published data of the articles.

Assessment of Heterogeneity and Subgroup Analysis

Fixed effects model was used to interpret the outcomes and to test the presence of statistical heterogeneity between studies using inconsistency (I^2) statistic where I^2 is 40% or less. For results with significant heterogeneity (p-value is <0.05 or $I^2 > 40\%$), random-effects model was employed. Subgroup analysis according to the type of technology used for telehealthcare was done when needed. Pooled data were presented graphically with forest plots.

Assessment of Methodological Quality

Quality of the retrieved articles was assessed and evaluated based on the critical appraisal tool on treatment (Table 1). Six major criteria for validity assessment were used wherein three categories were considered as primary criteria and the other three as secondary criteria. Scores were assigned for further categorization using assessment of methodological quality (Table 2). Studies were then rated based on the number of primary or secondary criteria met (Table 3). Articles with dropout rates more than 20% of their study population during the time of randomization were excluded. Since there was an objective outcome being measured, articles were considered regardless whether blinding were employed or not. Full-text papers were obtained for all studies that could not be excluded on the basis of title and abstract.

Table 1. Criteria for assessing validity based on CAT on treatment.

Primary Criteria
1. Was assignment of subjects to treatment randomized?
2. Was follow-up adequate and complete?
3. Were patients analyzed in the groups to which they were randomized?
Secondary Criteria
4. Were patients, health workers, and study personnel "blind" to treatment?
5. Were the groups similar at the start of the trial?
6. Aside from the experimental intervention, were the groups treated equal?

Assessment of Risk and Reporting of Bias in Included Studies

The risk of bias of inclusive RCTs were assessed in accordance with the Cochrane Handbook for Systematic Reviews of Interventions.[11] Biases were assessed with the following domains: bias arising from the randomization process, bias due to deviations from the intended interventions, bias due to missing outcome data, bias in measurement of outcomes, and bias arising from selective reporting of results. The authors contacted authors of trials with unclear or missing data, or excluded the study entirely. They used risk of bias graph to review authors' judgements about each risk of bias item presented as percentages across all included studies.

Results

Search Strategy

Initial search in PubMed identified 428 abstracts, which was narrowed down to 25 abstracts after applying filters: RCT, free full text, and studies done in the last 10 years. 12 additional records were identified through The Cochrane Library and 16 records were identified by reviewing the references, and other sources. After duplicates were removed, 41 records were screened for thorough full-text review. Furthermore, 11 records did not meet the inclusion criteria, 7 articles were excluded because it has no full data and the authors were not able to contact the authors, 2 articles were not RCT, 5 have different

Table 2. Assessment of methodologic quality.

	Randomization		Follow-up		Blinding
2	Allocation sequence generated	2	No dropouts/<20%	2	Double-blind
1	Described as randomized, method not described	1	Not described	1	Single blind
0	Inadequate generation of sequence	0	Dropout >20%	0	No blinding

Table 3. Basis for validity assessment rating.

Rating	Description
A	All the primary and secondary criteria were met
B	At least one (1) secondary criteria was NOT met
C	At least one (1) primary criteria was NOT met but dropout rate was <20%
D	At least one (1) primary criteria was NOT met but dropout rate was >20%

Table 4. Quality guide.

Parameter	Grade A	Grade B	Grade C	Grade D
Randomized controlled trial				
True concealment of allocation				
Objective outcome assessment				
Intention-to-treat analysis				

outcome measures, and 1 has different control measure. Among 21 studies included in the qualitative analysis, 6 were excluded in final meta-analysis because of the differences in comparator and outcome assessments. Finally, a total of 15 studies were included in the meta-analysis. Figure 1 details the search strategy for PubMed (Medline), Figure 2 from Clinicaltrials.gov, and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is shown in Figure 3.

Description of Studies

All studies were conducted in an OPD setting. A total of 3,015 patients were enrolled, with 1510 patients in the telemedicine group, and 1505 patients in the control group. The mean ages of the patients range 8-11 years old in the children group, and 29-50 years old in the adult group. Treatment durations among the included studies ranged from 3 months to 30 months. A variety of interventions were incorporated

History and Search Details

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Search	Actions	Details	Query	Results	Time
#4	•••	>	Search: **(asthma) AND ((telemedicine) OR (telehealthcare) OR (eHealth) OR (eCare))** Filters: **Free full text, Randomized Controlled Trial, in the last 10 years**	25	04:16:17
#3	•••	>	Search: **(asthma) AND ((telemedicine) OR (telehealthcare) OR (eHealth) OR (eCare))** Filters: **Free full text, Randomized Controlled Trial**	28	04:16:12
#2	•••	>	Search: **(asthma) AND ((telemedicine) OR (telehealthcare) OR (eHealth) OR (eCare))** Filters: **Free full text**	228	04:16:06
#1	•••	>	Search: **(asthma) AND ((telemedicine) OR (telehealthcare) OR (eHealth) OR (eCare))**	428	04:15:58

Showing 1 to 4 of 4 entries

Figure 1. Search strategy for Medline.

Terms Synonyms	Search Results*	Entire Database**
telemedicine	3 studies	1,435 studies
Telehealth	2 studies	583 studies
telehealthcare	--	10 studies
e-Health	2 studies	1,043 studies
Telehealth	2 studies	583 studies
e-Care	--	13 studies
Asthma	3 studies	3,829 studies
Asthmatic	--	559 studies

-- No studies found

* Number of studies in the search results containing the term or synonym

** Number of studies in the entire database containing the term or synonym

ClinicalTrials.gov Search Results 10/26/2020

	Title	Status	Study Results	Conditions	Interventions	Locations
1	Internet Telehealth for Pediatric Asthma Case Management	Completed	Has Results	•Asthma	•Behavioral: CHESS Internet telehealth	
2	School-Based Telemedicine Enhanced Asthma Management	Completed	Has Results	•Pediatric Asthma	•Other: School-Based Telemedicine Enhanced Asthma Management •Other: Enhanced Usual Care	•University of Rochester, Rochester, New York, United States
3	Improving Asthma Care by Partnering With School Nurses to Bring Asthma Care Into the Inner-City Schools	Completed	Has Results	•Asthma	•Device: Sensor cap system for inhalers •Other: App for SmartPhone •Behavioral: Motivational interviews •Other: Telehealth clinic visits	•Cincinnati Children's Hospital Medical Center, Cincinnati, Ohio, United States

U.S. National Library of Medicine | U.S. National Institutes of Health | U.S. Department of Health & Human Services

Figure 2. Search strategy in Clinicaltrials.gov

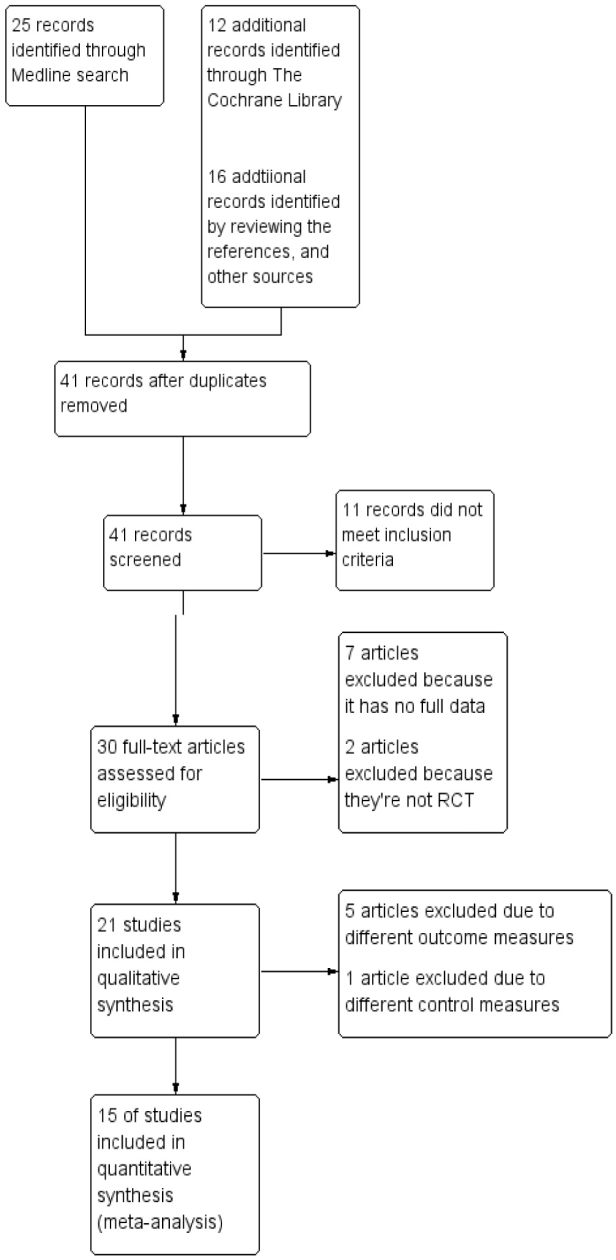

Figure 2. Search strategy in Clinicaltrials.gov

in telemedicine activities. Most control used was the conventional care done face-to-face. A description of studies we included is given in Table 5.

Critical Appraisal of Included Articles

Out of the 15 studies that were retrieved, 2 studies were rated A, 8 were rated B, none were rated C, and 5 were rated D. Those rated D were still included in the final analysis considering that blinding is not applicable in most of the studies due to the nature of the intervention, itself. The critical appraisal of each study can be seen in Table 6.

Risk of Bias in The Included Studies

All of the studies have low risk of selection bias, reporting bias and attrition bias. However, most studies have high risk of performance and detection biases due to non-blinding between the participants, personnel and outcome assessment. A summary of the risk of bias in the included studies can be seen in Figures 4 and 5.

The Effectiveness of Telemedicine

Asthma Control

The impact of telemedicine interventions on asthma control was assessed in 9 trials. ACQ was the most common asthma symptom score tool used among studies, hence only trials with this score tool was included. Of the 9 trials, 3 were telephone-based, while the remaining 6 were internet-based self-management. The remaining studies (Ahmed 2016, Van den Wijngaart 2017, Prabhakaran 2019) used Asthma Control Test questionnaire and were not included in the analysis.

Figure 6 shows the forest plots comparing the effect of telemedicine and usual care on the level of asthma control. Six studies showed benefit with telemedicine while 3 studies either did not show benefit or no difference at all. Pooled estimate showed a mean difference of -0.08, with a confidence interval ($p = 0.10$, 95% CI [-0.17, 0.02]), favoring telemedicine (Figure 6.a.). However, the Chi-square test showed significant heterogeneity ($Chi^2 = 23.73$, $I^2 = 66\%$, $p=0.003$) and so random effects model was then generated (Figure 6.b.). After accounting for heterogeneity, results still showed that telemedicine has a small benefit in asthma control but not statistically significant ($p = 0.39$)

Subgroup Analysis (Telephone-Based Telemedicine)

Due to significant heterogeneity, a subgroup analysis was done to compare only telephone-based telemedicine vs usual care as shown in Figure 6.c. Two studies showed benefit with telephone-based while study by Ryan 2012 did not show benefit. Pooled estimate showed a mean difference of -0.07, ($p = 0.10$, 95% CI [-0.179, 0.05]), favoring telemedicine however, still not statistically significant. The Chi-square test using fix effect model showed that included studies were homogenous in terms of outcome measure ($Chi^2 = 3.33$, $I^2 = 40\%$, $p=0.19$).

Asthma Quality of Life

Eight studies that investigated the impact of telemedicine on asthma related quality of life were included in the analysis. The AQLQ was the most frequent measurement tool used among studies. Of the 8 trials, 3 were telephone-based, while the remaining 5 were internet-based self-management. The remaining studies (Ahmed 2016 and Van den Wijngaart 2017) used mini-AQLQ and pediatric AQLQ respectively, hence were not included in the analysis for heterogeneity.

Figure 7 shows the forest plot comparing the effect of telemedicine and usual care on patient's quality of life. Only one study (Pinnock 2007)

Table 5. Characteristics of the included studies.

First Author	Year of Publication	Country	N (Exp vs Control)	Mean Age	Intervention	Comparison	Main Outcomes	Duration
Pinnock	2003	UK	278 (137 vs 141)	N/A	Telephone	Face-to-face consultation	Cost-Effectiveness	3 months
Gruffydd-Jones	2005	UK	194 (97 vs 97)	50 y/o	Telephone	Face-to-face consultation	Asthma control; quality of life; cost-effectiveness; Exacerbations	12 months
Pinnock	2007	UK	536 (270 vs 266)	N/A	Telephone	Face-to-face consultation	Asthma control; quality of life; cost-effectiveness	12 months
Meer	2009	Netherlands	200 (101 vs 99)	37 y/o	Internet-based self management	Face-to-face usual care	Asthma control; Asthma related quality of life; Lung function	12 months
Liu	2010	Taiwan	120 (60 vs 60)	50 y/o	Mobile telephone-based interactive self-care system	Written asthma diary and action plan	Lung function	6 months
Hashimoto	2010	Netherlands	95 (51 vs 38)	48 y/o	Internet-based management	Conventional asthma management	Asthma control; Quality of life; Exacerbation	6 months
Gustafson	2012	US	301 (148 vs 153)	8 y/o	Comprehensive Health Enhancement Support System (CHESS) + Phone Case Management (CM)	Face-to-face consultation	Asthma control	12 months
Araujo	2012	Europe	21 (12 vs 9)	29 y/o	Internet-based monitoring	Paper-based monitoring	Asthma control; Quality of Life; Lung function	12 months
Ryan	2012	UK	288 (145 vs 143)	48 y/o	Mobile phone-based monitoring	Paper-based monitoring	Asthma control; Qualify of life; Cost-effectiveness; Exacerbations	6 months
Lv	2012	China	100 (50 vs 50)	36 y/o	SMS reminder	Face-to-face usual care	Asthma related quality of life; Lung function	3 months
Van Gaalen	2013	Netherlands	107 (47 vs 60)	36 y/o	Internet-based self-management	Face-to-face consultation	Asthma Control; Quality of Life; Lung function	30 months
Ahmed	2016	Canada	100 (49 vs 51)	50 y/o	Web-based self-management	Face-to-face usual care	Asthma Control; Quality of Life; Exacerbation	6 months
Morrison	2016	UK	51 (26 vs 25)	45 y/o	'Living Well with Asthma' website	Face-to-face usual care	Asthma Control; Quality of Life; Lung Function; Exacerbation	3 months
Van den Wijngaart	2017	Netherlands	210 (105 vs 105)	11 y/o	Virtual Asthma Clinic	Face-to-face usual care	Asthma Control; Cost-effectiveness; Lung function; Exacerbation:	16 months
Prabhakaran	2019	Singapore	414 (212 vs 212)	37 y/o	eCare	Face-to-face routine care	Asthma control	3 months

Table 6. Critical appraisal of articles for inclusion in the study.

	Author (Year)	Randomization	Ff up	ITT	Blinding	Similar Baseline char	Groups treated equally	Rating
1.	Pinnock (2003)	1	2	Yes	1	Yes	No	B
2.	Gruffydd-Jones (2005)	2	0	No	0	Yes	No	D
3.	Pinnock (2007)	2	0	No	0	Yes	Yes	D
4.	Meer (2009)	2	2	Yes	0	Yes	Yes	A
5.	Liu (2010)	2	0	No	0	Yes	Yes	D
6.	Hashimoto (2010)	2	2	Yes	0	Yes	Yes	B
7.	Gustafson (2012)	2	2	Yes	0	Yes	Yes	B
8.	Araujo (2012)	2	2	Yes	0	Yes	Yes	B
9.	Ryan (2012)	2	2	Yes	1	Yes	Yes	A
10.	Lv (2012)	2	0	No	0	Yes	Yes	D
11.	Van Gaalen (2013)	2	2	Yes	0	Yes	Yes	B
12.	Ahmed (2016)	2	2	Yes	0	Yes	Yes	B
13.	Morrison (2016)	2	2	Yes	0	Yes	Yes	B
14.	Van den Wijngaart (2017)	2	2	Yes	0	Yes	Yes	B
15.	Prabhakaran (2019)	2	0	Yes	0	No	Yes	D

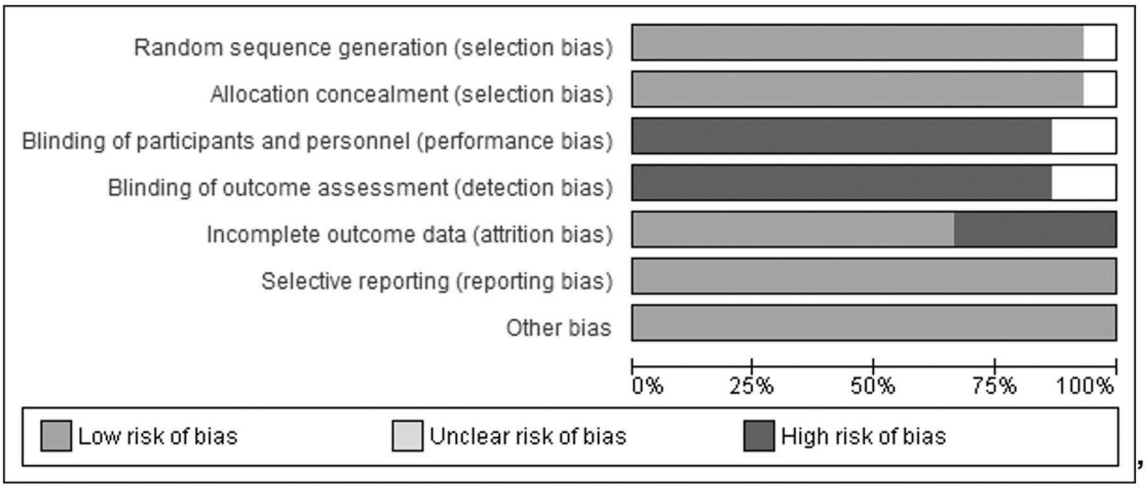

Figure 4. Risk of bias graph: review authors' judgements about each risk of bias item presented as percentages across all included studies.

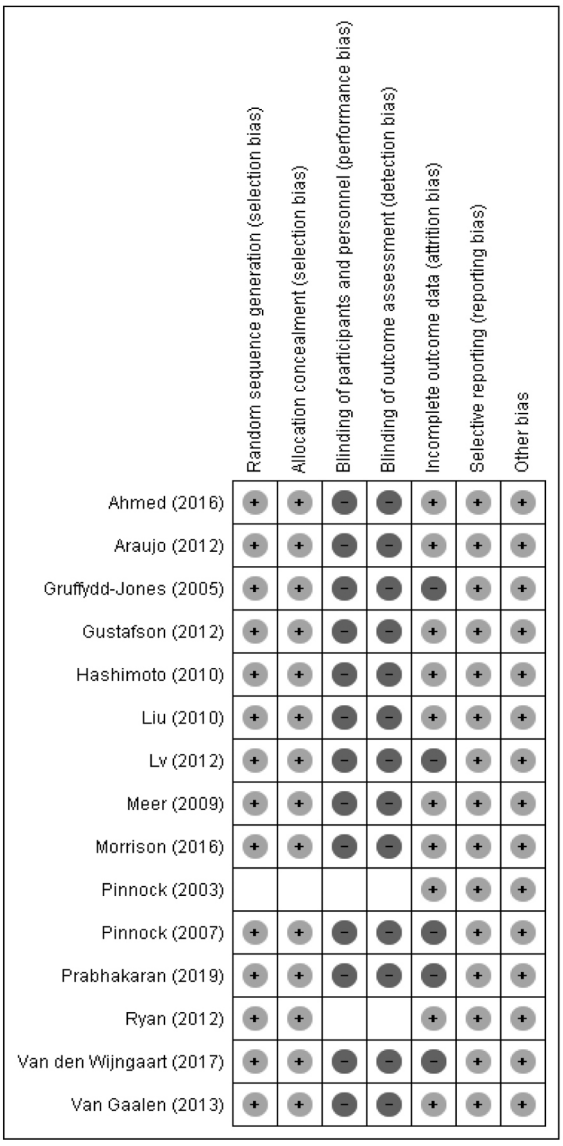

Figure 5. Risk of bias summary: review authors' judgements about each risk of bias item for each included study.

favored usual care, while remaining 7 studies favored telemedicine. Pooling the data from the 8 studies showed a statistically significant mean difference of 0.17, (95% CI [0.05, 0.29], p = 0.006), in favor of telemedicine. The Chi-square test using fix effect model showed that the included studies were homogenous ($Chi^2 = 9.92$, $I^2 = 29\%$, p=0.19).

Cost-Effectiveness

Figure 8 shows the forest plots comparing the effect of telemedicine and control on the total healthcare cost spent from 3 up to 16 months in European dollars. Only 4 studies assessed the cost-effectiveness of telemedicine. Two studies accumulated higher cost with telemedicine while the other two studies accumulated higher cost with usual care. Pooled estimate showed higher cost with telemedicine by £2.67, (p = 0.00001, 95% CI [-3.60, -1.74]) (Figure 8.a.). However, the Chi-square test showed significant heterogeneity ($Chi^2 = 13.63$, $I^2 = 78\%$, p=0.003) and so random effects model was generated (Figure 8.b.). After accounting for heterogeneity, results now showed that the usual care accumulated higher cost by £6.25, (CI [-17.47, 29.96]), therefore showing more savings with telemedicine but not statistically significant (p = 0.61). Subgroup analysis cannot be performed due to limited studies and sample size.

Lung Function

Six studies reported data on the effect of telemedicine and usual care on patient's pulmonary function in terms of FEV1% predicted as shown in Figure 9. In the control group, an increase in FEV1% predicted was seen in three studies. However, in the telemedicine group, an increase in FEV1% predicted was also seen in the other three studies. Pooled estimate using the fixed effect model showed a significant increase of FEV1% predicted by 8.05% in the telemedicine group, (p < 0.00001, 95% CI [7.05, 9.05]) (Figure 9.a.). However, the Chi-square test showed significant heterogeneity among the studies ($Chi^2 = 31.48$, $I^2 = 84\%$, p<0.00001) and so random effects model was then generated (Figure 9.b.). After accounting for heterogeneity, results still showed that the telemedicine group achieved increase in FEV1% predicted by 4.88%, (CI [-0.34, 10.10]), but over-all not statistically

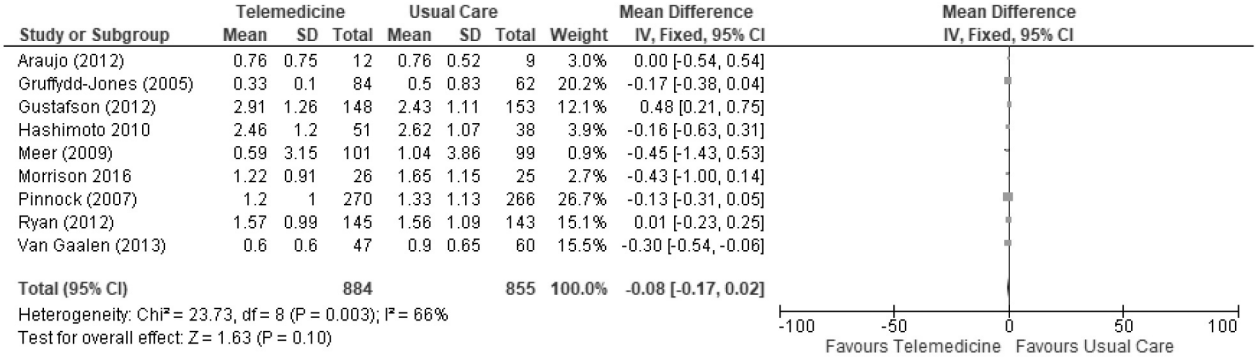

Figure 6.a. Forest plot using fixed effects model comparing the effect of telemedicine and usual care on asthma control.

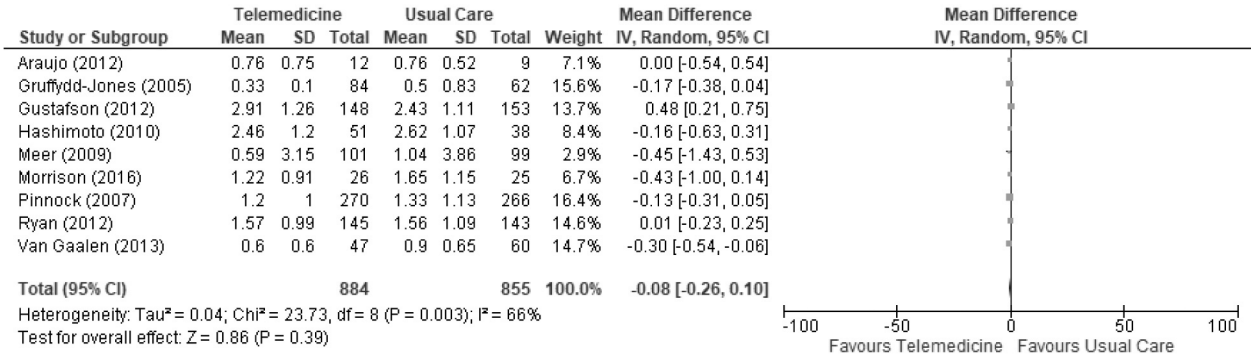

Figure 6.b. Forest plot using random effects model comparing the effect of telemedicine and usual care on asthma control.

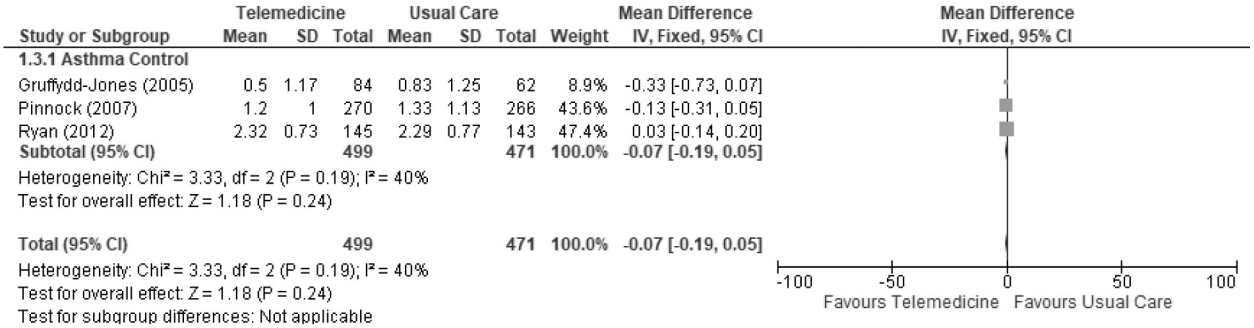

Figure 6.c. Forest plot using fixed effects model comparing the effect of telephone-based telemedicine and usual care on asthma control.

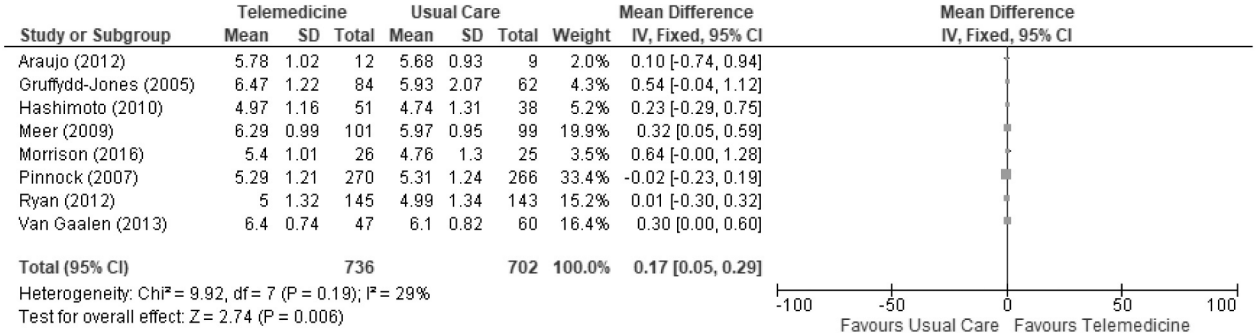

Figure 7: Asthma Quality of Life. Forest plot using fixed effects model comparing the effect of telemedicine and usual care on the quality of life among asthmatic patients.

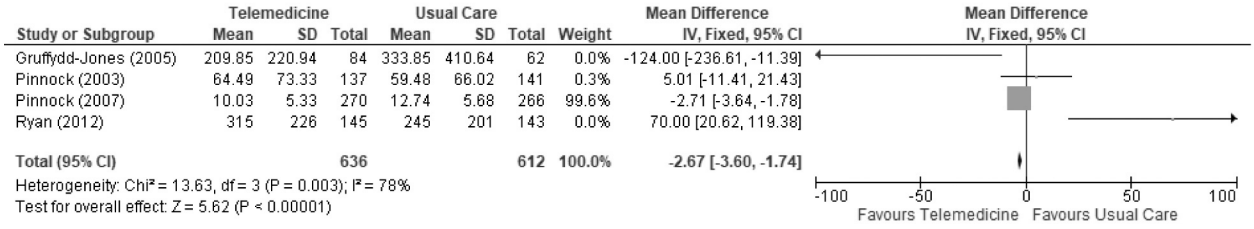

Figure 8a. Forest plot using fixed effects model comparing the total healthcare cost spent on telemedicine and usual care of asthmatic patients.

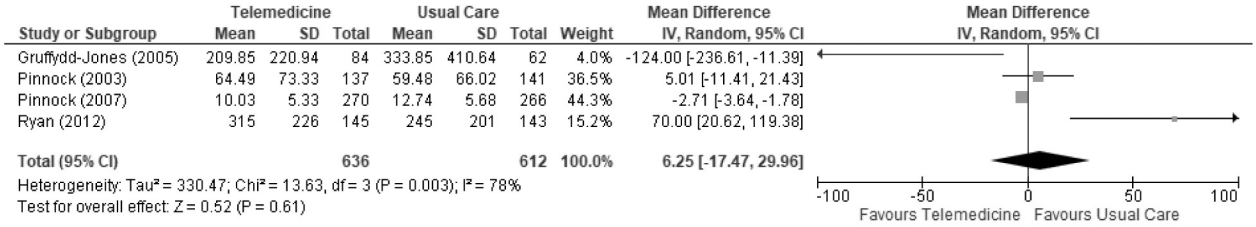

Figure 8b. Forest plot using random effects model comparing the total healthcare cost spent on telemedicine and usual care of asthmatic patients.

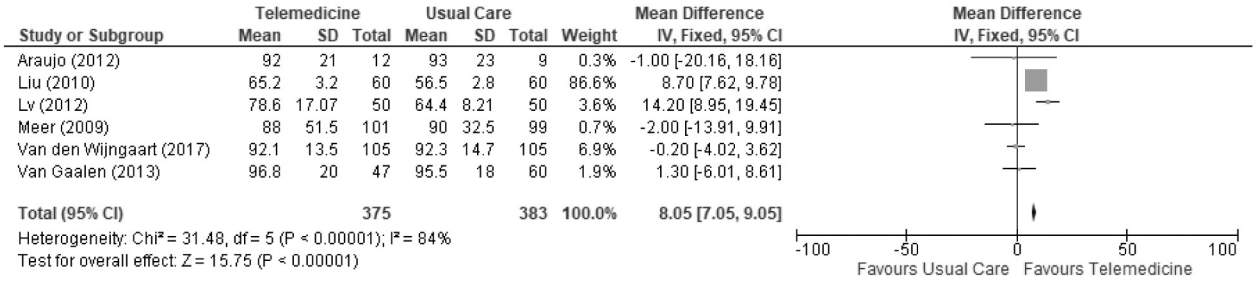

Figure 9. Lung Function (FEV1% Predicted).

Figure 9.a. Forest plot using fixed effects model comparing the effects of telemedicine and usual care on the pulmonary function (FEV1% predicted) of asthmatic patients.

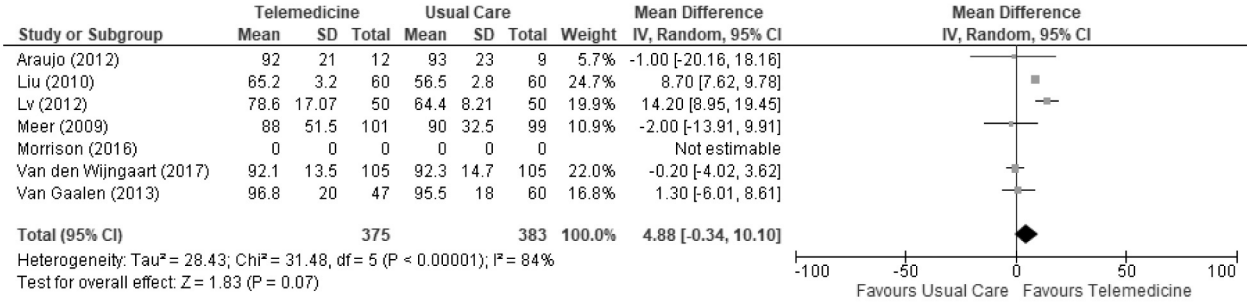

Figure 9.b. Forest plot using random effects model comparing the effects of telemedicine and usual care on the pulmonary function (FEV1% predicted) of asthmatic patients.

significant (p = 0.07). Subgroup analysis cannot be performed due to limited studies and sample size.

Exacerbation

Meta-analysis of the 7 studies that reported the number of patients admitted to hospital once or more within 6-12 months of randomization is shown in Figure 10 (summary OR 1.12 [95% CI 0.38 to 3.32]; p = 0.84). This included data from 1004 patients and suggests that the usual care reduced the risk of admission to hospital however still not statistically significant.

The effect of telemedicine on the number of patients with one or more visits to the emergency department over 12 months is shown in Figure 11. This meta-analysis included six trials representing 958 patients. It revealed a nonsignificant decrease in odd risk of less than one visit to the emergency department with telemedicine (OR 0.69 [95% CI 0.31 to 1.56]).

Discussion

Asthma Control

The positive effect on asthma control was consistent with the results of the meta-analysis of 12 RCTs reviewed by Chi Yan Hui, et al. (2016) where they assessed the use of mobile applications to support self-management for people with asthma in terms of clinical effectiveness and adherence.[12] The multiple features of telemedicine could explain its positive effect on asthma control. Similar findings were

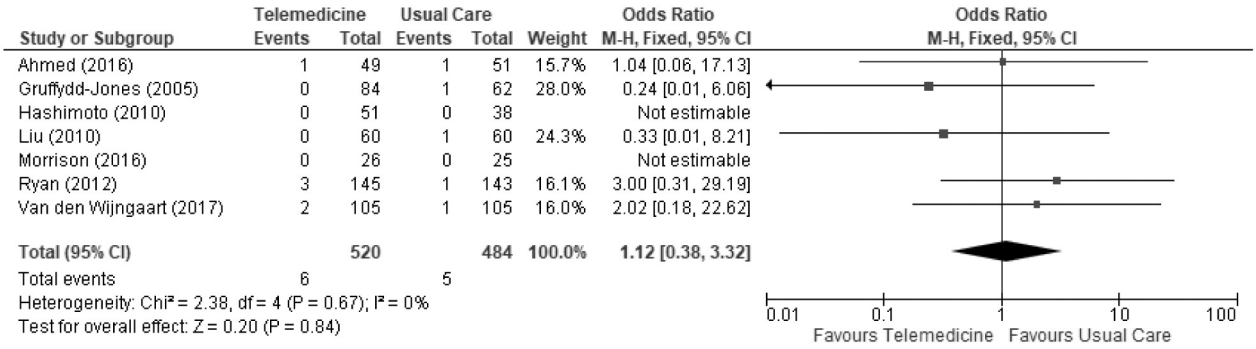

Figure 10. Exacerbation (Hospital Admission). Forest plot using fixed effects model of the odd ratios (ORs) and 95% CIs for the numbers of patients admitted to hospital.

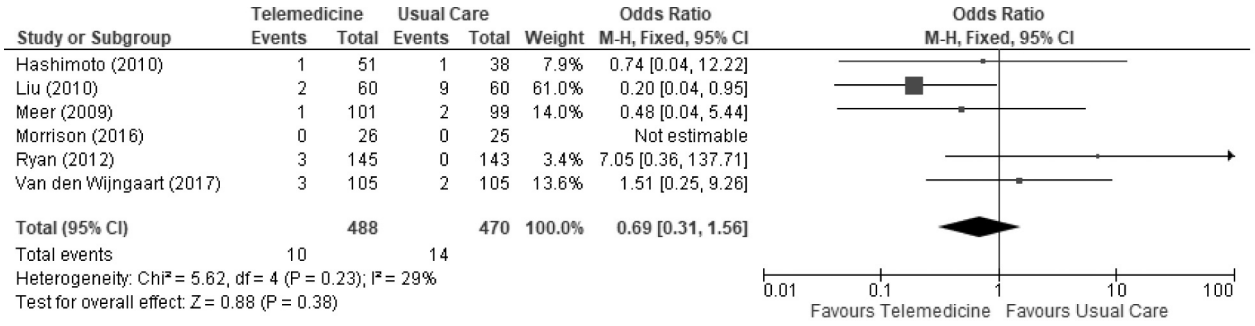

Figure 11. Exacerbation (Emergency Room Visits). Forest plot using fixed effect model of the odds ratios (ORs) and 95% CIs of the numbers of patients who visited the emergency department once or more over 12 months.

demonstrated by the meta-analysis done by Bunchai, et al. (July 2018) wherein combined-telemedicine involving tele-case management was found to improve asthma control compared with usual care.[13] In the studies of Gruffyd-Jones, et al. and Meer, et al. the improvement in asthma control were seen when telemedicine is extended at least over a 12-month period. However, significant heterogeneity among the included studies was observed due to differences in baseline characteristics, patient selection, length of study, and the difference in telemedicine intervention. The subgroup analysis done still showed positive effect of telephone based. Ryan (2012) predicated on a theory that using a mobile phone to monitor and receive instantaneous feedback on asthma control would help patients to integrate management into everyday life, engage them more fully in their care, and thus potentially improve asthma control. The authors also agree with Morrison, et al. that this technology may be effective in improving patient's education, self-management and optimizes medication use therefore overall improving asthma control.

Asthma-Related Quality of Life

Based on current findings, telemedicine significantly improved the quality of life of asthmatic patients. The authors believed this is because telemedicine incorporated several medical supportive managements such as collaborative patient's self-management, monitoring patients' health status, interactive communication, an action plan provision and convenience which telemedicine brings to significantly improve the over-all health experience of asthmatic patients in their day-to day living. Current findings are well aligned with the results from the previous meta-analyses done by Hui, et al. (2016) and Bunchai, et al. (2018), which both demonstrated the benefits of telemedicine for the improvement of patient's quality of life. In contrast, the meta-analysis by McClean, et al. (2011) failed to show an appreciable impact of tele-healthcare on disease-specific quality of life.

Cost-effectiveness

This meta-analysis demonstrated that telemedicine is more cost-effective than the usual clinic care by giving patients an average savings of £6.25 on the overall cost of healthcare but the difference between two groups was not significant. According to Gruffydd-Jones (2005), the savings can be attributed to reduced direct costs (transportation, loss of earnings) and societal indirect cost (time off work). But other cost like medication and consultation fees remains the same. In the individual study of Ryan (2012), healthcare costs were similar in both

groups, with the telemedicine expenses being an additional cost in the mobile group. Although the currency used among the studies were the same, the significant heterogeneity can be explained by the inflation through the years as the studies were done in different years from 2003 to 2017 and between different countries. Furthermore, the duration of the studies and the number of follow-ups differ thus affecting the total overall healthcare cost.

Lung Function

Current results suggest that telemedicine improves the lung function compared with usual care however not statistically significant. The level of asthma control and quality of life also correlates with the improvement of FEV1% predicted. In the study of Meer (2009), the improvement of lung function was observed when the use of inhaled corticosteroid was continued over 9 months. Evidence had shown that good control of asthma is based on the adherence to treatment guidelines (GINA) for daily management. Hence, adequate controller medication is essential for lung function improvement and asthma control.

Exacerbation

The telemedicine group tended to have fewer emergency room visits compared to the usual care. This was due to either increased asthma control in the telemedicine group and therefore fewer requirements for medical review. In addition, physician visits may have been substituted by online contacts reducing urgent care visits. This study further suggests that both improvement in asthma control and quality of life are associated with fewer subsequent asthma-related emergency department utilization, exacerbations and unscheduled visits. However, in this meta-analysis, usual face to face care is still beneficial in reducing the risk of admission to hospitals.

Limitations

Although this meta-analysis provides evidence-based review on the generalizability of the different information and communication technologies used in telemedicine versus usual face-to face medical care and their association with asthma health-related outcomes, there are several limitations. The primary limitation is the inclusion of trials with various telemedicine interventions which come in multiple features (i.e. telephone, internet-based, websites, applications, etc.), hence we could not provide evidence on the individual applicability and effectiveness of each feature, nor give recommendation on which intervention is better among the others. Second, although a general cost-effectiveness analysis was done in this study, analysis of each type of telemedicine strategy was not evaluated to recommend which is the most cost-effective one. Ethical, legal, economic, and sociocultural aspects need to be considered before implementing them. Third, the patients included in the trials have different level of asthma severity. Most studies enrolled only mild to moderately controlled asthma, while one study included severely uncontrolled asthma. This would affect the rate of asthma exacerbations needing ER visits and hospital admissions. The follow-up period of some studies was also too short to document admissions.

Conclusion

Telemedicine is increasing in importance in the healthcare system when the usual medical care is not feasible especially during pandemics such COVID-19. It changes the current pattern of patient care by improving access to health care services as well as patients' health outcome, resulting in reduced health care costs.[14] Telemedicine helps provide patients and their families with clinical education and medical supportive management, such as monitoring health status and interactive communication and it has the potential to support guided self-management. Although nothing beats the advantage of physically seeing patients face-to-face, this study just supports the knowledge that these innovative techniques are promising alternative interventions to promote good communication between patients and caregivers, resulting in adherence to asthma management, which leads to better asthma control, improvement of patients' quality of life and lung function, better cost-effectiveness and decrease in ER visits with decrease in exacerbation.

Since the authors did not look into the level of patient and physician satisfaction of these telemedicine interventions due to lack of studies, this can therefore be a future topic of interest by other researchers. Local research by Filipinos on knowledge, attitude and practices on telemedicine is also encouraged for baseline data as well as random controlled trials of telemedicine on asthma management to include cost-effectiveness in our local currency, Philippine peso.

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