

The Effects of Telemedicine on Asthma Control and Patients' Quality of Life in Adults: A Systematic Review and Meta-analysis



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What is already known about this topic? Telemedicine is increasingly used to improve health outcomes in asthma. However, it is still inconclusive which telemedicine works effectively.

What does this article add to our knowledge? This study gathers all relevant evidence and quantified pooled estimates to evaluate the effects of telemedicine in adults with asthma. Combined-telemedicine involving tele-case management or tele-consultation appear to be effective telemedicine interventions to improve asthma control and quality of life in adults.

How does this study impact current management guidelines? This study supports health care professionals for the use of combined-telemedicine involving tele-case management or tele-consultation for asthma control and the improvement of patients' quality.

BACKGROUND: Telemedicine is increasingly used to improve health outcomes in asthma. However, it is still inconclusive which telemedicine works effectively.

OBJECTIVE: This study aimed to determine the effects of telemedicine on asthma control and the quality of life in adults.

METHODS: An electronic search was performed from the inception to March 2018 on the following databases: Cochrane CENTRAL, CINAHL, ClinicalTrials.gov, EMBASE, PubMed, and Scopus. Randomized controlled trials that assessed the

effects of telemedicine in adults with asthma were included in this analysis, and the outcomes of interest were levels of asthma control and quality of life. Random-effects model meta-analyses were performed.

RESULTS: A total of 22 studies (10,281 participants) were included. Each of 11 studies investigated the effects of single-telemedicine and combined-telemedicine (combinations of telemedicine approaches), and the meta-analyses showed that combined tele-case management could significantly improve asthma control compared with usual care (standardized mean difference [SMD] = 0.78; 95% confidence interval [CI]: 0.56, 1.01). Combined tele-case management and tele-consultation (SMD = 0.52 [95% CI: 0.13, 0.91]) and combined tele-consultation (SMD = 0.28 [95% CI: 0.13, 0.44]) also significantly improved asthma outcomes, but to a lesser degree. In addition, combined tele-case management (SMD = 0.59 [95% CI: 0.31, 0.88]) was the most effective telemedicine for improving quality of life, followed by combined tele-case management and tele-consultation (SMD = 0.31 [95% CI: 0.03, 0.59]), tele-case management (SMD = 0.30 [95% CI: 0.05, 0.55]), and combined tele-consultation (SMD = 0.27 [95% CI: 0.11, 0.43]), respectively.

CONCLUSIONS: Combined-telemedicine involving tele-case management or tele-consultation appear to be effective telemedicine interventions to improve asthma control and quality of life in adults. Our findings are expected to provide health care professionals with current evidence of the effects of telemedicine on asthma control and patients' quality of life. © 2019 American Academy of Allergy, Asthma & Immunology (J Allergy Clin Immunol Pract 2019;7:199-216)

Key words: Telemedicine; Asthma control; Quality of life; Systematic review; Meta-analysis

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Abbreviations used

CI- Confidence interval

DM- Diabetes mellitus

HbA1c- Hemoglobin A1c

RCT- Randomized controlled trial

SMD- Standardized mean differences

Asthma is one of the most common chronic respiratory diseases, affecting approximately 300 million people worldwide.^{1,2} Its symptoms include coughing, wheezing, shortness of breath, chest tightness, and expiratory airflow limitation.² Asthma prevalence has been increasing over the last few decades, and is reported to be higher in developed countries than that in developing countries.³ The highest prevalence was reported in Australia (21%), followed by Sweden (20.2%), the United Kingdom (18.2%), and the Netherlands (15.3%), respectively.³ This prevalence is increasing in developing countries, narrowing the gap between developed and developing countries.^{1,3}

Telemedicine is the use of information and communication technology to improve patients' health outcomes by increasing access to medical information and treatment. The World Health Organization⁴ defines telemedicine as "The delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities." Telemedicine allows health care professionals to provide medical services to their patients who live in remote areas using advanced telecommunication and is also used to improve patients' health outcomes in various diseases including asthma.⁵⁻⁹

Previous systematic reviews and meta-analyses determined the effects of telemedicine for asthma. One systematic review and meta-analysis,¹⁰ including 21 randomized controlled trials (RCTs), indicated that telemedicine can significantly improve patients' quality of life and reduce the number of hospitalizations over a 12-month period. However, there was a nonsignificant difference in the number of emergency department visits by patients. Another systematic review and meta-analysis,¹¹ which included 11 RCTs, showed that telemedicine did not significantly improve asthma control compared with usual care. The most updated systematic review and meta-analysis,¹² which included 5 RCTs, revealed that telemedicine involving the use of interactive digital interventions was an effective tool used for asthma control and patients' quality of life improvement. The aforementioned studies did not provide important information regarding which types of telemedicine intervention were useful to improve asthma control and patients' quality of life according to the activities involved. This study aims to determine the effects of each type of telemedicine intervention on asthma control and patients' quality of life. Our findings are expected to provide health care professionals with current evidence of telemedicine effects for asthma control and patients' quality of life.

METHODS**Search strategy**

The search was performed from the inception to March 2018 using the following databases: CENTRAL, CINAHL, [ClinicalTrials.gov](http://www.clinicaltrials.gov), EMBASE, PubMed, and Scopus. Search terms included

(asthma AND [tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application]). The search filter of RCT was applied to all aforementioned databases. All the search terms used are listed in [Table E1](#) in this article's Online Repository at www.jaci-inpractice.org. The bibliographies of retrieved articles were also examined to identify relevant studies not indexed in the databases.

Study selection

All RCTs that investigated the effects of any type of telemedicine on asthma control and patients' quality of life in adults were included. Initially, titles and abstracts of all included articles were reviewed to identify potential studies. Subsequently, full texts of relevant studies were assessed by independent investigators (BC and PD), and all disagreements between the investigators were resolved by a third reviewer (TD).

Data extraction

Data extraction was undertaken by BC and PD using a standardized data collection form. The extracted data included author, year, country of study, number and age of participants, intervention characteristics, and outcome measurement. Outcomes of interest were asthma control and patients' quality of life. The categorization for all the telemedicine was based on the proposed activities that they supported, and that involved case management, consultation, education, monitoring, and reminding. These were derived based on Bashshur et al¹³ and the American Telemedicine Association,¹⁴ being classified into 5 categories: (1) tele-case management, (2) tele-consultation, (3) tele-education, (4) tele-monitoring, and (5) tele-reminder ([Table E2](#), available in this article's Online Repository at www.jaci-inpractice.org). In addition, we classified studies that used a combination of more than one type of telemedicine into 3 categories: (1) combined tele-case management, (2) combined tele-consultation, and (3) combined tele-case management and tele-consultation. Interventions that met the definitions of tele-case management and other telemedicine but not tele-consultation were classified as combined tele-case management. Interventions that met the definitions of tele-consultation and other telemedicine but not tele-case management were classified as combined tele-consultation. However, if interventions met the definitions of both tele-case management and tele-consultation along with other telemedicine, they were classified as combined tele-case management and tele-consultation. In summary, combined tele-case management referred to the use of any type of telemedicine in addition to tele-case management. Similarly, combined tele-consultation is the use of any type of telemedicine in addition to tele-consultation. For the combined tele-case management and tele-consultation, this referred to the use of any type of telemedicine in addition to tele-case management and tele-consultation. Characteristics of telemedicine and telemedicine types are described in [Table E3](#) in this article's Online Repository at www.jaci-inpractice.org.

Quality assessment

All the included studies were assessed for methodological quality by BC and PD using the Cochrane risk of bias tool version 2.0 for RCTs,¹⁵ which considered the following criteria: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported results. Furthermore, the Grades of Recommendation, Assessment,

Development and Evaluation (GRADE) criteria were also used to assess the quality of evidence for each outcome on the following domains: risk of bias, inconsistency, imprecision, indirectness, and publication bias.¹⁶ All disagreements between the investigators were solved by a consensus.

Data analyses

A pairwise meta-analysis was performed to estimate the effects of each telemedicine. Standardized mean difference (SMD) along with 95% confidence interval (CI) was used to calculate such effects for the studies that measured outcomes on different scales, whereas mean difference with 95% CI was used for the studies that were on the same scale. Heterogeneity among studies was assessed using the χ^2 and I^2 statistical test.¹⁷ Once a statistical heterogeneity was observed, potential sources of heterogeneity were explored accordingly. Publication bias was assessed by using funnel plots and statistical tests including Begg's¹⁸ and Egger's tests.¹⁹ All the analyses were performed using STATA version 15.0 (Stata Corp., College Station, Tex).

RESULTS

Initial search yielded 5426 articles, and 2661 duplicates were removed. The remaining articles were screened through the titles and abstracts, of which 2717 were removed because of the irrelevance to telemedicine and asthma. This resulted in 48 articles being full text reviewed for the eligibility. Of those, 26 articles were excluded for the following reasons: conducted in children or adolescents ($n = 5$), lacked the outcome of interest ($n = 8$), as well as review article, study protocols and letter to the editor ($n = 13$). Finally, a total of 22 studies were included in this systematic review for qualitative synthesis, and that of 16 studies for quantitative synthesis. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is shown in Figure 1.

Study characteristics

Nineteen studies (86%) were conducted in developed countries (United States,²⁰⁻²⁵ United Kingdom,²⁶⁻³⁰ the Netherlands,³¹⁻³³ Australia,³⁴ Canada,³⁵ Denmark,³⁶ Korea,³⁷ and Taiwan³⁸). The remaining 3 studies (14%) were from developing countries (China^{39,40} and Turkey⁴¹). Most studies (77%) were conducted in urban area.^{20-26,32-41} Two studies (9%) were conducted in both urban and rural areas^{28,29} and 1 study (5%) in semirural area.²⁷ Two studies (9%) did not report the study's area.^{30,31} A total of 5293 patients were in the telemedicine group, whereas 4988 patients were in the control group. The mean ages of patients ranged from 21.8 to 58.2 years. Treatment durations among included studies ranged from 2 weeks to 30 months. The most frequent telemedicine was tele-case management,^{23,25,27,34,37,38} followed by combined tele-consultation,^{20,21,24,39,40} combined tele-case management,^{22,32,41} and combined tele-case management and tele-consultation.^{31,33,35} Other telemedicine were tele-education,^{29,30} tele-consultation,²⁸ tele-monitoring,²⁶ and tele-reminder³⁶ (Table I).

Health care professionals involved in the use of telemedicine were varied: physician and nurse (5 studies^{20,27,31,33,35} [23%]), physician (4 studies^{38,40-42} [18%]), nurse (2 studies^{28,32} [10%]), and pharmacist (1 study²⁶ [5%]). Ten studies^{22-25,29,30,34,36,37,39} (44%) did not report their health care professionals involvement. A variety of medical supportive managements were incorporated

in telemedicine activities: interactive communication (20 studies^{20-29,31-35,37-41} [82%]), self-management support (18 studies^{20-25,27,28,31-35,37-41} [82%]), monitoring patients' health status (14 studies^{20,22,23,25-27,31-35,37,38,41} [64%]), an action plan provision (11 studies^{21,24,27,29,32-35,37,38,41} [50%]), education support (11 studies^{20,24,29-33,35,39-41} [50%]), and the reminding strategy (5 studies^{22,24,36,40,42} [23%]). The duration of period between services among individual telemedicine ranged from 1 day to 6 months, whereas the duration of studies ranged from 0.5 to 30 months. Features of telemedicine and their supportive managements are presented in Table II.

The effect of telemedicine

Among 22 studies, 6 were not included in a meta-analysis because of the differences in participant characteristics,^{31,37} telemedicine interventions,²⁶ comparators,²² outcome assessments,³⁸ and comparators and outcome assessments³⁰ (Tables III and IV). In brief, a study by Kim et al³⁷ reported that tele-case management did not improve asthma control and quality of life in fragile asthmatic patients compared with the usual care. Another study by Hashimoto et al³¹ determined the effect of combined tele-case management and tele-consultation for facilitating the tapering of oral corticosteroids in patients with severe asthma. The study concluded that combined tele-case management and tele-consultation did reduce total corticosteroid consumption without compromising asthma control and patients' quality of life after 6 months, but it did not improve asthma control and quality of life ($P > .05$). A study by Barbanel et al²⁶ showed that tele-monitoring in combination with patients' self-management provided by pharmacists significantly improved asthma control when compared with the usual care ($P < .001$), whereas another study by Kolmodin MacDonell et al²² investigated the effect of combined tele-case management on promoting adherence to the controller medication compared with telephone texting-based tele-education. It showed that there was no significant difference between groups at 3 months ($P = .10$). A study by Liu et al³⁸ determined the effect of tele-case management on patients' quality of life. It showed that tele-case management significantly improved quality of life compared with usual care at 6 months ($P < .01$). A study by Newhouse et al³⁰ investigated the effect of tele-education using experience-based information on quality of life in adults compared with tele-education using fact- and figures-based information. It revealed that tele-education with experience-based information did not improve patients' quality of life ($P > .05$) at 2 weeks.

Meta-analysis

Asthma control. Thirteen studies^{20,24,25,27-29,32-34,36,39-41} that investigated the effects of telemedicine on asthma control were included in the analysis. Asthma Control Questionnaire was the most common asthma symptom score tool used among studies.^{27,29,32-34,36,40} The remaining were Asthma Control Test,^{20,24,25,41} short questionnaire,²⁸ and the Perceived Control of Asthma Questionnaire³⁹ (Table III). Results indicated that none of the single-telemedicine interventions provided a significant improvement in asthma control. On the other hand, all combined-telemedicine significantly improved asthma control: combined tele-case management (SMD = 0.78 [95% CI: 0.56, 1.01], $P < .001$, $I^2 = 0\%$, low certainty evidence), combined tele-case management and tele-consultation (SMD = 0.52 [95% CI: 0.13,

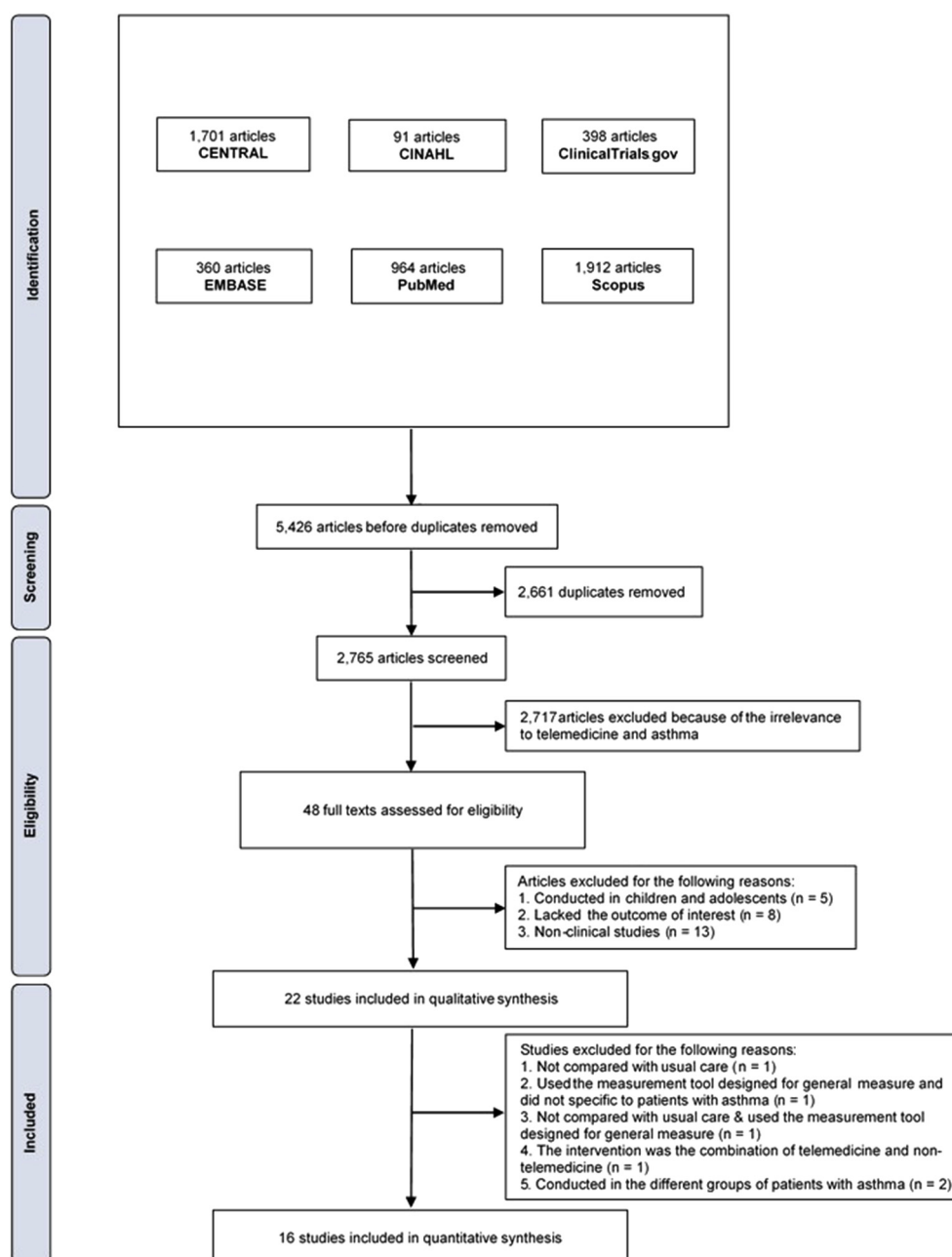


FIGURE 1. A PRISMA flow diagram. This figure shows the process of articles being included in our systematic review and meta-analysis. A total of 5426 articles were identified, 22 studies were included in qualitative analysis but only 16 studies were used in quantitative analysis.

0.91], $P = .009$, moderate certainty evidence), and combined teleconsultation (SMD = 0.28 [95% CI: 0.13, 0.44], $P < .001$, $I^2 = 0\%$, moderate certainty evidence) (Figure 2).

Patients' quality of life. Fourteen studies^{20,21,23,24,27-29,32,34-37,39,40} that investigated the effect of telemedicine on quality of life were included in the analysis. The Mini Asthma Quality of Life Questionnaire was the most frequent measurement tool used among studies.^{21,23,24,27-29,34-36} The other measures were Asthma Quality of Life Questionnaire,^{20,32,40} Standard Asthma-specific Quality of Life Questionnaire,³⁹ and the Quality of Life

Questionnaire for Adult Korean Asthmatics³⁷ (Table IV). Results showed that tele-case management slightly improved patients' quality of life (SMD = 0.30 [95% CI: 0.05, 0.55], $P = .018$, $I^2 = 64.3\%$, low certainty evidence). Other single-telemedicine showed a nonsignificant difference when compared with usual care. In addition, combined tele-case management, combined tele-case management and tele-consultation, and combined tele-consultation were shown to improve quality of life (SMD = 0.59 [95% CI: 0.31, 0.88], $P < .001$, moderate certainty evidence; SMD = 0.31 [95% CI: 0.03, 0.59], $P = .028$, $I^2 = 0\%$, low certainty evidence; and SMD = 0.27 [95% CI: 0.11, 0.43],

TABLE I. Characteristics of the included studies

First author (y)	Country	Setting	Study area	Patient characteristics		Sample size (intervention vs control)	Intervention	Control	Duration (mo)
				Age* (y)	Male (%)				
Barbanel (2003) ²⁶	UK	Community pharmacy	Urban	Intervention 45.0 ± 17.0 Control 47.0 ± 17.0	85	12 vs 12	Tele-monitoring and community pharmacy service	Usual care	3
Pinnock (2003) ²⁸	UK	4 General hospitals	Urban and rural	Intervention 54.6 ± 17.5 Control 56.4 ± 17.5	41	137 vs 141	Tele-consultation	Usual care	3
Gruffydd-Jones (2005) ²⁷	UK	Single general hospital	Semirural	Intervention 50.8 ± 15.4 Control 49.6 ± 16.1	45	90 vs 82	Tele-case management	Usual care	12
Vollmer (2006) ²³	US	Health maintenance organization	Urban	Intervention 51.8 ± 16.1 Control 51.4 ± 16.2	35	3581 vs 3367	Tele-case management	Usual care	10
Clark (2007) ²¹	US	Single university hospital	Urban	Intervention 48.2 ± 13.1 Control 48.7 ± 14.3	0	424 vs 384	Tele-consultation and tele-reminder	Usual care	12
Strandbygaard (2009) ³⁶	Denmark	Single general hospital	Urban	Intervention 34.4 ± NR Control 30.7 ± NR	54	12 vs 14	Tele-reminder	Usual care	3
Van der Meer (2009) ³²	The Netherlands	37 general hospitals and 1 academic outpatient department	Urban	Intervention 36.0 ± 7.8 Control 37.0 ± 8.0	31	101 vs 99	Tele-case management and tele-education	Usual care	12
Bender (2010) ²⁰	US	National Jewish Health Center	Urban	Intervention 39.6 ± 12.8 Control 43.5 ± 14.3	36	25 vs 25	Tele-consultation and tele-education and tele- monitoring	Usual care	2.5
Hashimoto (2011) ³¹	The Netherlands	2 university hospitals and 4 general hospitals	NR	Intervention 48.5 ± 12.4 Control 52.4 ± 11.7	46	51 vs 38	Tele-case management and tele-consultation and tele-education	Usual care	6
Liu (2011) ³⁸	Taiwan	Single university hospital	Urban	Intervention 50.4 ± 12.5 Control 54.0 ± 16.3	49	43 vs 46	Tele-case management	Usual care	6
Lv (2012) ³⁹	China	Single university hospital	Urban	Intervention 36.2 ± 11.1 Control 41.1 ± 12.1	58	30 vs 14	Tele-consultation and tele-education	Usual care	3
Van Gaalen (2013) ³³	The Netherlands	37 general hospitals and 1 academic outpatient department	Urban	Intervention 36.0 ± 8.7 Control 37.0 ± 8.0	31	47 vs 60	Tele-case management and tele-consultation and tele-education	Usual care	30
Cingi (2015) ⁴¹	Turkey	3 university hospitals, 2 training and research hospitals, and ENT hospital	Urban	Intervention 32.0 ± 3.7 Control 34.5 ± 8.2	58	60 vs 29	Tele-case management and tele-education	Usual care	3
Ahmed (2016) ³⁵	Canada	2 general hospitals	Urban	Intervention NR Control NR	34	47 vs 51	Tele-case management and tele-consultation and tele-education	Usual care	6
Kim (2016) ³⁷	Korea	Single university hospital	Urban	Intervention 49.0 ± 13.3 Control 51.0 ± 8.3	27	22 vs 22	Tele-case management	Usual care	2
Kolmodin MacDonell (2016) ²²	US	Single university hospital and its affiliated medical center	Urban	Intervention 21.8 ± 4.0 Control 23.1 ± 3.4	25	25 vs 23	Tele-case management and tele-reminder	Tele-education	3

(continued)

TABLE 1. (Continued)

First author (y)	Country	Setting	Study area	Patient characteristics		Sample size (intervention vs control)	Intervention	Control	Duration (mo)
				Age* (y)	Male (%)				
Morrison (2016) ²⁹	UK	20 general hospitals	Urban and rural	Intervention 44.6 ± 17.0 Control 46.5 ± 14.0	25	25 vs 26	Tele-education	Usual care	3
Newhouse (2016) ³⁰	UK	9 general hospitals	NR	Intervention 58.2 ± 11.7 Control 55.7 ± 13.9	41	73 vs 75	Tele-education	Tele-education	0.5
Zairina (2016) ³⁴	Australia	2 general hospitals	Urban	Intervention 31.1 ± 4.7 Control 31.8 ± 4.3	0	36 vs 36	Tele-case management	Usual care	6
Patel (2017) ²⁴	US	Single university hospital	Urban	Intervention 42.0 ± 14.8 Control 43.4 ± 15.2	0	212 vs 210	Tele-consultation and tele-education and tele-reminder	Usual care	24
Pool (2017) ²⁵	US	A large insurer	Urban	Intervention 47.6 ± 9.1 Control 47.2 ± 9.6	38	203 vs 204	Tele-case management	Usual care	12
Cao (2018) ⁴⁰	China	Single university hospital	Urban	Intervention 39.1 ± 14.3 Control 41.4 ± 12.0	22	37 vs 30	Tele-consultation and tele-education and tele-reminder	Usual care	3

NR, Not reported; UK, United Kingdom; US, United States.

*Values are presented as mean ± standard deviation.

$P = .001$, $I^2 = 38.5\%$, moderate certainty evidence, respectively (Figure 3).

Quality assessment

All studies had a low risk of bias in selection of the reported results. Nineteen studies (82%) had low risk of bias due to missing outcome data.^{20-22,24-27,29-32,34,35,37-41} Most studies indicated some risk of bias due to deviations from intended interventions (21 studies: 95%),^{20-32,34-41} bias in measurement of the outcome (19 studies: 86%),^{20,22-29,31,32,35-41} and bias arising from the randomization process (14 studies: 64%)^{20,22-24,27,31,32,35-41} (Table E4, available in this article's Online Repository at www.jaci-inpractice.org). According to the GRADE criteria to rate the quality of evidence among all telemedicine for asthma control, tele-education, tele-consultation, combined tele-consultation, and combined tele-case management and tele-consultation were judged to have moderate quality of evidence. Tele-reminder, tele-case management, and combined tele-case management were of low quality of evidence. For the improvement of patients' quality of life, tele-education, tele-consultation, combined tele-case management, and combined tele-consultation were deemed as having moderate quality of evidence. Other telemedicine (tele-case management, tele-reminder, and combined tele-case management and tele-consultation) were of low quality (Table E5, available in this article's Online Repository at www.jaci-inpractice.org).

Publication bias

There was no significant publication bias for studies evaluating the change in asthma control assessed by Egger's test ($P = .399$) and Begg's test ($P = .760$), as well as for those studies evaluating the change in quality of life ($P = .668$ for Egger's test and $P = .743$ for Begg's test). The funnel plots of studies that evaluated the changes in asthma control and quality of life are presented in Figures E1 and E2 in this article's Online Repository at www.jaci-inpractice.org.

DISCUSSION

Despite several studies having been conducted to evaluate the use of telemedicine for asthma, the effects estimated by each specific type of telemedicine are still lacking information. This is the first systematic review and meta-analysis of telemedicine that investigated the effects of each telemedicine activity on asthma control and patients' quality of life. Our findings demonstrated the benefits of combined-telemedicine as an additional patient care activity provided by health care professionals. The combined-telemedicine involving tele-case management or tele-consultation was found to improve asthma control and quality of life compared with usual care, whereas single tele-case management was effective in the improvement of patients' quality of life, but showed no benefit for the control of asthma.

Regarding the effects of each telemedicine type in other diseases, a systematic review and meta-analysis⁴³ investigated the effects of telemedicine for the management of glycemic control and clinical outcomes in patients with type 1 diabetes mellitus (DM). This revealed that the use of combined tele-education and tele-consultation was the only effective telemedicine in reducing hemoglobin A1c (HbA1c) in adults with type 1 DM. The effects of single-telemedicine were not significantly different compared with the controls. Another systematic review and network meta-analysis⁶ studied the comparative effectiveness of telemedicine

TABLE II. Features of telemedicine and their supportive managements in the included studies

First author (y)	Type of telemedicine	HCP's involvement/ device	Medical supportive managements						Duration of period between services
			Self-management support	Monitoring patients' health status	Interactive communication	Action plan provision	Education support	Reminding strategy	
Single-telemedicine									
Gruffydd-Jones (2005) ²⁷	TCM	Physician, nurse/ telephone	Patients were provided with an advice on what to do if asthma control deteriorated.	Patients were assessed by the RCP's "3 questions" plus 2 extra questions related to a high risk of asthma death.	Yes	Yes	—	—	6 mo
Vollmer (2006) ²³	TCM	NR/telephone	Patients were offered tailored feedback regarding their asthma control, and their use of medications.	Patients were assessed: (1) recent ED or hospital care for which they had not had a follow-up visit, (2) current level of asthma control, (3) current patterns of medication use, and (4) whether they could identify a primary care provider whom they usually saw for asthma care.	Yes	—	—	—	5 mo
Liu (2011) ³⁸	TCM	Physician/ mobile application	Patients were provided with an advice to adjust their asthma treatments.	Patients were provided with an electronic diary to record asthma symptom, use of medications, and lung function.	Yes	Yes	—	—	1 d
Kim (2016) ³⁷	TCM	NR/mobile application	Patients were provided with individual asthma status about their asthma control, and were advised to record symptoms and lung functions when their asthma worsened.	Patients were instructed to record their asthma symptoms and lung function.	Yes	Yes	—	—	1 d
Zairina (2016) ³⁴	TCM	NR/mobile application	Patients were provided with a feedback regarding their asthma status.	Patients were provided with a specifically designed Breathe-easy application to record asthma symptoms and their use of asthma medications, and a COPD-6 to measure their lung function daily.	Yes	Yes	—	—	1 d
Pool (2017) ²⁵	TCM	NR/computer website	Patients were provided tailored feedback to remind patients to: (1) ask health care providers specific questions that may improve asthma control and (2) consistently perform specific self-care behaviors.	Participants were provided a series of questions about their asthma symptoms, availability of oral corticosteroids at home for exacerbations, and asthma care received from providers. In addition, participants entered the names of all of their current asthma medications, reported the number of days each week that each medication was used, and identified if any medicines bothered them. Finally, participants were asked to update their tobacco use and pregnancy status (if applicable) as well as record their next scheduled visit with their asthma care provider.	Yes	—	—	—	1 mo
Pinnock (2003) ²⁸	TC	Nurses/ telephone	Patients were provided with any follow-up consultations they have.	—	Yes	—	—	—	Anytime

(continued)

TABLE II. (Continued)

First author (y)	Type of telemedicine	HCP's involvement/ device	Medical supportive managements						Duration of period between services
			Self-management support	Monitoring patients' health status	Interactive communication	Action plan provision	Education support	Reminding strategy	
Morrison (2016) ²⁹	TE	NR/computer website	—	—	Yes	Yes	Patients were provided with asthma education regarding their asthma status, and the benefits of taking medications as prescribed.	—	Anytime
Newhouse (2016) ³⁰	TE	NR/computer website	—	—	—	—	Patients were provided with a multimedia website including thematic analyses of key asthma topics. Topics are illustrated with interview extracts in short video, audio, and written formats.	—	Anytime
Barbanel (2003) ²⁶	TM	Pharmacist/telephone	—	Patients were encouraged to report to pharmacist with any problem they might have.	Yes	—	—	—	1 wk
Strandbygaard (2009) ³⁶	TR	NR/mobile SMS	—	—	—	—	—	Patients received the SMS reminder to take their medications.	1 d
Combine-telemedicine									
Van der Meer (2009) ³²	Combined TCM	Nurse/computer website, telephone	Patients were able to contact nurse through the website or by telephone if they had any questions.	Patients were encouraged to complete ACQ, and received feedback on the current state of their asthma control along with an advice on how to adjust their asthma treatments.	Yes	Yes	Patients were provided with asthma education including asthma information, news, frequently asked questions.	—	1 wk
Cingi (2015) ⁴¹	Combined TCM	Physician/mobile application	Patients were able to ask for assistance with the SMS option.	Patients were encouraged to submit their overall health status with an emoticon, share a status update, send and receive messages, track their medicine use with a diary, and were encouraged to complete the ACT.	Yes	Yes	Patients were provided with asthma education.	—	1 d
Kolmodin MacDonell (2016) ²²	Combined TCM	NR/computer website	Patients were provided with (1) feedback regarding medication use and asthma symptoms, (2) feedback on readiness to improve adherence, (3) decisional balance, or pros and cons of taking medications, and (4) a summary regarding the youth's interest in improving adherence, followed by optional goal setting.	Patients were encouraged to submit their medication adherence, asthma control, lung functions, and satisfactions.	Yes	—	—	Patients received the SMS reminder to take their medications.	1 d

Clark (2007) ²¹	Combined TC	Physician/ computer website, telephone	Patients were provided with an advice on any concern they had.	—	Yes	Yes	—	Patients received postcards to remind them of diary keeping and lung function monitoring,	1 mo
Lv (2012) ³⁹	Combined TC	NR/mobile SMS	Patients were provided with an advice on any questions they had.	—	Yes	—	Patients were provided with asthma education including introduction to asthma, classes of asthma medications, proper device use, common types of triggers, strategies for avoiding triggers, how to make an action plan, and how to handle asthma acute attacks.	—	1 d
Bender (2010) ²⁰	Combined TC	Physician, nurse/ telephone	Patients were able to discuss their symptoms with physician, and were informed about a free telephone service staffed by nurses capable of answering most questions.	Patients were assessed by the 3 questions inquiring whether during the previous week the participants had been awakened at night, had limited their activities, or had used their rescue inhaler more than twice because of asthma symptoms.	Yes	—	Patients were provided with asthma education about the benefits of asthma medications.	—	1 mo

(continued)

TABLE II. (Continued)

First author (y)	Type of telemedicine	HCP's involvement/ device	Medical supportive managements						Duration of period between services
			Self-management support	Monitoring patients' health status	Interactive communication	Action plan provision	Education support	Reminding strategy	
Patel (2017) ²⁴	Combined TC	NR/telephone	Participants were introduced to the self-regulatory problem-solving process and were encouraged to examine factors that affect asthma management, including sex and gender roles and cultural influences. The health educator guided the participant in applying the problem-solving process to an identified goal. Each subsequent session focused on sequentially teaching and reinforcing the steps of self-regulatory problem-solving processes: problem identification, self-observation, goal setting, evaluation of progress, and establishing rewards for positive behavioral change. During the fourth and fifth counseling sessions, the health educator worked with the participant to identify any problems in achieving goals and formulating potential solutions together.	—	Yes	Yes	Participants were mailed an asthma education kit including a program workbook, asthma symptom diaries, a peak flow meter with instructions, and asthma resources.	During the observation month, participants received weekly postcards to remind them to complete asthma diaries and a mid-month telephone call from the health educator.	5 mo
Cao (2018) ⁴⁰	Combined TC	Physician/ mobile application	Participants could leave messages, voices, and videos on the smartphone platform and be replied by physicians within 48 h.	—	Yes	—	On the smartphone platform, participants can read educational articles about asthma and watch the online videos about various inhaler devices for self-education.	Participants received messages sent to remind them to perform drug inhalation.	Anytime
Hashimoto (2011) ³¹	Combined TCM and TC	Physician, Nurse/ computer website	Patients were coached and were monitored data entered at website by nurse. They were able to communicate with pulmonologists facilitated by nurse.	Patients were encouraged to record their asthma symptoms, registered their medication doses, lung functions, and exhaled NO before medicine intake, as well as ACQ and AQLQ.	Yes	—	Patients were provided with asthma education	—	1 wk
Van Gaalen (2013) ³³	Combined TCM and TC	Physician, Nurse/ computer website	Patients were able to contact the nurse by E-messaging, telephone, or web-based communication if they had any questions.	Patients were encouraged to record their asthma control, lung functions, and personal action plan, and received feedback on self-monitoring outcomes and a predefined action plan.	Yes	Yes	Patients were provided with asthma education.	—	1 wk

Ahmed (2016) ³⁵	Combined TCM and TC	Physician, Nurse/computer website	Participants communicated and received support as needed from a nurse case manager using my asthma portal (MAP). On receiving this notice, the nurse followed up with the participant within 24 h through the MAP mail system or by telephone. Additional alerts were sent to the nurse case manager when a new participant was enrolled and needed their prescribed action plan reviewed, the participant indicated lack of understanding of the action plan, or there was a change in medication use based on the self-reported adherence monitoring assessment.	Patients were encouraged to provide basic demographic and health information and selected their own initial health goals for action. Initial feedback was generated automatically from the MAP system using monitoring information entered by the participant and data from the provincial administrative database sent to MAP from the Medical Office for the 21st century, an electronic health record with a prescription and computerized drug and disease management system.	Yes	Yes	Patients were provided with general asthma information through links to specific educational websites.	1 wk
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ACQ, Asthma Control Questionnaire; ACT, Asthma Control Test; AQOL, Asthma Quality of Life Questionnaire; COPD, chronic obstructive pulmonary disease; ED, emergency department; HCP, health care provider; NO, nitric oxide; NR, not reported; RCP, Royal College of Physicians; SMS, short message service; TC, teleconsultation; TCM, tele-case management; TE, tele-education; TM, tele-monitoring; TR, tele-reminder.

on type 2 diabetes management. Its findings showed that a telemedicine combination produced an effective trend in reducing HbA1c more than a single-telemedicine. These findings resembled what we found in this systematic review and meta-analysis. Comparing combined- and single-telemedicine, we believe that the higher number of medical supportive managements integrated in combined rather than single types of telemedicine contributed to a greater improvement to patients' health.

Based on our findings, tele-case management was the only effective single-telemedicine for the improvement of patients' quality of life. We believe that this is because most tele-case management incorporated several medical supportive managements, including a collaborative patients' self-management, monitoring patients' health status, interactive communication, and an action plan provision. Combining such medical supportive managements other than single-telemedicine may be the key for tele-case management to be solely effective. Although tele-case management was not effective for asthma control, it demonstrated a trend toward improvement. This may be because the number of patients studied using tele-case management for asthma control was far less than that for the improvement of patients' quality of life (652 vs 7192). We believe that increasing the number of studies using tele-case management would produce positive results for asthma control as well as the improvement of patients' quality of life.

A previous systematic review and meta-analysis by McLean et al¹⁰ showed that telemedicine can significantly improve the quality of life in children and adults with asthma. Even though the scope of our study is confined to only adults with asthma, which is more focused than the previous review, a larger number of studies were included in our review. Our findings are well aligned with the results from the previous systematic reviews and meta-analyses that demonstrated the benefits of telemedicine for the improvement of patients' quality of life. In contrast to our findings regarding the effects of telemedicine for asthma control, a systematic review and meta-analysis by Zhao et al¹¹ revealed a nonsignificant difference in the change of asthma symptoms score between telemedicine and the control groups. In that study, the authors included only 6 studies in their meta-analyses, and 2 of them were not included in ours, because they demonstrated a difference in participant characteristics and telemedicine interventions compared with other studies. Study participants in the Hashimoto et al³¹ study were only patients with severe asthma, whereas other studies were carried out on patients with varying levels of asthma severity. Including the Hashimoto et al study in our meta-analyses would create clinical heterogeneity because of the difference in the baseline participant characteristics. Telemedicine intervention in the Barbanel et al²⁶ study was part of the self-management service provided by pharmacists in a community setting. Including the Barbanel et al study in our meta-analyses may mislead readers regarding telemedicine that will have a synergistic effect, because of the self-management service provided by pharmacists (nontelemedicine).

The findings from the most updated systematic review and meta-analysis by McLean et al¹² revealed that telemedicine involving the use of interactive digital interventions was effective for asthma control and improvement of the quality of life. This study included only 5 RCTs, and 3 of them were included in the meta-analysis. This was because the authors focused on evidence pertaining to the interactive digital interventions that can be

TABLE III. A summary of the study outcomes: asthma control

First author (y)	Comparisons (intervention vs control)	Sample size (intervention vs control)	Duration (mo)	Measurement	Measuring score		
					Intervention group* (baseline vs final visit)	Control group* (baseline vs final visit)	Mean difference* (intervention vs control)
Barbanel [†] (2003) ²⁶	Tele-monitoring and community pharmacy service vs usual care	12 vs 12	3	NEASS	26.3 ± 4.8 vs 20.3 ± 4.2	27.8 ± 3.7 vs 28.1 ± 3.5	−6.0 ± 4.5 vs 0.3 ± 3.6
Pinnock (2003) ²⁸	Tele-consultation vs usual care	137 vs 141	3	Short Q	2.1 ± 2.0 vs 2.1 ± 2.2	1.9 ± 1.8 vs 2.0 ± 2.0	0.0 ± 2.0 vs 0.1 ± 1.9
Gruffydd-Jones (2005) ²⁷	Tele-case management vs usual care	90 vs 82	12	ACQ	0.5 ± 1.2 vs 0.3 ± 0.1	0.8 ± 1.3 vs 0.5 ± 0.8	−0.2 ± 0.8 vs −0.3 ± 0.8
Strandbygaard (2009) ³⁶	Tele-reminder vs usual care	12 vs 14	3	ACQ	NR	NR	−0.9 ± 1.1 vs −0.6 ± 0.8
Van der Meer (2009) ³²	Combined tele-case management vs usual care	101 vs 99	12	ACQ	NR	NR	−0.5 ± 0.6 vs −0.1 ± 0.6
Bender (2010) ²⁰	Combined tele-consultation vs usual care	25 vs 25	2.5	ACT	NR	NR	−1.1 ± 3.9 vs −1.8 ± 4.1
Hashimoto [†] (2011) ³¹	Combined tele-case management and tele-consultation vs usual care	51 vs 38	6	ACQ	NR	NR	0.3 ± 0.6 vs 0.1 ± 0.7
Lv (2012) ³⁹	Combined tele-consultation vs usual care	50 vs 50	3	PCAQ	NR	NR	7.1 ± 4.4 vs 4.8 ± 5.8
Van Gaalen (2013) ³³	Combined tele-case management and tele-consultation vs usual care	47 vs 60	30	ACQ	1.0 ± 0.7 vs 0.6 ± 0.2	0.9 ± 0.6 vs 0.9 ± 0.2	−0.4 ± 0.6 vs −0.1 ± 0.5
Cingi (2015) ⁴¹	Combined tele-case management vs usual care	68 vs 68	3	ACT	15.5 ± 4.3 vs 21.0 ± 2.5	15.0 ± 3.5 vs 18.0 ± 2.5	5.5 ± 3.7 vs 3.0 ± 3.1
Kim [†] (2016) ³⁷	Tele-case management vs usual care	22 vs 22	2	ACT	22.0 ± 4.0 vs 21.0 ± 4.8	22.0 ± 4.5 vs 23.0 ± 3.3	−1.0 ± 4.4 vs 1.0 ± 4.0
Kolmodin MacDonell [†] (2016) ²²	Combined tele-case management vs tele-education	25 vs 23	3	ACT	NR	NR	2.3 ± 3.5 vs 0.5 ± 3.8
Morrison (2016) ²⁹	Tele-education vs usual care	25 vs 26	3	ACQ	1.9 ± 0.6 vs 1.2 ± 0.9	2.0 ± 0.7 vs 1.7 ± 1.2	−0.7 ± 0.8 vs −0.3 ± 1.0
Zairina (2016) ³⁴	Tele-case management vs usual care	36 vs 36	6	ACQ	NR	NR	−0.3 ± 0.7 vs 0.1 ± 0.6
Patel (2017) ²⁴	Combined tele-consultation vs usual care	212 vs 210	24	ACT	17.2 ± 4.4 vs 19.6 ± 4.4	16.9 ± 4.3 vs 18.0 ± 4.7	2.4 ± 4.4 vs 1.1 ± 4.5
Pool (2017) ²⁵	Tele-case management Vs usual care	203 vs 204	12	ACT	17.7 ± 0.5 vs 19.9 ± 0.5	17.9 ± 0.5 vs 19.1 ± 0.5	2.2 ± 6.2 vs 1.2 ± 6.0
Cao (2018) ⁴⁰	Combined tele-consultation vs usual care	40 vs 40	3	ACQ	2.0 ± 0.1 vs 1.4 ± 0.1	2.1 ± 0.2 vs 1.6 ± 0.1	−0.7 ± 2.3 vs −0.5 ± 3.0

ACQ, Asthma Control Questionnaire; ACT, Asthma Control Test; NEASS, North of England Symptoms Questionnaire; NR, not reported; PCAQ, Perceived Control of Asthma Questionnaire; Short Q, short questionnaire.

*Values are presented as mean ± standard deviation.

†Studies (n = 4) were not included in the meta-analysis because of the difference in participant characteristics,^{31,37} telemedicine intervention,²⁶ and comparator.²²

TABLE IV. A summary of the study outcomes: patients' quality of life

First author (y)	Comparisons (intervention vs control)	Sample size (intervention vs control)	Duration (mo)	Measurement	Measuring score		
					Intervention group* (baseline vs final visit)	Control group* (baseline vs final visit)	Mean difference* (intervention vs control)
Pinnock (2003) ²⁸	Tele-consultation vs usual care	137 vs 141	3	mAQLQ	5.2 ± 1.2 vs 5.2 ± 1.3	5.2 ± 1.2 vs 5.2 ± 1.1	-0.0 ± 1.3 vs 0.1 ± 1.2
Gruffydd-Jones (2005) ²⁷	Tele-case management vs usual care	90 vs 82	12	mAQLQ	6.1 ± 1.2 vs 6.5 ± 0.9	5.7 ± 1.2 vs 5.9 ± 1.5	0.4 ± 1.1 vs 0.2 ± 1.4
Vollmer (2006) ²³	Tele-case management vs usual care	3581 vs 3367	12	mAQLQ	5.0 ± 1.2 vs 5.2 ± 1.2	5.2 ± 1.3 vs 5.1 ± 1.2	0.2 ± 1.2 vs -0.1 ± 1.3
Clark (2007) ²¹	Combined tele-consultation vs usual care	424 vs 384	12	mAQLQ	2.4 ± 0.9 vs 2.1 ± 0.9	2.1 ± 0.8 vs 2.1 ± 0.9	0.3 ± 0.9 vs 0.0 ± 0.9
Strandbygaard (2009) ³⁶	Tele-reminder vs usual care	12 vs 14	3	mAQLQ	NR	NR	0.6 ± 0.9 vs 0.6 ± 0.8
Van der Meer (2009) ³²	Combined tele-case management vs usual care	101 vs 99	12	AQLQ	NR	NR	0.6 ± 0.6 vs 0.2 ± 0.7
Bender (2010) ²⁰	Combined tele-consultation vs usual care	25 vs 25	2.5	AQLQ	NR	NR	-0.2 ± 0.9 vs -0.4 ± 1.1
Hashimoto [†] (2011) ³¹	Combined tele-case management and tele-consultation vs usual care	51 vs 38	6	AQLQ	NR	NR	-0.0 ± 0.7 vs 0.1 ± 0.8
Liu [†] (2011) ³⁸	Tele-case management vs usual care	60 vs 60	6	SF-12 PCS	41.6 ± 1.5 vs 45.5 ± 1.4	43.2 ± 1.4 vs 40.0 ± 1.5	3.9 ± 1.5 vs -3.2 ± 1.5
				SF-12 MCS	48.6 ± 1.1 vs 50.4 ± 1.1	48.6 ± 1.2 vs 44.4 ± 1.4	1.8 ± 1.1 vs -4.2 ± 1.3
Lv (2012) ³⁹	Combined tele-consultation s usual care	50 vs 50	3	AQLQ (S)	NR	NR	31.4 ± 30.4 vs 16.5 ± 21.1
Van Gaalen (2013) ³³	Combined tele-case management and tele-consultation vs usual care	47 vs 60	30	mAQLQ	5.9 ± 0.7 vs 6.4 ± 1.0	5.8 ± 0.8 vs 6.1 ± 1.5	0.5 ± 0.9 vs 0.2 ± 1.3
Ahmed (2016) ³⁵	Combined tele-case management and tele-consultation vs usual care	47 vs 51	6	mAQLQ	4.8 ± 1.3 vs 5.6 ± 1.2	4.9 ± 1.3 vs 5.2 ± 1.2	0.8 ± 1.3 vs 0.3 ± 1.3
Kim [†] (2016) ³⁷	Tele-case management vs usual care	22 vs 22	2	QLQAKA	67.0 ± 13.3 vs 70.0 ± 14.8	69.0 ± 14.0 vs 72.0 ± 14.0	3.0 ± 14.1 vs 3.0 ± 14.0
Morrison (2016) ²⁹	Tele-education vs usual care	25 vs 26	3	mAQLQ	5.0 ± 1.0 vs 5.4 ± 1.0	4.7 ± 1.0 vs 4.8 ± 1.3	0.4 ± 1.0 vs 0.1 ± 1.2
Newhouse [†] (2016) ³⁰	Tele-education vs tele-education	73 vs 75	0.5	SF-36 PCS	NR	NR	NR vs NR
				SF-36 MCS	NR	NR	NR vs NR
Zairina (2016) ³⁴	Tele-case management vs usual care	36 vs 36	6	mAQLQ	NR	NR	0.5 ± 1.0 vs -0.2 ± 0.9
Patel (2017) ²⁴	Combined tele-consultation vs usual care	212 vs 210	24	mAQLQ	5.0 ± 1.3 vs 5.5 ± 1.2	4.9 ± 1.2 vs 5.2 ± 1.2	0.4 ± 1.3 vs 0.3 ± 1.2
Cao (2018) ⁴⁰	Combined tele-consultation vs usual care	40 vs 40	3	AQLQ	5.4 ± 0.1 vs 6.0 ± 0.1	5.5 ± 0.1 vs 5.7 ± 0.1	0.6 ± 2.7 vs 0.2 ± 2.3

AQLQ, Asthma Quality of Life Questionnaire; AQLQ (S), Standard Asthma-specific Quality of Life Questionnaire; mAQLQ, Mini Asthma Quality of Life Questionnaire; MCS, mental component summary; NR, not reported; PCS, physical component summary; QLQAKA, Quality of Life Questionnaire for Korean Asthmatic Adults; SF, short form.

*Values are presented as mean ± standard deviation.

†Studies (n = 4) were not included in the meta-analysis because of the difference in participant characteristics,^{31,37} outcome assessment,³⁸ and comparator and outcome assessment.³⁰

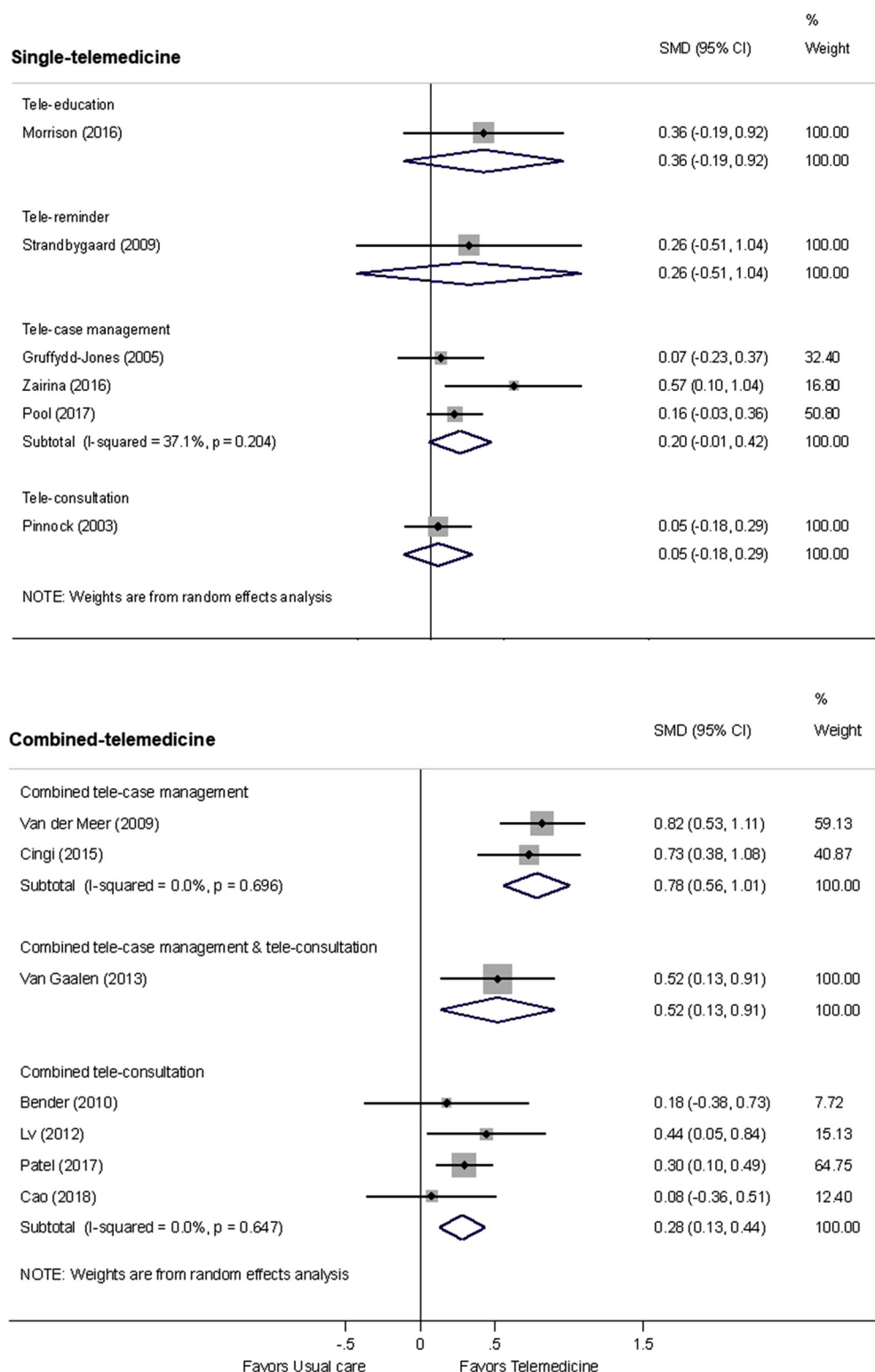


FIGURE 2. Forest plots of the change in asthma control. The upper forest plot shows the pooled effect of each particular single-telemedicine on asthma control, whereas the lower forest plot shows the pooled effect of each particular combined-telemedicine on asthma control. *CI*, Confidence interval; *SMD*, standardized mean difference.

accessed through computer programs or applications that provide self-management information. The limitations of this study were the low numbers being included, and the small sample sizes. This

limits generalizability of the findings and made it difficult to recommend the use of interactive digital interventions in real clinical practices. According to our findings, telemedicine

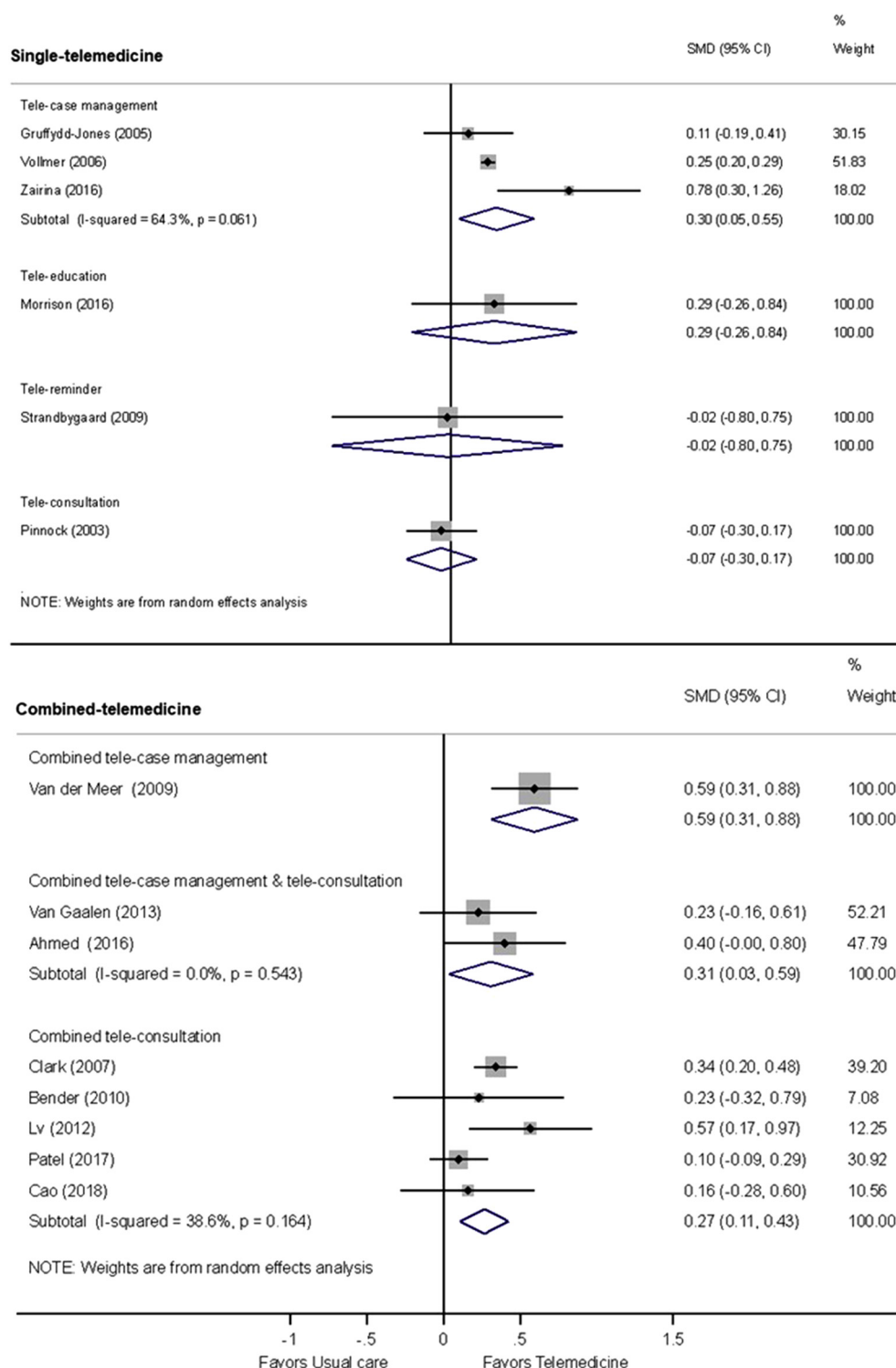


FIGURE 3. Forest plots of the change in quality of life. The upper forest plot shows the pooled effect of each particular single-telemedicine on quality of life, whereas the lower forest plot shows the pooled effect of each particular combined-telemedicine on quality of life. *CI*, Confidence interval; *SMD*, standardized mean difference.

demonstrated the benefits for asthma control and the improvement of patients' quality of life. Combined-telemedicine involving tele-case management or tele-consultation appear to be effective interventions. We believe that the current systematic

review and meta-analysis provides the most updated evidence pertaining to the effects of telemedicine on asthma control and quality of life based on justified assumptions and study methodology.

Results of this study also suggest that the duration of intervention might affect the treatment effects of telemedicine. A previous systematic review and meta-analysis⁴³ demonstrated that the studies with telemedicine delivered for at least 6 months were positively associated with higher improvements, and more likely to be associated with higher success in type 1 diabetic individuals, and concur with the findings from the current study. We found that the studies with telemedicine delivered for at least 6 months had higher proportions of patients with significant improvements in asthma control and patients' quality of life compared with the studies with less than 6 months (4 of 6 studies [67%] vs 2 of 7 studies [29%] for asthma control, and 4 of 8 studies [50%] vs 1 of 6 studies [17%] for patients' quality of life). As asthma is a chronic condition, results maybe an indication of the length of time needed to observe any effects. Although we attempted to elucidate the impact of this in our subgroup analysis, this was not possible due to the limited number of included studies. Further research is warranted to strengthen our findings from the current knowledge of the duration of each type of telemedicine applied for asthma control and the quality of life improvement.

Another study worth mentioning is the study by Ryan et al,⁴⁴ which determined the effects of mobile application supported self-monitoring in 288 adolescents and adults with asthma. Even though we found the Ryan et al study in our search results, we decided (based on our inclusion criteria) not to include this study in our analysis because they recruited patients aged 12 years or more. Although the reported average age of patients was more than 18 years, results of the study were not sufficiently detailed for us to extract information for adults. This rigid inclusion was because we believe that the care of these 2 cohorts is distinctively different. Adolescents with asthma may need some help from their families/carers to achieve and maintain their asthma control, whereas adults are generally capable of their own asthma self-care management. Including adolescents in our review may create clinical heterogeneity from the disparity of patient groups. Furthermore, the effects of telemedicine in adolescent patients might be due in part to support from their families/carers (nontelemedicine). This could be one of the reasons why the Ryan et al study found no significant difference in asthma control ($P = .680$) and quality of life ($P = .495$) among adolescents and adults in telemedicine and control groups.

The classification and definition of individual telemedicine types were adapted from a review of telemedicine taxonomy.^{13,14} In this systematic review and meta-analysis, we found that tele-case management and tele-consultation were the 2 most effective types of telemedicine compared with others, likely because both integrated important supportive roles, particularly in the self-management and the interactive communication between health care professionals and patients. All the combined-telemedicine in this study were classified into combined tele-case management, combined tele-consultation, and combined tele-case management and tele-consultation to prevent confusion when interpreting the results with many types of telemedicine. There is no standard definition and classification of telemedicine to date. We believe that our definitions of telemedicine and their types are appropriate, and based on qualified research evidence.

Several limitations should be acknowledged. First, we performed a meta-analysis using the SMD. The pooled estimate was difficult to interpret because it was reported in the unit of standard deviation rather than that of measurement scales. In fact, using the

SMD was the only valid approach because the included studies reported their outcomes measured in various measurement scales. Second, most of included studies were at high risk of bias. However, they are the only evidence pertaining to these research areas that are available. Caution should be exercised when interpreting the findings because bias arising from these studies could affect their reported outcomes, thus influencing the pooled estimates of the meta-analysis results. Use of GRADE assessment revealed that the quality of evidence for both outcomes was low to moderate primarily due to the risk of bias and imprecision, suggesting that further large-scale research with rigorous methodology is warranted to prevent the potential for bias and imprecise results. Third, there were various lengths of follow-ups in the included studies that can be associated with the efficacies of telemedicine. However, we could not perform subgroup analysis by the length of the follow-ups because of the limited number of included studies. Health care professionals should consider the length of follow-ups conducted in studies when assessing whether they should implement telemedicine in their practice. Lastly, even though a total of 16 studies were included in our meta-analysis, efficacies of some telemedicine interventions for asthma control (tele-education, tele-reminder, tele-consultation, and combined tele-case management and tele-consultation), as well as the improvement of patients' quality of life (tele-education, tele-reminder, tele-consultation, and combined tele-case management), were from 1 study. This raises concerns on generalizability of telemedicine interventions. Health care professionals who would like to implement the interventions should evaluate whether their settings are comparable with those of the studies.

Telemedicine is increasing in importance in the health care system. 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.^{45,46} Telemedicine helps provide patients and their families with clinical education and medical supportive management, such as monitoring health status and interactive communication. This study supports the use of combined-telemedicine involving tele-case management or tele-consultation for asthma control and the improvement of patients' quality. We believe that the value of this study is highlighted 2-fold: to provide health care professionals with current evidence of the effects of telemedicine for asthma, as well as an insight into each type of telemedicine for future research development. Although the effects of telemedicine interventions were evaluated in this study, the future challenge is to conduct a cost-effectiveness analysis of each telemedicine strategy, and ethical, legal, economic, and sociocultural aspects need to be considered before implementing them.

CONCLUSIONS

This systematic review and meta-analysis gathered all relevant evidence and quantified pooled estimates to evaluate the effects of telemedicine in adults with asthma. Combined-telemedicine involving tele-case management or tele-consultation were effective telemedicine intervention for asthma control and the improvement of patients' quality of life. Further research is warranted to strengthen our findings from the current literature. Our findings are expected to provide health care professionals with current evidence of the effects of telemedicine for asthma control and quality of life.

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ONLINE REPOSITORY

TABLE E1. Search results

CENTRAL		
No	Keyword	Found
1	Asthma	9,920
2	tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application	303,562
3	1 AND 2 (search filter: randomized controlled trial)	1,701
CINAHL		
No	Keyword	Found
1	Asthma	31,731
2	tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application	1,426,992
3	1 AND 2 (search filter: randomized controlled trial)	91
ClinicalTrials.gov		
No	Keyword	Found
1	Asthma	5,885
2	tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application	23,243
3	1 AND 2 (search filter: randomized controlled trial)	398
EMBASE		
No	Keyword	Found
1	Asthma	213,179
2	tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application	2,564,652
3	1 AND 2 (search filter: randomized controlled trial)	360
PubMed		
No	Keyword	Found
1	Asthma	114,313
2	tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application	5,225,174
3	1 AND 2 (search filter: randomized controlled trial)	964
Scopus		
No	Keyword	Found
1	Asthma	461,924
2	tele* OR email OR e-mail OR *health OR web* OR internet OR video OR VDO OR electronic OR SMS OR *phone OR mobile OR message OR text* OR application	28,588,145
3	1 AND 2 (search filter: randomized controlled trial)	1,912

TABLE E2. Telemedicine classification

Telemedicine	Description
Tele-case management	The collaborative initiation to integrate an assessment, care, coordination, and evaluation to improve patient care and meet patient needs.
Tele-consultation	An interactive communication between a patient and health care provider aims at providing care from a distance.
Tele-education	An educating, teaching, or training patient using interactive or stored-and-forward educational material.
Tele-monitoring	The monitoring process that allows for the delivery and/or exchange of patient information to monitor patient health status remotely.
Tele-reminder	The reminding approach that aims at reminding patients to facilitate their self-managements remotely.

TABLE E3. Characteristics of telemedicine and telemedicine types

First author (y)	Characteristics of telemedicine	Telemedicine types
Single-telemedicine		
Gruffydd-Jones (2005) ^{E1}	Patients were contacted by telephone at 6-monthly intervals by 1 of 2 trained asthma nurses. If no reply was obtained, the patient was telephoned at another time until contact was made. The patient was then asked the Royal College of Physician's "3 questions" plus 2 extra questions related to a high risk of asthma death ("Have you ever needed treatment in intensive care for your asthma?"; "Have you been admitted to hospital with your asthma within the last year?"). Patients were considered "low risk" if they answered "no" to all the questions above. The nurse formulated an individualized asthma action plan with the patient, with advice on what to do if asthma control deteriorated.* A written version of the plan was sent to the patient with an agreement that the patient would be routinely followed up in 6 mo. If patients answered "yes" to any of the questions, they were deemed "high risk" and a clinic asthma review actively arranged.	Tele-case management
Vollmer (2006) ^{E2}	The intervention consisted of 3 rounds of calling about 5 mo apart. The calls consisted of a series of questions designed to assess: (1) recent emergency department or hospital care for which the member had not had a follow-up visit, (2) current level of asthma control, (3) current patterns of asthma medication use, and (4) whether the member could identify a primary care provider whom he or she usually saw for asthma care.* We also asked if the patient had ever been told he or she had "emphysema or COPD" as a means of identifying patients with COPD who were not flagged as such on the problem list. These patients received an abbreviated intervention but were kept on the call list unless a diagnosis of COPD was subsequently added to their problem list. Based on the responses to these initial questions, members were offered (optional) tailored feedback regarding their overall level of asthma control and their use of asthma medications.*	Tele-case management
Liu (2011) ^{E3}	The mobile telephone-based interaction self-care software provided an electronic diary to record patients' daily asthma symptom score (sleep quality, severity of coughing, difficulty in breathing, and daily activities affected by asthma), use of relievers, peak expiratory flow rate (PEFR) and PEFR variability. After uploading the diary data, the patient received the assessment of their asthma status and the corresponding management advice, which were displayed immediately on the mobile telephone via GPRS. Patients in the mobile telephone group were asked to follow the management advice to adjust their anti-inflammatory agents if there was high variability of PEFR, increased frequency of daytime or night time asthma episodes, or decreased response to bronchodilators.* These management suggestions were based on GINA guidelines for asthma control. The patients and medical staff reviewed the daily, weekly, and monthly data of patients' asthma symptom scores, PEFR, PEFR variability, and use of relievers on the website. The data were given to the physicians to adjust their treatment plan when patients returned to their clinics.*	Tele-case management

(continued)

TABLE E3. (Continued)

First author (y)	Characteristics of telemedicine	Telemedicine types
Kim (2016) ^{E4}	The user group was provided a smartphone application and peak flow meter, and was instructed for how to use in details before the clinical trials. The application was developed on the basis of a written asthma action plan. It included the questionnaire items from the action plan, and let the patients to input their daily symptom score. The participants were instructed to record their asthma symptoms and peak expiratory flow (PEF) twice a day regularly, and also were asked to record the symptoms and PEF when their asthma worsened. The application followed the logic of the written asthma action plan, and was set to give daily signals to the users about their asthma control status, such as “doing well,” “getting worse,” “medical alert,” or “emergent situation,” based on symptoms and PEF values, and offered action plans to patients.*	Tele-case management
Zairina (2016) ^{E5}	Participants allocated to intervention group were provided with COPD-6 to measure their lung function (forced expiratory volume in 1 s [FEV₁] and FEV₆) daily and a specifically designed Breathe-easy application installed on a loaned “smart” mobile phone to record asthma symptoms and asthma medication usage weekly. Participants were also prompted to follow an individualized written asthma action plan specifically developed by the study team as part of the intervention package.* An automated feedback message regarding her asthma status was sent weekly based on the Breathe-easy algorithm.	Tele-case management
Pool (2017) ^{E6}	Participants in the intervention condition (IC) were asked to use the online tool at least once every 30 d and within 14 d of their next scheduled health care provider visit, though they could use it any time. During each website use, IC participants answered a series of questions about their asthma symptoms, availability of oral corticosteroids at home for exacerbations, and asthma care received from providers, such as an asthma management plan. In addition, participants entered the names of all of their current asthma medications, reported the number of days each week that each medication was used, and identified if any medicines bothered them. Finally, participants were asked to update their tobacco use and pregnancy status (if applicable) as well as record their next scheduled visit with their asthma care provider. The online tool then provided tailored feedback to remind patients to: (1) ask health care providers specific questions that may improve asthma control and (2) consistently perform specific self-care behaviors.* Once the actionable recommendations were identified, questions were identified to measure adherence to the recommendation and then feedback was written to remind patients what questions they may want to ask their provider at an upcoming visit as well as what self-care they should be more adherent to, based on the guidelines.	Tele-case management
Pinnock (2003) ^{E7}	Nurses were told to make up to 4 attempts to contact the patient by phone. The nurses were given no instructions about the content of the review except that it should reflect their normal practice and be appropriate to each patient’s clinical need. Details about the consultation, including failed attempts at phone calls and the duration of the consultation, were recorded immediately after the review on a piloted consultation record. Nurses arranged any follow-up consultations (whether in the surgery or by telephone) they deemed clinically necessary. Patients were free to arrange any consultations they wished.†	Tele-consultation

(continued)

TABLE E3. (Continued)

First author (y)	Characteristics of telemedicine	Telemedicine types
Morrison (2016) ^{E8}	The intervention development aimed to (1) provide an understanding of the current level of asthma control and how to improve it, specifically by optimizing the use of prescribed medication, (2) challenge attitudes and concerns around medications, (3) learn how to get the most out of their annual asthma review, (4) prompt provision and use of a personal asthma action plan from a health professional, and (5) send timely reminders for influenza vaccination and reordering refill inhaler prescriptions. The website did not advise medication changes, but suggested contacting a health professional if inadequate control was identified, with clear advice for seeking help in an emergency. The website is interactive, aiming to engage the users in recognizing that their asthma is uncontrolled, and illustrate the benefits via case vignettes (based on real life examples) of taking their medications as prescribed. [‡] The website is tailored based on their current use of preventer inhalers (never been prescribed; prescribed but do not really use; use regularly).	Tele-education
Newhouse (2016) ^{E9}	The intervention was a multimedia website developed by the University of Oxford Health Experiences Research Group and the Healthtalk.org charity. The website included thematic analyses of key topics from interviews with a purposive sample of 40 people with asthma about their experiences of their condition. Topics are illustrated with interview extracts in short video, audio, and written formats. Video and audio extract varied in length but were typically 2 min long. The content was presented on the website in such a way that users were able to browse topics according to relevance and interest. The content was not personalized to individual users and information flow was not guided or “tunneled” in any way; all intervention users experienced the same website and could navigate content in any chosen order. To maintain a stable intervention, we did not include user interactivity that could change the content of the website, other than the option to provide feedback to the research team. Users were able to comment on and rate each page if desired. [‡] To compare this intervention site with a “gold standard” matched alternative, we provided a control website based on “facts and figures” about asthma self-management. We constructed a new site that closely resembled the design and features of the intervention yet was populated with the asthma self-management information taken from NHS Choices (http://www.nhs.uk), as the authoritative provider of online health information in the United Kingdom.	Tele-education
Barbanel (2003) ^{E10}	Intervention participants were telephoned weekly by the pharmacist and encouraged to return to the pharmacy with any problems. [§] This contact continued for 3 mo.	Tele-monitoring
Strandbygaard (2009) ^{E11}	The participants randomized to the SMS group received the following short text message daily at 10 a.m.: “Remember to take your asthma medication morning and evening. From the Respiratory Unit.” [¶] The service was administered via the internet.	Tele-reminder
Combine-telemedicine		

(continued)

TABLE E3. (Continued)

First author (y)	Characteristics of telemedicine	Telemedicine types
Van der Meer (2009) ^{E12}	The internet-based self-management program consisted of the 4 principal components of asthma self-management and was accessed through the specially designed website, which allowed monitoring through the website (or text message on a mobile telephone), use of an internet-based treatment plan, online education, and web communications with a specialized asthma nurse. Patients monitored their asthma weekly by completing an electronic version of the Asthma Control Questionnaire on the website and instantly received feedback on the current state of their asthma control along with advice on how to adjust their treatment according to a predefined algorithm and treatment plan. In addition to weekly assessments, patients could optionally report daily symptoms and lung function and were able to contact our asthma nurse through the web or by telephone.* Thus, any acute deterioration warranting a visit to the general practitioner or hospital could be detected. We aimed to empower patients to use the internet-based self-management tool and to develop a patient-provider partnership in asthma care. Self-management education consisted of both web-based and face-to-face, group-based education. Web-based education included asthma information, news, frequently asked questions, and interactive communication with a respiratory nurse specialist.†	Combined tele-case management
Cingi (2015) ^{E13}	The intervention group received a mobile phone application, specifically designed for the trial. Our research design provided the opportunity to track patient health status and to share motivational and educational content‡ while also reminding the patient to take prescribed medications. The patient application enabled the patients to submit their overall health status on a 7-point scale (6 = very good, 0 = extremely bad) with an emoticon, share a 140-character status update, send and receive messages, and ask for immediate assistance with an urgent message option, track their medicine use with a diary that sent automated reminders according to their prescribed treatment plan (once or twice daily) and complete the Rhinitis Quality of Life Questionnaire or Asthma Control Test within 24 h after enrollment and again at the end of the study.*	Combined tele-case management
Kolmodin MacDonell (2016) ^{E14}	The intervention consisted of 2 computerized intervention authoring software delivered sessions* with personalized, daily text-messaged reminders to take medication delivered between these sessions.† There were key components to each session, consistent with the principles of motivational interviewing: (1) feedback regarding medication use and symptoms, (2) feedback on readiness to improve adherence, (3) decisional balance, or pros and cons of taking medications, and (4) a summary regarding the youth's interest in improving adherence, followed by optional goal setting.*	Combined tele-case management

(continued)

TABLE E3. (Continued)

First author (y)	Characteristics of telemedicine	Telemedicine types
Clark (2007) ^{E15}	Women in the intervention group were introduced to a self-regulatory problem-solving process to be performed in accordance with the patient's therapeutic plan. An important component of the intervention was that each participant's developmental phase of self-regulation was determined at baseline, and telephone counseling was then tailored to that particular level of self-regulation. The women were mailed an educational kit containing a workbook, a list of sex-related and gender-related asthma concerns, specially designed diaries, and a peak flow meter with an instructional videotape. During the first 45-min counseling session, women were instructed in the first step of the Women Breathe Free approach, and were asked to use the peak flow meter and the personalized graph diary as observational tools to monitor their symptoms and behaviors. They were also asked to observe potential influences on peak flow rate and symptoms, as well as the effects of changes in medicine use, and possible associations between symptoms and phases of the menstrual cycle, or use of estrogen replacement or oral contraceptives, for example. During the observation month, they received weekly postcards to remind them of participation in diary keeping and peak flow monitoring,[‡] and a mid-month phone call from the health educator to discuss any concerns they might have with observation or other elements of the program.[†] After the month of self-observation, the women in the program received a total of four 30-min to 45-min telephone counseling interventions at 2-week intervals. Each subsequent session focused on sequentially teaching the women the steps of a self-regulatory problem-solving processes, including the problem addressed, the management goal set, and the step-by-step action plan.	Combined tele-consultation
Lv (2012) ^{E16}	Patients received short text messages reminder about how to manage asthma at 10:00 a.m. and 8:00 p.m. every day from clinic investigators. The content of the short text messages included introduction to asthma, classes of asthma medications, proper device use, common types of triggers, strategies for avoiding triggers, how to make an action plan, and how to handle asthma acute attacks.[‡] If they had any questions about asthma, patients could send short text messages by their mobile phone to clinic investigators and receive answers.[†]	Combined tele-consultation
Bender (2010) ^{E17}	The interactive voice response (IVR) systems can be programmed to make and receive automated telephone calls and have the capability to ask questions and give information, which tailors IVR responses to the answers given by the respondent using their telephone keypad. Each patient received at least 2 calls separated by 1 mo. Content of the call then included an explanation of how the call works followed by 3 questions inquiring whether during the previous week the participant had been awakened at night, had limited their activities, or had used their rescue inhaler more than twice because of asthma symptoms (symptom module).[§] Participants who responded affirmatively to any of the 3 questions were told that daily use of their controller medication should help prevent such symptoms and were advised to discuss the symptoms with their physician.[†] All participants also listened to a short module about the benefits of their asthma medication[‡] and were asked about whether they were filling and using their medication, with IVR responses tailored to specific participant responses (refill module). Finally, participants were informed about the Lung Line, a free telephone service staffed by nurses capable of answering most questions about asthma.[†]	Combined tele-consultation

(continued)

TABLE E3. (Continued)

First author (y)	Characteristics of telemedicine	Telemedicine types
Patel (2017) ^{E18}	Culture-related influences on asthma management were integrated into each counseling session. The program was delivered by trained health educators through a series of 6 telephone counseling sessions (30-45 min in duration, 2 wk apart) to participants randomized to the intervention. All participants assigned to the intervention were mailed an asthma education kit, including a program workbook, asthma symptom diaries, a peak flow meter with instructions, and asthma resources by the health educator. [‡] The first month of the intervention was devoted to self-observation. Participants were instructed on how to use a daily asthma diary. During the observation month, they received weekly postcards to remind them to complete asthma diaries and a mid-month telephone call from the health educator. [¶] Participants were offered a list of potential asthma management problems, including those associated with their sex and gender roles, culture, and other relevant challenges. Examples include feeling symptoms when doing housework, wheezing when exercising, family thinking prayer is all that is needed to take care of asthma, and so on. After 1 month of self-observation, participants were asked by their health educator to select an aspect of their asthma management they would like to focus on for overall improvement. During the counseling sessions, participants were introduced to the self-regulatory problem solving process and were encouraged to examine factors that affect asthma management, including sex and gender roles and cultural influences. The health educator guided the participant in applying the problem-solving process to an identified goal. Each subsequent session focused on sequentially teaching and reinforcing the steps of self-regulatory problem-solving processes: problem identification, self-observation, goal setting, evaluation of progress, and establishing rewards for positive behavioral change. During the fourth and fifth counseling sessions, the health educator worked with the participant to identify any problems in achieving goals and formulating potential solutions together. A final booster telephone contact was made 6 mo after the fifth session. [‡]	Combined tele-consultation
Cao (2018) ^{E19}	Participants were invited to subscribe to the WeChat public account “Assistant of Respiratory Diseases” on their smartphone. On this public platform, participants can read educational articles about asthma and watch the online videos about various inhaler devices for self-education. [‡] Conveniently, messages, voices, and videos can be left on the platform and be replied to by physicians within 48 h. [‡] Messages are sent to patients to remind them to perform drug inhalation. [¶] A timer helped participants remember the time for drug usage every day and provided data about the next visit.	Combined tele-consultation
Hashimoto (2011) ^{E20}	The internet-based management tool comprised: (1) an electronic diary, (2) treatment decision support for the patients, and (3) monitoring support by a study nurse. Patients recorded symptoms, registered their dose of oral corticosteroids, lung function using a hand-held spirometer, and exhaled nitric oxide using a hand-held nitric oxide analyzer before medicine intake on a daily basis. Asthma control questionnaires were completed weekly, and asthma-related quality of life questionnaires were completed at baseline and every 3 mo thereafter.* Patients registered their data via a validated asthma monitoring service using an internet application or SMS messages. Patients had daily information about their asthma graphically on the web page[‡] and received weekly instructions via the web page for stepwise corticosteroid dose adjustments according to a built-in algorithm.* A study nurse was responsible for coaching the patients, monitoring the data entered at the web page, and facilitating the communication between patients and pulmonologists. [‡]	Combined tele-case management and tele-consultation

(continued)

TABLE E3. (Continued)

First author (y)	Characteristics of telemedicine	Telemedicine types
Van Gaalen (2013) ^{E21}	We incorporated modules for electronic monitoring of asthma control and lung function, a personal action plan, communication with a respiratory nurse (RN), and education. The program included reminder options for monitoring activities (ie, Asthma Control Questionnaire, day and night symptom score, lung function), which were initially sent once weekly by either e-mail or mobile phone SMS text messaging, but during follow-up frequency could be adjusted according to the preferences of the individual patient. Patients received immediate feedback (to maintain, step up or step down in medication, and/or to contact a health care professional) on self-monitoring outcomes according to a treatment algorithm and a predefined action plan based on 6 medication steps.* E-messaging, telephone, or web-based communication allowed patients to interact with the RN. In addition, the RN supported patients by nurse-initiated communication characterized by a supportive style to give positive feedback on achieved successes (eg, step down in medication) or to inquire for reasons on not following treatment advice (eg, side effect).† On average, the RN spent 1-2 h per week on patient- and nurse-initiated communication for all internet group patients. Education components were provided both online (eg, educational pages, newsfeed) and offline.‡	Combined tele-case management and tele-consultation
Ahmed (2016) ^{E22}	My asthma portal (MAP) was developed to support patient self-management and facilitate communication with the care team between visits. The features within MAP are based on increasing individuals' knowledge as well as their confidence to carry out the behaviors that are necessary for patients to improve their asthma health. Participants were given a MAP username and password, advised that they could access the site from anywhere, and asked to login at least once per week for the 6 mo of the study. During the first log-in, patients provided basic demographic and health information and selected their own initial health goals for action. Within MAP, participants could: (1) view their personal health information, (2) view general asthma information through links to specific educational websites and receive information tailored to identified knowledge gaps,‡ and (3) monitor and receive feedback regarding current self-management practices. Initial feedback was generated automatically from the MAP system using monitoring information entered by the participant and data from the provincial administrative database sent to MAP from the Medical Office for the 21st century, an electronic health record with a prescription and computerized drug and disease management system. An e-mail alert was sent to patients under the following conditions: (1) when suboptimal asthma control was identified by the system and the participants indicated that they did not initiate activities outlined in their action plan, (2) if the action plan was updated by the nurse as prescribed by the patient's physician, and (3) if they had not logged in for at least 7 d.* Participants communicated and received support as needed from a nurse case manager using MAP. The nurse case-management system was designed to: (1) quickly identify patients that may require immediate care, (2) collate relevant medical and monitoring information for each participant, and (3) document case-management information, including interactions (phone and e-mails), along with advice and interventions provided by the case manager. On receiving this notice, the nurse followed up with the participant within 24 h through the MAP mail system or by telephone. Additional alerts were sent to the nurse case manager when a new participant was enrolled and needed their prescribed action plan reviewed, the participant indicated lack of understanding of the action plan, or there was a change in medication use based on the self-reported adherence monitoring assessment.†	Combined tele-case management and tele-consultation

Note: Combined-telemedicine was classified into 3 categories: (1) Combined tele-case management, (2) combined tele-consultation, and (3) combined tele-case management and tele-consultation. Combined tele-case management referred to the use of any type of telemedicine in addition to tele-case management. Combined tele-consultation referred to the use of any type of telemedicine in addition to tele-consultation. Combined tele-case management and tele-consultation referred to the use of any type of telemedicine in addition to tele-case management and tele-consultation.

COPD, Chronic obstructive pulmonary disease; GINA, Global Initiative for Asthma; GPRS, General Packet Radio Service; NHS, National Health Service; SMS, short message service.

*Tele-case management (bold text).

†Tele-consultation (bold text).

‡Tele-education (bold text).

§Tele-monitoring (bold text).

¶Tele-reminder (bold text).

TABLE E4. Methodological quality assessment of the included studies

First author (y)	Risk of bias domains					Summary
	Bias arising from the randomization process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	
Barbanel (2003) ^{E10}	L	S	L	S	L	S
Pinnock (2003) ^{E7}	L	S	S	S	L	H
Gruffydd-Jones (2005) ^{E1}	H	S	L	S	L	H
Vollmer (2006) ^{E2}	S	S	S	S	L	H
Clark (2007) ^{E15}	H	S	L	L	L	H
Strandbygaard (2009) ^{E11}	S	S	S	S	L	H
Van der Meer (2009) ^{E12}	S	S	L	S	L	H
Bender (2010) ^{E17}	S	S	L	S	L	H
Hashimoto (2011) ^{E20}	S	S	L	S	L	H
Liu (2011) ^{E3}	S	S	L	S	L	H
Lv (2012) ^{E16}	S	S	L	S	L	H
Van Gaalen (2013) ^{E21}	H	S	L	S	L	H
Cingi (2015) ^{E13}	S	L	L	S	L	S
Ahmed (2016) ^{E22}	S	S	L	S	L	H
Kim (2016) ^{E4}	S	S	L	S	L	H
Kolmodin MacDonell (2016) ^{E14}	S	S	L	S	L	H
Morrison (2016) ^{E8}	L	S	L	S	L	S
Newhouse (2016) ^{E9}	L	S	L	L	L	S
Zairina (2016) ^{E5}	L	S	L	L	L	S
Patel (2017) ^{E18}	S	S	L	S	L	H
Pool (2017) ^{E6}	H	S	L	S	L	H
Cao (2018) ^{E19}	S	S	L	S	L	H

H, High risk of bias; L, low risk of bias; S, some concerns risk of bias.

TABLE E5. A summary of GRADE criteria

Telemedicine (no. of studies)	Rating quality of evidence						Sample size		SMD (95% CI)	Summary
	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Intervention	Control		
Asthma control										
Tele-education (1) ^{E8}	RCT	Serious	No	No	Very serious	Undetected	25	26	0.36 (−0.19 to 0.92)	⊕ ⊕ ⊕ O Moderate
Tele-reminder (1) ^{E11}	RCT	Very serious	No	No	Very serious	Undetected	12	14	0.26 (−0.51 to 1.04)	⊕ ⊕ OO Low
Tele-case management (3) ^{E1,E5,E6}	RCT	Very serious	Serious	Serious	Serious	Undetected	330	322	0.20 (−0.01 to 0.42)	⊕ ⊕ OO Low
Tele-consultation (1) ^{E7}	RCT	Very serious	No	No	Serious	Undetected	137	141	0.05 (−0.18 to 0.29)	⊕ ⊕ ⊕ O Moderate
Combined tele-case management (2) ^{E12,E13}	RCT	Very serious	No	Serious	Serious	Undetected	169	167	0.78 (0.56 to 1.01)	⊕ ⊕ OO Low
Combined tele-case management and tele-consultation (1) ^{E21}	RCT	Very serious	No	No	Serious	Undetected	47	60	0.52 (0.13 to 0.91)	⊕ ⊕ ⊕ O Moderate
Combined tele-consultation (4) ^{E16-E19}	RCT	Very serious	No	Serious	No	Undetected	327	325	0.28 (0.13 to 0.44)	⊕ ⊕ ⊕ O Moderate
Patients' quality of life										
Tele-case management (3) ^{E1,E2,E5}	RCT	Very serious	Serious	Serious	Serious	Undetected	3,707	3,485	0.30 (0.05 to 0.55)	⊕ ⊕ OO Low
Tele-education (1) ^{E8}	RCT	Serious	No	No	Very serious	Undetected	25	26	0.29 (−0.26 to 0.84)	⊕ ⊕ ⊕ O Moderate
Tele-reminder (1) ^{E11}	RCT	Very serious	No	No	Very serious	Undetected	12	14	−0.02 (−0.80 to 0.75)	⊕ ⊕ OO Low
Tele-consultation (1) ^{E7}	RCT	Very serious	No	No	Serious	Undetected	137	141	−0.07 (−0.30 to 0.17)	⊕ ⊕ ⊕ O Moderate
Combined tele-case management (1) ^{E12}	RCT	Very serious	No	No	Serious	Undetected	101	99	0.59 (0.31 to 0.88)	⊕ ⊕ ⊕ O Moderate
Combined tele-case management and tele-consultation (2) ^{E21,E22}	RCT	Very serious	No	Serious	Serious	Undetected	94	111	0.31 (0.03 to 0.59)	⊕ ⊕ OO Low
Combined tele-consultation (5) ^{E15-E19}	RCT	Very serious	No	Serious	No	Undetected	751	709	0.27 (0.11 to 0.43)	⊕ ⊕ ⊕ O Moderate

CI, Confidence interval; RCT, randomized controlled trial; SMD, standardized mean difference.

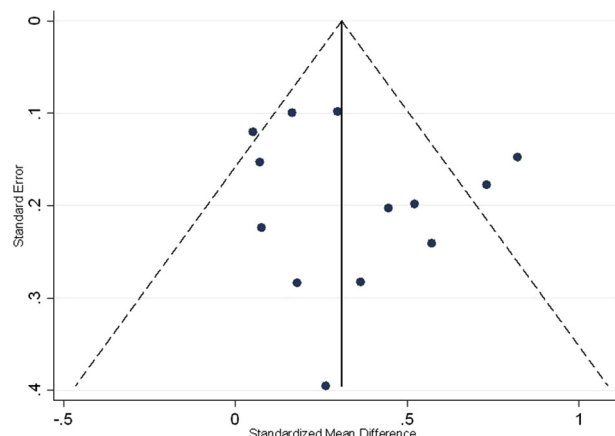


FIGURE E1. A funnel plot of the standardized mean difference of asthma control versus standard error between telemedicine and control.

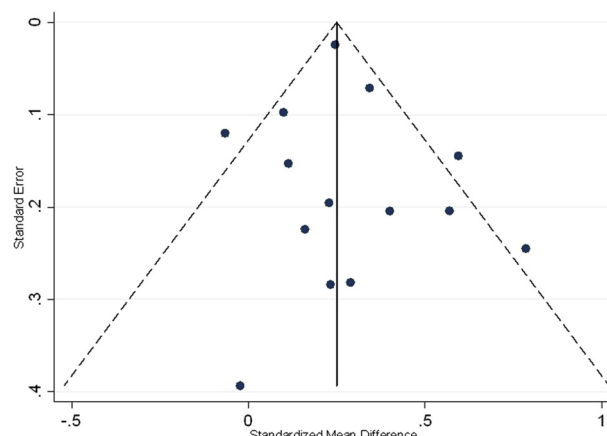


FIGURE E2. A funnel plot of the standardized mean difference of quality of life versus standard error between telemedicine and control.

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