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SLEEP BREATHING PHYSIOLOGY AND DISORDERS • REVIEW

Effects of telemedicine interventions in improving continuous positive airway pressure adherence in patients with obstructive sleep apnoea: a meta-analysis of randomised controlled trials

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Abstract

Purpose This meta-analysis was conducted to assess the effects of telemedicine interventions on continuous positive airway pressure (CPAP) adherence in patients with obstructive sleep apnoea (OSA).

Methods The PubMed, Cochrane Library, OVID, Web of Science and EBSCO host databases were searched from January 2004 to February 2020 for randomised controlled trials (RCTs) that assessed the effects of telemedicine interventions on CPAP adherence in patients with OSA. The study inclusion criteria were RCTs that compared patients who received telemedicine interventions with a control group and reported a change in CPAP adherence. The primary outcome was the improvement in CPAP adherence.

Results In total, there were 11 RCTs (n = 1358) with quantitative analyses. Intervention times ranged from 1 to 6 months. Compared to controls, the telemedicine group exhibited better adherence to CPAP therapy (pooled mean difference (MD) = 0.57, 95% CI = 0.33 to 0.80, I^2 = 7%, p < 0.00001). We performed sensitivity analyses by the type of telemedicine intervention, comorbidity burden, and OSA severity to explore whether or not their effect sizes may have affected the time of CPAP application. We performed subgroup analyses by follow-up duration, age, and OSA Epworth sleepiness scale (ESS) symptoms to determine if their effect sizes may have affected the time of CPAP application. However, these analyses did not change the statistical significance of the pooled estimate.

Conclusions The use of telemedicine for up to 6 months may enhance CPAP adherence in patients with OSA, when compared to no intervention. Our study was searched from January 2004 to February 2020 for randomised controlled trials (RCTs) that assessed the effects of telemedicine interventions on CPAP adherence in patients with OSA. Future studies can continue to search for articles after February 2020

Keyword Telemedicine, · Obstructive sleep apnoea, · Adherence, · Meta-analysis

Introduction

Obstructive sleep apnoea (OSA) refers to repeated episodes of partial or complete upper airway obstruction during sleep, leading to a significant reduction or complete interruption of airflow, which can cause intermittent disturbances of gas exchange such as hypercapnia and hypoxemia, as well as large fluctuations in blood pressure and fragmented sleep [1]. OSA

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clinical symptoms include snoring, apnoea, morning headache, dry mouth after waking, daytime sleepiness, etc. [2], which may contribute to risk of stroke, coronary heart disease, arrhythmia, hypertension, and increased cardiovascular mortality [3]. Multiorgan damage makes OSA an economic burden for society [1]. One study reported that OSA afflicts nearly 30 million adults in the USA, and its cost in 2015 was approximately $US 12.4 billion [4]. OSA has strong negative effects on families and society, so treating patients with OSA is very important.

Continuous positive airway pressure (CPAP) is the optimal treatment for OSA [5]. A meta-analysis found that CPAP can improve OSA patients' sleep quality [6]. CPAP may reduce the risk of cardiovascular complications and reduce the mortality of patients with severe obstructive sleep apnoea-hypopnoea syndrome (OSAHS) [7, 8]. Some studies have defined good CPAP adherence as use for at least 4 h per night and for more than 70% of nights [9] for the average daily CPAP treatment time within 1 month [10]. However, adherence to CPAP in patients with OSA is low. One study indicated that 25–50% of patients with OSAH patients had poor adherence to CPAP [11]. Another study reported that at 3 months of treatment, the rate of adherence was only 60% [12]. Lack of adherence to CPAP may cause complications that affect patients' quality of life and put great pressure on healthcare workers. A solution to this problem is needed. Some studies have found that telemedicine improves adherence to treatment in patients with chronic diseases [13, 14].

Telemedicine is defined as using telecommunications technology (such as a wireless modem, computer-based telecommunications system, or smartphone application) to provide health service information remotely and achieve remote communication between patients and medical staff [15]. The use of telemedicine to manage patients with OSA has been reported [16, 17]. However, the effects of telemedicine interventions on CPAP use in patients with OSA remain controversial. Some studies have reported that telemedicine interventions improve CPAP adherence in these patients [18–20], while other studies have found that they do not [21–23].

Because of these different findings, it is difficult to judge whether or not telemedicine interventions can improve CPAP adherence in patients with OSA. Therefore, we conducted a meta-analysis of randomised controlled trials (RCTs) to evaluate if telemedicine can improve CPAP compliance.

Methods

Our study had registered with the International Prospective Register of Systematic Reviews (PROSPERO), number CRD42020201043.

Literature search strategy

An electronic database search (including web platforms for registration of clinical trials) from January 2004 to February 2020 was performed using PubMed, the Cochrane Library, OVID, Web of Science, and EBSCO host. The following search terms were used: telemedicine OR telehealth OR e-health OR mobile health OR mobile application OR mobile apps OR Internet OR computer OR videoconferencing OR video recording OR telecommunication OR tele-management OR remote OR and sleep disordered breathing OR sleep apnea syndromes OR obstructive sleep apnea, sleep disordered breathing (OSA) and continuous Positive Airway Pressure OR CPAP and Random OR Randomized controlled trials (RCTs) (Fig. 1).

Study selection

Inclusion criteria were as follows:

(1) Patients were adults (age 18 years or older).
(2) Patients could use telemedicine intervention equipment (such as telephone, computerised systems for information exchange, Internet, etc.).
(3) Patients had been diagnosed with OSA [24], mainly based on medical history, signs, and polysomnography (PSG) results. Symptoms such as characteristic sounds, repeated sleep apnoea, superficial breathing, intermittent hypoxemia, and daytime sleepiness were present. PSG monitoring revealed that during 7 hours of sleep, incidents of apnoea were repeated ≥ 30 times, or the apnoea-hypopnoea index (AHI) was greater than or equal to 5 times/h.
(4) Patients were initiating or using CPAP therapy for OSA.
(5) Data were available on CPAP average usage per day (time/night) or mean adherence (minute per day).
(6) The study design was a randomised control trial and follow-up time was greater or equal to 1 month.

Exclusion criteria were as follows:

(1) The study design was not a randomised controlled trial (RCT).
(2) Patients could not use the telemedicine system and CPAP equipment.
(3) Duplicate publications.
(4) Incomplete data or no related outcomes.

Assessment of risk of bias

Two researchers independently screened the articles for inclusion and exclusion criteria. When there were

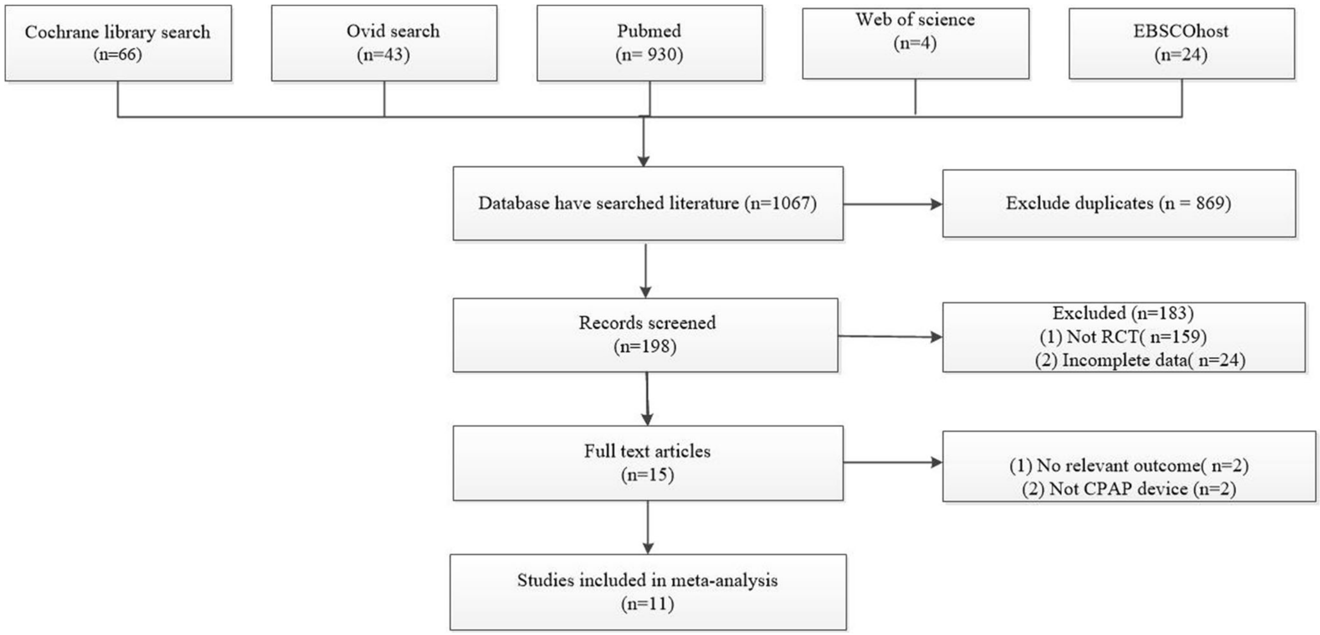


Fig. 1 Flow diagram of study selection

differences of opinion, a third researcher was consulted to resolve disagreements. The Cochrane Collaboration's tool [25] was used to evaluate the quality of the screened articles. If the study fully met the standard content of 7 items, the quality level was A; if the standards were partially met, the quality level was B; and if the standards were not at all met, the quality level was C.

Statistical analyses

The primary outcome was the improvement in CPAP adherence. Review Manager 5.3 software was used for this study for statistical analyses. The mean difference (MD) with 95% CI was used to pool continuous variable outcomes. Study heterogeneity was evaluated using the Cochran Q statistic and I^2 statistic. When the p value was > 0.05 and I^2 was < 50%, a fixed effects model was used; otherwise, a random effects model was used. When the value of I^2 was > 50% which is considered highly heterogeneous, subgroup analyses and sensitivity analyses will be used to analyze heterogeneity.

Results

Search results

Figure 1 presents the process of search and selection. In total, 1067 articles were found: 66 from the Cochrane Library, 4 from Web of Science, 43 from Ovid, 930 from PubMed and 24 from the EBSCO host. Only 11 articles met the inclusion and exclusion criteria [26–36] (Fig. 1).

Study characteristics

Tables 1 and 2 summarise the characteristics of the 11 studies [26–36]. This meta-analysis included study data from 1440 patients (telemedicine group n = 678; control group n = 680). Of the 11 studies, 6 were conducted in the USA, 2 in Spain and 1 each in Canada, France and Belgium. The intervention duration ranged from 1 to 6 months. The total number of participants ranged from 15 to 126 in the telemedicine groups and from 15 to 129 in the control groups. The mode of positive airway pressure was CPAP (see Table 1). Telemedicine interventions included a web platform, a universal telemonitoring unit, a computer-based telecommunications system and others (see Table 2). Most interventions involved patients using a telemedicine device to transmit data (CPAP time, mask leak, apnoea-hypopnoea index (AHI) and other OSA data) to the researchers' website, with the research team contacting patients to provide appropriate guidance or to set up a visit with a researcher if the data were abnormal (Table 2).

Risk-of-bias assessment

In 11 studies selected for this meta-analysis, 82% (9 of 11) presented adequate random sequence generation; 36% (4 of 11) reported allocation concealment; 0% (0 of 11) met the

Table 1 Summary of basic characteristics of the 11 studies

Study (ref)	Country	N (I: C)	AHI event/h	Mean age in years (SD) (I/C)	Males (%) (I/C)	Duration (months)
Hwang D et al., 2017 [26]	USA	125/129	AHI ≥ 5	48.8 11.8/51.9 ± 13.1	60.8/56.6	3
Turino C et al., 2017 [27]	Spain	52/48	AHI > 15	56 ± 13/54 ± 12	77/77	3
Stepnowsky C J et al., 2007 [28]	USA	20/20	AHI ≥ 15	60 ± 10.8/ 58 ± 13.7	Not reported	2
Taylor Y, et al. 2006 [29]	USA	59/62	AHI > 4	45.8 ± 10/44.6 ± 8.5	66/71	1
Fox N et al., 2012 [30]	Canada	28/26	AHI ≥ 15	52.0 ± 10.8/55.2 ± 11.5	82.0/77.8	3
Demolles D A et al., 2004 [31]	USA	15/15	AHI > 15	49.8 ± 15.7/42 ± 13	Not reported	2
Isetta V et al., 2015 [32]	Spain	64/64	49 (35–46)	51.0 ± 8.9/47.0 ± 10.9	85/87	6
Hoet F et al., 2017 [33]	Belgium	23/23	AHI ≥ 20	59 ± 13/54 ± 14	17/57	3
Stepnowsky C et al., 2013 [34]	USA	126/114	AHI ≥ 15	52.7 ± 13.4/51.5 ± 13.2	Not reported	4
Munafo D et al., 2016 [35]	USA	58/64	AHI > 15	52.3 ± 10.6/50.0 ± 11.7	72.5/65.2	3
Pépin JL et al., 2019 [36]	France	117/122	AHI > 30	60.8 [53.8; 66]/61.8[54.7;66.1]	73.2/74.5	6

Data are mean ± (SD) or mean; I, Intervention; C, Control; AHI, Apnoea-Hypopnea Index; OSA, obstructive sleep apnoea; median (1st quartile–3rd quartile), median [25th; 75th percentiles]

criteria of blinding of participants and personnel; 9% blinded assessment of outcomes (1 of 11); and 73% presented incomplete outcome data (8 of 11). The methodological quality summary is shown in Table 3.

Meta-analysis of CPAP adherence

CPAP adherence was the main outcome. All 11 studies [26–36] (n = 1358) reported that the use of telemedicine interventions significantly improved CPAP adherence when compared to controls (pooled MD = 0.57; 95% CI = 0.33 to 0.80; I^2 = 7%; $P < 0.00001$; see Fig. 2).

Results of sensitivity analyses

Sensitivity analyses by type of telemedical intervention

Four types of telemedical intervention were used in the 11 studies: computer software (n = 2, 18%), Internet-based monitoring systems (n = 5, 46%), wireless modems (n = 3, 27%) and a smart device (n = 1, 9%). We performed sensitivity analyses to explore if the types of intervention were important in terms of effect sizes on the timing of CPAP use. We sequentially omitted individual studies. The pooled weighted mean difference ranged from 0.52 (95% CI 0.28 to 0.76) to 0.62 (95% CI 0.37 to 0.86). This analysis did not change the statistical significance of the pooled estimate.

Sensitivity analyses by comorbidity burden

Of the 11 studies, 1 [33] described the OSA comorbidities; the other 10 did not. Therefore, we performed sensitivity analyses after omitting that study to explore whether or not heterogeneity was evident. The heterogeneity was MD = 0.52, 95% CI = 0.28 to 0.76; I^2 = 0%; $p < 0.0001$. When we sequentially omitted the other studies individually, the pooled estimate did not affect the statistical significance.

Sensitivity analyses by severity of OSA

The OSA classification of the 2013 American College of Physicians (ACP) adult OSA management guidelines is as follows: no OSA, AHI < 5/h; mild OSA, 5/h < AHI < 15/h; moderate OSA, 15/h < AHI < 30/h; and severe OSA, AHI > 30/h [37]. Of the 11 studies, only one [36] dealt with severe OSA. The other studies did not specify OSA classifications. We performed sensitivity analyses omitting that single study to explore whether or not OSA severity affected CPAP use. The heterogeneity was low ($I^2 < 50\%$). The statistical significance of the pooled estimate was not affected.

Results of subgroup analyses

We performed subgroup analyses by follow-up duration, age, and ESS scores.

Subgroup analyses by follow-up duration

When we compared patients on CPAP therapy for 1 to 3 months (8 studies, 751 patients) and 4 to 6 months (3 studies, 607 patients), the heterogeneities were low (MD = 0.61, 95% CI = 0.30 to 0.92; I^2 = 25%; $p < 0.0001$,vs. MD = 0.50, 95% CI = 0.14 to 0.86; I^2 = 0%; p = 0.006, Fig. 3). The statistical significance of the pooled estimate was not affected.

Table 2 Characteristics of study interventions

Author, year	Device	Intervention description	Follow-up (months)	Main outcomes
Hwang D et al., 2017 [26]	The cloud-based application (U-Sleep, ResMed Inc)	When receiving their CPAP device, patients were educated about the automated feedback process and asked to state their preferred method for receiving messages (text messaging, email, phone call, etc.). If CPAP usage thresholds were met, a message was automatically sent to the patient providing encouragement to improve use or positively reinforcing successful adherence [26].	3 months	CPAP adherence
Turino C et al., 2017 [27]	Mobile 2G (GSM/GPRS) technology	Each CPAP device given to patients was equipped with mobile 2G (GSM/GPRS) technology capable of sending daily information on CPAP adherence, CPAP pressures and mask leak etc. events to the MyOSA–Oxigen Salud web database (www.oxigensalud.com). In case of alarm, the pulmonary specialist medical officer of the CPAP provider contacted the patient, providing case-by-case problem solving [27].	3 months	CPAP adherence
Stepnowsky C J et al., 2007 [28]	A ResTraxx wireless transmitter (ResMed Corp, Poway, CA)	The wireless telemonitoring system was used by patients to monitoring and uploading data about compliance adherence, AHI and mask leak etc. data. The clinical team would check the CPAP compliance and efficacy data values on the ResTraxx Data Center website for each patient, if the data was abnormal, they would take intervention measures to treat patients [28].	2 months	CPAP adherence
Taylor Y, et al. 2006 [29]	A home computer called “Health Buddy”	The telemedicine group received a “Health Buddy” computer that provided patients daily internet based informational support and feedback for problems experienced with CPAP use [29].	1 month	CPAP adherence
Author, year	Apparatus	Intervention	Follow-up (months)	Main outcomes
Fox N et al., 2012 [30]	A web-based modem	The modem was programmed to send physiologic information directly to a web-based database across the telephone line each morning related indicators. Patients were contacted by the research coordinator after 2 days to ask about progress and compliance, and to troubleshoot any problems with the machine [30].	4-6 week, 3 months	CPAP adherence
Demolles D A et al., 2004 [31]	A computer-based telecom-munications system	Use telephone-Linked communication (TLC) system asks questions, monitors the patients, self-reported behaviour, and provides education and behavioural reinforcement for targeted health-related behaviours [31].	2-week, 2 months	CPAP adherence
Isetta V et al., 2015 [32]	A website	Patients received their follow-up at home supported by a website developed, where they could find information about OSA and CPAP therapy, and a biweekly six-item questionnaire about their status, physical activity, sleep time, CPAP use and treatment side effects [32].	1,3 and 6 months	CPAP adherence
Hoet F et al., 2017 [33]	The General Packet Radio Service (GPRS) network	Patients use of T4P CPAP device through the General Packet Radio Service to via transmission of data (including mask leaks, CPAP pressure, and residual AHI via et al) (GPRS) network. When these data were abnormal, sleep laboratory technical staff were required to call the patient and to set up a visit with the staff [33].	2 times a week, 3 months	CPAP adherence
Author, year	Device	Intervention	Follow-up	Main outcomes
Stepnowsky C et al., 2013 [34]	A wireless modem	A wireless modem was attached to patients CPAP device, which could then send the data from the device to a Web-portal accessible by sleep research team. When data were abnormal the sleep physician will provide guidance to patients [34].	1 week, 1 month, 4 months	CPAP adherence
Munafo D et al., 2016 [35]	U-Sleep (ResMed Corp) Program	Clinicians remotely monitor their patients’ progress using U-Sleep technology via metrics including daily usage, apnoea-hypopnea index (AHI) values, and leak. When CPAP usage falls, e-mail and text messages are sent to encourage patients to use CPAP more regularly [35].	When CPAP usage falls and 3 months	CPAP adherence
Pépin JL et al., 2019 [36]	Telemonitoring equipment	Secured data transmission from the physiological sensors and patient reported outcomes to the medical staff members’ computers and secured websites allowed for easy telemonitoring, providing a complete integrated care management system [36].	At day 8 and 1 and 6 months.	CPAP adherence

CPAP adherence: the average daily CPAP treatment time within 1 month, >4 h is good compliance [10] (use of CPAP for 4 h·day−1) AHI: apnoea-hypopnea index

Table 3 Risk of bias of included studies (n = 11)

Author, year	1	2	3	4	5	6	7	8
Hwang D et al., 2017 [26]	Low	High	Unclear	Unclear	Low	Low	Unclear	B
Turino C et al., 2017 [27]	Low	Unclear	Unclear	Unclear	Low	Low	Unclear	B
Stepnowsky C J et al., 2007 [28]	Low	Low	Unclear	Unclear	Low	Low	Unclear	B
Taylor Y, et al. 2006 [29]	Low	Low	Unclear	Unclear	Low	Low	Unclear	B
Fox N et al., 2012 [30]	Low	Low	Unclear	Unclear	Unclear	Low	Unclear	B
Demolles D A et al., 2004 [31]	Unclear	Unclear	Unclear	Unclear	Low	Low	Unclear	B
Isetta V et al., 2015 [32]	Low	Low	Unclear	Unclear	Low	Low	Unclear	B
Hoet F et al., 2017 [33]	Low	Unclear	Unclear	Unclear	Unclear	Low	Unclear	B
Stepnowsky C et al., 2013 [34]	Unclear	Unclear	High	Low	Unclear	High	Unclear	B
Munafo D et al., 2016 [35]	Unclear	Unclear	Unclear	Unclear	High	Low	Unclear	B
Pépin JL et al., 2019 [36]	Low	High	High	Low	Low	Low	Unclear	B

1: Random sequence generation; 2: Allocation concealment; 3: Blinding of participant and personnel; 4: Blinding of outcome assessment; 5: Incomplete outcome data; 6: Selective reporting; 7: Other bias; 8: Quality grade

Subgroup analyses for ages

The second subgroup analysis stratified ages; in one study, 36 were excluded, because its data cannot be merged. We found that patients less than 50 years old OSA patients use CPAP (3 studies, 398 patients) versus more than 50 years old use CPAP (7 studies, 673patients) demonstrated that the heterogeneity were (MD = 0.47, 95% CI = 0.02 to 0.92; I^2 = 13%; p = 0.04, vs. MD = 0.69, 95% CI = 0.36 to 1.02; I^2 = 28%; p < 0.0001, Fig. 4). This result found that ages have small heterogeneity (I^2 < 50%), and the results did not affect OSA patients use CPAP.

Subgroup analyses by ESS score

Six of the eleven studies used the ESS to evaluate daytime sleepiness. We subjected the ESS scores to subgroup analyses. We found that use/non-use of the ESS (6 studies, 955 patients; 5 studies, 403 patients, respectively) was associated with low heterogeneity (MD = 0.62, 95% CI = 0.34 to 0.91; I^2 = 0%; p < 0.0001, vs. MD = 0.45, 95% CI = 0.05 to 0.86; I^2 = 30%; p = 0.03, Fig. 5). The use of CPAP therapy was not affected.

Publication bias

A funnel plot showed symmetric distribution of data around the average, which suggested the absence of publication bias (Fig. 6).

Discussion

This meta-analysis of 11 studies [26–36] with 1358 patients revealed that telemedicine interventions may improve CPAP adherence in patients with OSA compared to no intervention.

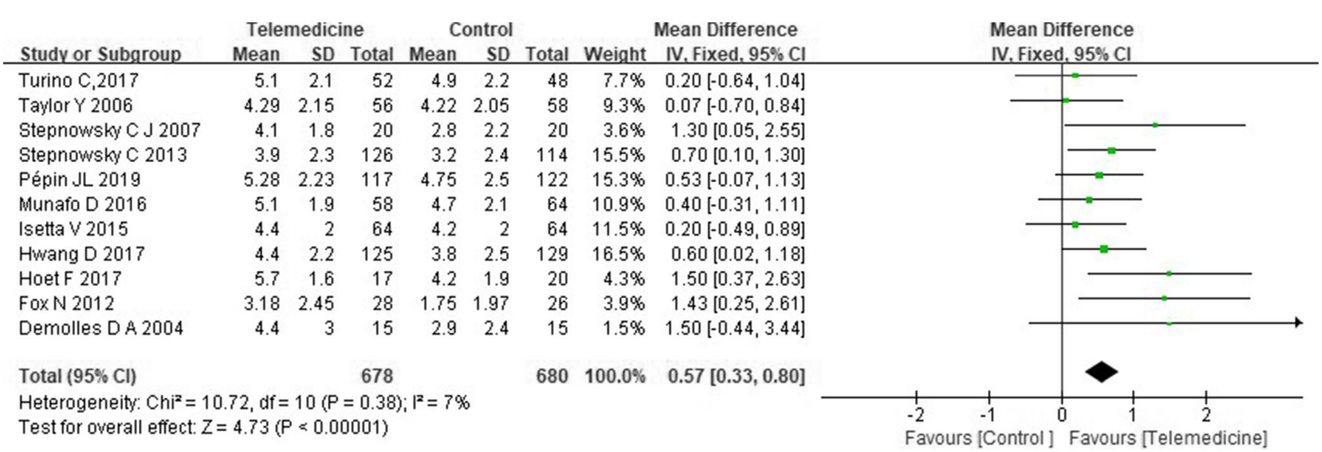


Fig. 2 Forest plot showing results

Study or Subgroup	Telemedicine Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
1.2.2 1-3 months follow up								
Turino C,2017	5.1	2.1	52	4.9	2.2	48	7.7%	0.20 [-0.64, 1.04]
Taylor Y 2006	4.29	2.15	56	4.22	2.05	58	9.3%	0.07 [-0.70, 0.84]
Stepnowsky C J 2007	4.1	1.8	20	2.8	2.2	20	3.6%	1.30 [0.05, 2.55]
Munafo D 2016	5.1	1.9	58	4.7	2.1	64	10.9%	0.40 [-0.31, 1.11]
Hwang D 2017	4.4	2.2	125	3.8	2.5	129	16.5%	0.60 [0.02, 1.18]
Hoet F 2017	5.7	1.6	17	4.2	1.9	20	4.3%	1.50 [0.37, 2.63]
Fox N 2012	3.18	2.45	28	1.75	1.97	26	3.9%	1.43 [0.25, 2.61]
Demolles D A 2004	4.4	3	15	2.9	2.4	15	1.5%	1.50 [-0.44, 3.44]
Subtotal (95% CI)			**371**			**380**	**57.7%**	**0.61 [0.30, 0.92]**
Heterogeneity: Chi² = 9.35, df = 7 (P = 0.23); I² = 25%								
Test for overall effect: Z = 3.89 (P < 0.0001)								
1.2.3 4-6months follow up								
Stepnowsky C 2013	3.9	2.3	126	3.2	2.4	114	15.5%	0.70 [0.10, 1.30]
Pépin JL 2019	5.28	2.23	117	4.75	2.5	122	15.3%	0.53 [-0.07, 1.13]
Isetta V 2015	4.4	2	64	4.2	2	64	11.5%	0.20 [-0.49, 0.89]
Subtotal (95% CI)			**307**			**300**	**42.3%**	**0.50 [0.14, 0.86]**
Heterogeneity: Chi² = 1.16, df = 2 (P = 0.56); I² = 0%								
Test for overall effect: Z = 2.73 (P = 0.006)								
Total (95% CI)			**678**			**680**	**100.0%**	**0.57 [0.33, 0.80]**
Heterogeneity: Chi² = 10.72, df = 10 (P = 0.38); I² = 7%								
Test for overall effect: Z = 4.73 (P < 0.00001)								
Test for subgroup differences: Chi² = 0.21, df = 1 (P = 0.65), I² = 0%								

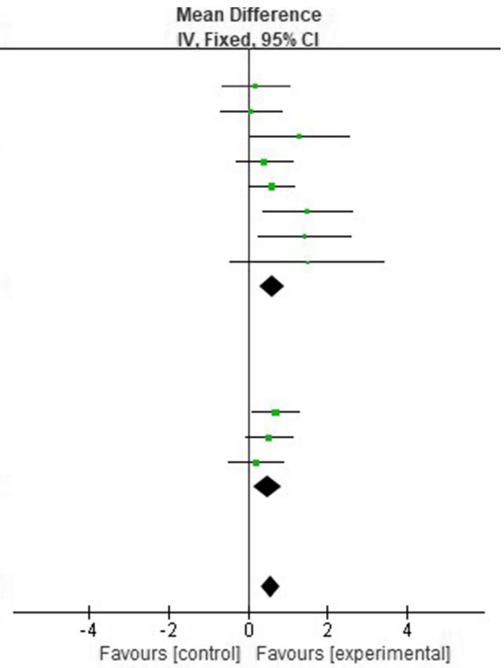


Fig. 3 Subgroup analyses for follow up duration

Using the 11 studies, we performed sensitivity analyses by the type of telemedical intervention, comorbidity burden and OSA severity. We performed subgroup analyses by follow-up duration, age and use of the ESS. We found nothing to suggest that telemedicine was inappropriate. The among-study heterogeneities were small; telemedicine improved adherence with CPAP therapy. Poor adherence with CPAP therapy has been associated with certain patient characteristics (such as age), disease characteristics (symptom severity), side effects of CPAP use (skin irritation, dry nose or mouth), titration procedures and psychosocial factors (mental health issues, self-perceived efficacy and social support) [38–41]. Faced with these problems, what can physicians and nurses do? Patient characteristics cannot be changed. CPAP side effects, treatment titration procedures and psychosocial factors may receive intervention. A study on the effects of telemedicine intervention on CPAP side effects in patients with OSA found that only dry

Study or Subgroup	Telemedicine Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
1.3.2 Less than 50 years old								
Demolles D A 2004	4.4	3	15	2.9	2.4	15	1.9%	1.50 [-0.44, 3.44]
Hwang D 2017	4.4	2.2	125	3.8	2.5	129	21.4%	0.60 [0.02, 1.18]
Taylor Y 2006	4.29	2.15	56	4.22	2.05	58	12.0%	0.07 [-0.70, 0.84]
Subtotal (95% CI)			**196**			**202**	**35.3%**	**0.47 [0.02, 0.92]**
Heterogeneity: Chi² = 2.30, df = 2 (P = 0.32); I² = 13%								
Test for overall effect: Z = 2.04 (P = 0.04)								
1.3.3 More than 50 years old								
Fox N 2012	3.18	2.45	28	1.75	1.97	26	5.1%	1.43 [0.25, 2.61]
Hoet F 2017	5.7	1.6	17	4.2	1.9	20	5.6%	1.50 [0.37, 2.63]
Isetta V 2015	4.4	2	64	4.2	2	64	14.9%	0.20 [-0.49, 0.89]
Munafo D 2016	5.1	1.9	58	4.7	2.1	64	14.2%	0.40 [-0.31, 1.11]
Stepnowsky C 2013	3.9	2.3	126	3.2	2.4	114	20.2%	0.70 [0.10, 1.30]
Stepnowsky C J 2007	4.1	1.8	20	2.8	2.2	20	4.6%	1.30 [0.05, 2.55]
Turino C,2017	5.1	2.1	52	4.9	2.2	0		Not estimable
Subtotal (95% CI)			**365**			**308**	**64.7%**	**0.69 [0.36, 1.02]**
Heterogeneity: Chi² = 6.97, df = 5 (P = 0.22); I² = 28%								
Test for overall effect: Z = 4.06 (P < 0.0001)								
Total (95% CI)			**561**			**510**	**100.0%**	**0.61 [0.34, 0.88]**
Heterogeneity: Chi² = 9.88, df = 8 (P = 0.27); I² = 19%								
Test for overall effect: Z = 4.47 (P < 0.00001)								
Test for subgroup differences: Chi² = 0.60, df = 1 (P = 0.44), I² = 0%								

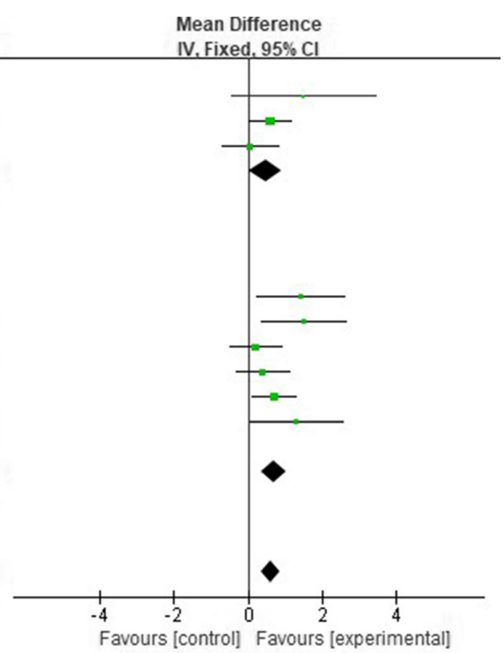


Fig. 4 Subgroup analyses for ages

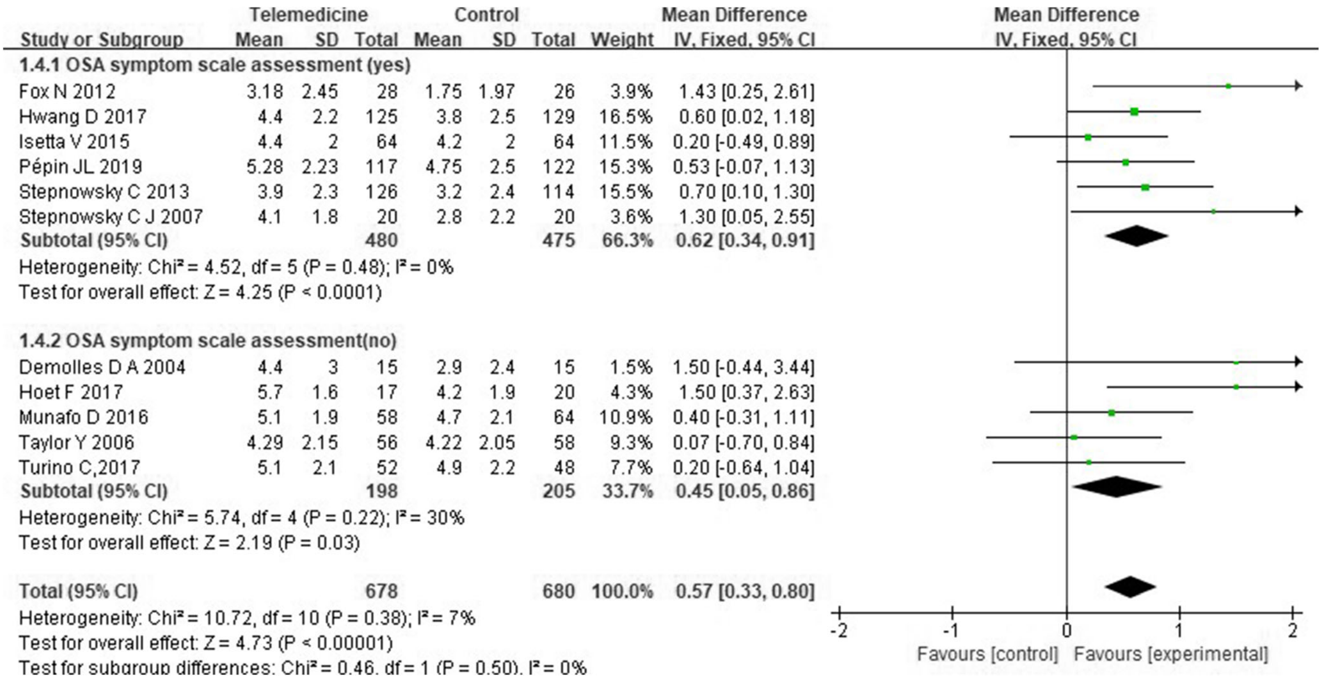
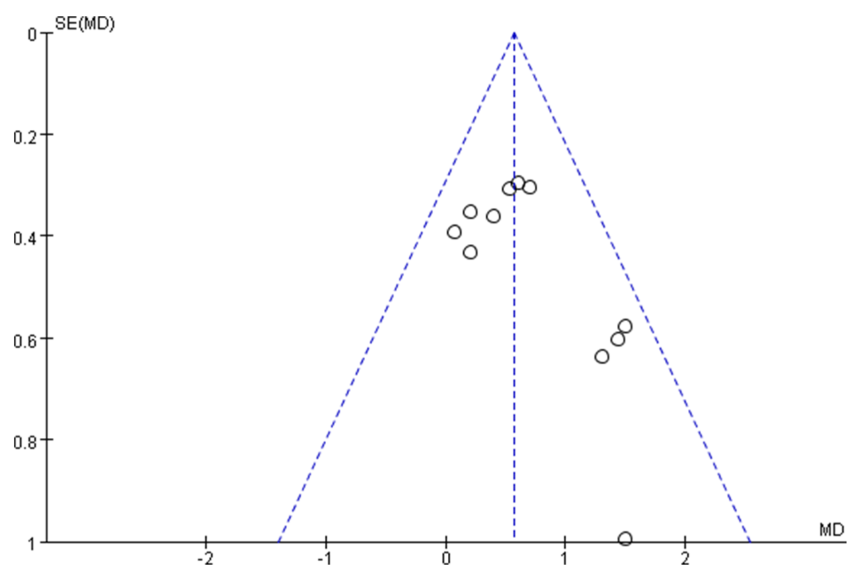


Fig. 5 Subgroup analyses for OSA ESS symptom scale assessment

mouth was statistically significant ($p < 0.05$) [30]. Other side effects such as frequent awakenings, discomfort, and difficulty falling asleep were not significant ($p > 0.05$) [30]. The sample sizes were only 28 in the telemedicine group and 26 in the control group. The follow-up time was 3 months. Future studies should enroll larger sample sizes and extend the follow-up time [30]. Gentina found that marriage quality and partner engagement affected nightly CPAP use and, thus, adherence to therapy [42]. One study found that the support of and frequent interaction with a partner improved program satisfaction and increased CPAP use after 90 days of treatment compared to usual care [43].

CPAP can decrease apnoea-hypopnoea index (AHI) and improve sleep quality [44]. One study that analysed the effects of CPAP treatment in patients with OSA with various levels of adherence found that sleep quality and blood pressure improved more with good adherence [45]. Two studies found that OSA patients who used CPAP treatment daily had a significant improved quality of life, less daytime sleepiness and greatly reduced risk factors [46, 47]. Therefore, CPAP adherence can influence the effects of CPAP treatment [18, 48, 49].

Fig. 6 Funnel plot of CPAP adherence



Our meta-analysis revealed that telemedicine may improve CPAP adherence in patients with OSA. Telemedicine devices can upload daily data related to factors such as CPAP adherence, CPAP pressure, and mask leaks to the sleep laboratory's platform. When researchers determine that data are abnormal, they are able to contact patients via the network platform or call them to provide professional guidance for behavioural intervention. These measures can help improve knowledge and confidence in patients, thereby improving their CPAP adherence.

Our results support those of previously published systematic reviews [50]. One previous review found that a web-based patient-facing application (PFA) was associated with improved adherence to PAP therapy. However, that review only included two RCTs focusing on PFA use. In contrast, we included 11 RCTs focusing on telemedicine; our sample was larger than that in the previous analysis, and intervention device content was more varied (including wireless modems, telephone-linked communication (TELE) systems and smartphone applications). Another meta-analysis [51] of five RCTs (n = 269 patients) found that teleconsultation/telemonitoring improved CPAP adherence in two trials (n = 19; n = 75), while no between-group differences were observed in two trials (n = 114; n = 75). Additionally, their search ended with papers published in November 2015. In contrast, our meta-analysis of 11 RCTs extended to February 2020 and included teleconsultation and telemonitoring.

Our meta-analysis had potential limitations. First, none of the 11 RCTs included blinded participants and personnel, which may have led to implementation bias or measurement bias. However, one study noted that lack of blinding was unlikely to affect an objectively assessed outcome [52]. Second, our meta-analysis included different types and durations of interventions, with no long-term follow-up (≥ 1 year), so it is unclear whether or not the results could be generalised to long-term follow-up. Third, we did not search for so-called grey literature; we only searched for published literature starting from January 2004.

Conclusions

This meta-analysis revealed that telemedicine interventions may be successfully used to support CPAP adherence in patients with OSA.

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