Home telemonitoring in COPD: a systematic review of methodologies and patients' adherence

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Research Highlights

- Telemonitoring interventions should to be adjusted to their target population;
- Assessment of patients' acceptance of telemonitoring technology should be considered prior to its implementation;
- Future research should consider the inclusion of easy-to-use technology and more training sessions;
- Frequency of data collection/transmission should be flexible to improve adherence;
- Changes in patients' self-management behavior should be explored in future studies.

Summary Points

What is already known on the topic:

- The number of patients with COPD being managed at home is increasing to reduce health-related costs while trying to increase patients' comfort;
- Home telemonitoring is an innovative approach which facilitates patients' management at home, by exchanging information between patients and their healthcare professionals;
- There are systematic reviews available on the topic of home telemonitoring in respiratory patients and, specifically, in patients with COPD. However, they lack information about telemonitoring methodologies and patients' adherence.

What has this study added to our knowledge:

- Home telemonitoring interventions, although promising, still need to be adjusted to ensure their suitability to the target population. Assessment of patients' needs, characteristics and acceptance of the technology may facilitate patients' adherence to telemonitoring regimens;
- Future home telemonitoring interventions for COPD should consider the inclusion of easy-to-use technology and more training sessions to facilitate patients' education on the use of the technologies, and they should be flexible in frequency of data collection and transmission to improve adherence;
- The impact of telemonitoring interventions on patients' self-management behavior and satisfaction should also be explored, as well as their associations with patient outcomes and healthcare utilization.

ABSTRACT

Aim: This systematic review aimed to provide a comprehensive description of the methodologies used in home telemonitoring interventions for Chronic Obstructive Pulmonary Disease (COPD) and to explore patients' adherence and satisfaction with the use of telemonitoring systems.

Methods: A literature search was performed from June to August and updated until December of 2012 on Medline, Embase, Web of Science and B-on databases using the following keywords: [tele(-)monitoring, tele(-)health, tele(-)homecare, tele(-)care, tele-home health or home monitoring] and [Chronic Obstructive Pulmonary Disease or COPD]. References of all articles were also reviewed.

Results: Seventeen articles were included, 12 of them published from 2010 to the present. The methodologies were similar in the training provided to patients and in the data collection and transmission processes. However, differences in the type of technology used, telemonitoring duration and provision of prompts/feedback, were found. Patients were generally satisfied and found the systems useful to help them manage their disease and improve healthcare provision. Nevertheless, they reported some difficulties in their use, which in some studies were related to lower compliance rates.

Conclusions: Telemonitoring interventions are a relatively new field in COPD research. Findings suggest that these interventions, although promising, present some usability problems that need to be considered in future research. These adjustments are essential before the widespreading of telemonitoring.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a highly prevalent disease worldwide [1]. As the disease progresses, patients become more susceptible to respiratory exacerbations which cause frequent hospital admissions and readmissions and, thus, have a considerable impact on patients' quality of life and healthcare costs [2, 3]. This poses COPD as a public health problem of increasing concern to healthcare systems worldwide [4]. A number of interventions have been developed to help patients self-manage their disease and improve their quality of life, therefore reducing pressures on healthcare resources. Recent studies have shown that the number of patients with COPD being managed at home is increasing to reduce health-related costs while trying to increase patients' comfort [5].

Home telemonitoring is a relatively new approach (dating back to the early 1990s) which facilitates patients' management at home [6]. It is defined as the use of telecommunication technologies to transmit data on patients' health status (e.g., oxygen saturation, vital signs) from home to a healthcare center [6, 7]. By systematically monitoring patients' health condition, home telemonitoring can be used for a timely assessment of an acute exacerbation or as a mechanism to generate alarms to the patients and/or healthcare professionals when clinical changes that may constitute a risk to the patient occur [8]. This approach aims to empower patients to manage their disease (e.g., by recognizing the early signs of exacerbations), improve patient-professional interactions and prevent unplanned hospital admissions [8, 9].

Five systematic reviews are available on the topic of home telemonitoring in respiratory patients [7] and, specifically, in patients with COPD [5, 10-12]. However, they focus on clinical outcomes (e.g., quality of life) [7, 11, 12], reduction in healthcare service utilization [5, 7, 11, 12], feasibility and use [7], and on economic [5, 7] and organizational [10] impacts of telemonitoring. None of these studies provides a comprehensive description of the

telemonitoring methodologies, which is essential to enhance the design of future telemonitoring interventions and facilitate comparisons between studies. Furthermore, optimal interventions require patients' adherence [13], but there is still limited information about adherence to telemonitoring in COPD research. Previous studies on telemonitoring in different health conditions have suggested that adherence is related to patients' satisfaction with the telemonitoring regimens [14-16], so satisfaction should be considered when assessing patients' adherence. Thus, this systematic review aimed to: (1) provide a comprehensive description of the methodologies used in home telemonitoring for COPD and; (2) describe the current state of literature on patients' adherence and satisfaction with the use of telemonitoring systems.

METHODS

Information sources and search strategy

A literature search was performed from June to August of 2012 in the medical databases Medline (1948-2012) and Embase (1974-2012) and wide-ranging scientific databases Web of Science (1970-2012) and B-on Online Knowledge Library (1999-2012). These databases were included to ensure that all relevant articles were retained. Search terms were based on a combination of the following keywords: [tele(-)monitoring or tele(-)health or tele(-)homecare or tele(-)care or tele-home health or home monitoring] and [Chronic Obstructive Pulmonary Disease or COPD]. Search was customized for each database according to their filtering specificities. Additional searches for relevant studies were performed within the bibliography of the selected articles and weekly automatic updates retrieved from the databases until December of 2012.

Eligibility criteria and study selection

This systematic review is structured according to Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) guidelines [17, 18]. Eligible studies included adult people with a diagnosis of COPD whose health condition was telemonitored at home. Home telemonitoring was defined according to the following criteria [6, 7]: i) patients or their caregivers had to periodically record patients' clinical data (e.g., physiological signs or symptoms) at home; ii) these data had to be transmitted using telecommunication technologies from patients' home to a monitoring center. Studies were excluded if they: i) included patients with diseases other than COPD (i.e., the intervention was not specific to COPD population); ii) included only regular telephone calls, video-consultation or teleconference interventions without telemonitoring clinical data; iii) involved downloading the data during healthcare visits or at the end of the study; iv) were limited to a technical description of the technology employed; vi) provided telemonitoring in other places than patients' home. Studies without information on patients' adherence and satisfaction were still retained in the review to enable a full description of the methodologies used in home telemonitoring (the first aim of the paper). In this review, the term *adherence* followed the definition proposed by the World Health Organization (2003) [13] and consisted of the extent to which the patient's behavior corresponds to the recommendations provided by the monitoring center regarding the use of the telemonitoring technology. The studies considered for review were randomized controlled trials (RCTs) and quasi-experimental studies; observational studies which did not include a telemonitoring intervention and case studies were excluded. Non-original articles (e.g., review papers, editorials, commentaries to articles, study protocols) and abstracts of communications or meetings were not considered suitable and, therefore, were excluded from this review although their reference list was reviewed closely. Papers without abstracts or written in languages other than English, Portuguese and Spanish were also excluded.

Study selection followed the stages recommended by the guidelines for conducting systematic reviews [19]. Initial screening of articles was based on type of publication and relevance for the scope of the review according to their title, abstract and keywords. Then, the full-text of potentially relevant articles was screened for content to decide its inclusion in the review. Studies with multiple publications were identified to avoid duplicate reports.

Data collection process

One reviewer extracted the data from the included studies and a second reviewer checked the extracted data. Disagreements were resolved by discussion between the two reviewers. Data were extracted in a structured table-format (developed prior to data collection) according to the following topics: first author's last name and year of publication, study design, country where the study was conducted, participants, type(s) of intervention(s), telemonitoring methodology, patients' adherence and satisfaction. The telemonitoring methodology data were synthesized in sub-categories: i) telemonitoring duration; ii) type of technology; iii) patients' training to use the system; iv) data collection and transmission; v) use of prompts, reminders and/or feedback and detection of health deterioration. Patients' adherence was obtained by accessing dropout and compliance rates of patients who participated in the telemonitoring interventions. When available, reasons for non-adherence were also collected. Meta-analyzes could not be performed due to the nature of the data collected (description of methodologies) and lack of comparable outcomes to measure patients' adherence and satisfaction. Instead, a narrative synthesis was employed to synthesize the findings [20].

Quality assessment

Quality of studies was formally assessed according to the guidelines for conducting systematic reviews [19], using a modified version of the scoring system developed by Hailey et al. [21] to

evaluate telemedicine research. This modified version was summarized in a recent systematic review on COPD [12] and consists of 5 levels, from grade A (high quality) to E (poor quality), taking into consideration the study design and performance. For study design, scores were assigned to 4 types of study: large RCTs (≥50 subjects in each arm), small RCTs, prospective non-randomized studies and retrospective studies. For study performance, five areas of interest were considered: patient selection, description/specification of the intervention, specification and analysis of study, patient disposal and outcomes reported.

The quality of studies was independently assessed by two reviewers and inter-rater agreement calculated using the Cohen's kappa coefficient. The kappa values can be interpreted as [22]: slight agreement (≤0.20), fair agreement (0.21–0.40), moderate agreement (0.41–0.60), substantial agreement (0.61–0.80) and almost perfect agreement (≥0.81). Disagreements between reviewers were resolved by consensus.

RESULTS

Study selection

The database search identified 455 records. After duplicates removal, 130 records were screened for relevant content. During title, abstract and keyword screening, 109 articles were excluded due to the following reasons: non-original articles (n=55), case studies (n=3), no abstract provided (n=6), inclusion of non-COPD patients (n=17), absence of telemonitoring interventions (n=22) and other languages rather than English, Portuguese or Spanish (n=6). The full-text of the 21 potentially relevant articles was assessed and 8 articles were excluded. Reasons for exclusion included: no telemonitoring information (n=4), laboratory testing of the system (n=2), participants with diseases other than COPD (n=1) and provision of teleconsultations alone (n=1). Automatic updates from the databases and search for relevant articles within the bibliography of selected articles retrieved 4 articles, which were also

included (Figure 1). From the articles included in the analysis, eight were identified as referring to the same studies: 2 articles per study in 2 studies [23-26] and 4 articles pertaining to a single study [27-30]. In total, 17 articles on 12 studies were included, all published in English.

(Insert Figure 1 about here)

Study characteristics

Study characteristics are presented in Table 1. Most studies were randomized controlled trials (n=5), followed by uncontrolled before-and-after studies (n=4) and non-randomized controlled trials (n=3). Sample sizes varied from 20 to 165 patients with COPD, mostly older people. Ten studies included specifically patients in advanced stages of the disease. Most studies recruited patients during/following hospital admission or those receiving specialized care at the hospital or at home.

In 6 studies, the intervention consisted of telemonitoring clinical data plus other health care components such as: in-home nurse visits (n=1), virtual visits/consultations or regular telephone calls from the healthcare team (n=5) or provision of education (n=5).

(Insert Table 1 about here)

Quality assessment

Quality levels differed across articles: 4 were rated A (high quality) [26-28, 31], 7 were rated B (good quality) [25, 32-37], 5 were rated C (fair to good quality) [23, 24, 29, 30, 38] and 1 was rated E (poor quality) [39]. The articles rated as A and 3 articles rated as B [25, 32, 33] were referring to randomized controlled trials. Cohen's kappa coefficient revealed substantial agreement between raters (K=0.78, p=0.001) for study quality levels.

Description of telemonitoring methodology

Telemonitoring duration

The length of the telemonitoring period ranged from 2 to 12 months (Table 1). While 8 studies defined a specific period for telemonitoring, 2 reported that the duration was defined according to patients' needs.

Technology

The telemonitoring systems were different across studies (Table 1). Some studies provided detailed information about them, including the peripheral devices that could be connected to a main device, such as: oximeters (n=5), spirometers (n=3), blood pressure monitors (n=1), thermometers (n=1), electrocardiographs (n=1), respiratory rate sensors (n=1) and/or electronic stethoscopes (n=1). The main device was frequently a mobile/web phone with an integrated touch-screen (n=4) or a touch-screen computer (n=1) that allowed patients to record data collected via the peripheral devices and/or to answer questions about their symptoms and disease management. Two studies used the same main device, which also provided patients with information about the disease and/or educational questions to answer regularly.

Patients' training

Training to use the telemonitoring systems was described in 9 studies (Table 2). Four studies reported that patients were trained in their homes during the initial home visit by a nurse working in the telemonitoring project. Patients had to demonstrate the use of the system in 3 studies and they received information about the normal clinical parameters in only 1 study. In 2 studies, ongoing support could be given according to patients' needs.

(Insert Table 2 about here)

Data collection and transmission

Table 3 summarizes the clinical data collected through the telemonitoring systems. The most common parameters collected were symptoms (n=9), oxygen saturation (n=8), spirometric parameters (n=6), medication (n=6), heart rate (n=5), temperature (n=3) and weight (n=3).

(Insert Table 3 about here)

Data collection process was similar across studies. Answers to symptoms and self-management questions (e.g., changes in medication, patient knowledge about COPD) were performed manually using touch-screen monitors. Regarding clinical data, it was not always clear if the information had to be inserted manually or if the process was automatic (i.e., the peripheral devices enabled automatic data transfer to the main device). Four studies required data collection at a specific time of the day and in 2 studies the data were collected more than once per day (Table 3).

Data were transmitted on a daily basis in almost all studies. This process was usually performed via telephone line to a secure server, either on real time (n=2) or at a specific time of the day (n=2). Data were received in a healthcare center, call center or manufacturer center. There, healthcare professionals could monitor the data, generally on a daily basis (Table 2). In 6 studies, the information transmitted was automatically analyzed and alerts were sent to healthcare professionals and/or researchers when readings fell outside pre-established parameters. When data were not transmitted on consecutive days, patients were contacted via telephone call (n=3) or via message in the monitor screen (n=1).

Reminders, feedback and detection of health deterioration

Three studies provided reminders or prompts via the telemonitoring system to patients (Table 2). Prompts consisted of step-by-step instructions to help patients complete the

measurements and/or questions or instructions to attach a peripheral to the main device. One study provided patients with a medication and pursed-lip breathing reminder.

Two types of automatic feedback could be given by the systems: feedback about blank and/or correct/incorrect answers (n=1) or alerts when readings fell outside pre-established parameters (n=3). When deterioration of health condition was detected, patients could contact the healthcare professionals (n=1) or be contacted via telephone calls (n=9). Patients' answers about their health condition could determine the next action to be taken (Table 2): contact of a physician to make a decision about treatment (n=4) or providing patients with an action plan and an emergency supply of medication to commence as soon as an exacerbation was recognized (n=2).

Patients' adherence and satisfaction

Compliance and dropout rates

Since these data were intended to inform about the adherence of patients to telemonitoring regimens, information about the control groups (if it existed) was not included.

All studies provided information on patient dropouts. From these, only 3 provided information on dropouts before intervention [23, 25, 31]. Reasons for withdrawal included [31]: worsening of patient's physical condition, financial-related reasons (patients did not have enough money to attend the follow-up and to afford the additional cost of recharging the batteries of the device every other day), refusal to use the belt for measuring respiratory rate in cold weather, the device was too difficult to carry around at work or the frequency of telemonitoring was too demanding (i.e., 3 times/day on weekdays).

Five of the studies which provided dropout information during the intervention period had a high number of dropouts (≥20%) and/or low compliance rates (≤80%) [23, 31, 32, 36, 37], while 5 reported low dropout rates [27, 33-35, 38]. The frequency of data transmission was

related to lower compliance rates in one study. Chau et al. [31] found that patients' compliance rates were high when data were transmitted once per day (98% for oxygen saturation and 83% for respiratory rate), but they decreased when the frequency was the recommended 3 times a day (79% and 60%, respectively).

Overall, dropout reasons were related to usability problems (n=2) [23, 37] and technical problems with the system or the telephone line (n=3) [33, 35, 37]. Other reasons not related to the telemonitoring system itself included the occurrence of respiratory exacerbations or illness (n=3) [23, 27, 31], relocation (n=2) [32, 36] and patients' death (n=4) [25, 32, 36, 38].

Patients' satisfaction

Nine studies assessed patient satisfaction with the telemonitoring system (Table 4). Studies used quantitative scales/questionnaires (n=5), qualitative interviews (n=1) or both (n=2). Only one study did not provide information about how these data were collected. Patient satisfaction assessments were conducted face-to-face or through telephone calls. Most quantitative data were collected using non-validated scales and none of the studies used the same questionnaire. Thus, a meta-analysis could not be performed.

(Insert Table 4 about here)

Overall, patients found the technology easy to learn and/or use (n=7) and useful (n=5). Most patients reported that the system improved self-management of their health condition, as they: had a better understanding of their disease, symptoms and ways to control them; were more involved in their health care; and recognized earlier the signs of exacerbations. In the patients' perspective, the system also improved the care received from healthcare professionals. Patients felt a sense of security and reassurance when using the system because they knew their health condition was being monitored and they would be contacted if deterioration occurred (n=5). Furthermore, patients reported that the system helped them to

improve communication with healthcare professionals and facilitated the access to professional advice (n=3). Levels of satisfaction were reduced regarding the medication prompt (n=2); patients did not find it useful because they already took their medication correctly.

In some studies, open-ended questions provided additional information about the difficulties felt by patients when using the systems (n=3). Patients reported the following difficulties regarding the device itself: the display screen was too small and words too small to read; the touch-screen was difficult to use due to deficits in sensation and poor fine motor control; push buttons were too small to manipulate and the button to initiate an emergency call too sensitive or the volume was difficult to adjust. In one study, patients mentioned that the mobile phone was far too technologically advanced for them and they did not know how to operate when unexpected characters were displayed. As a result, some patients needed help from their caregiver to transmit the data. Difficulties such as determining the precise area to apply the device or using the belt of the respiratory rate sensor due to dyspnea or discomfort were also described in 2 studies.

Some concerns with the system functioning were reported: the batteries of peripheral devices were of short-lived duration and needed a long time to charge, power supply connection was small and confusing (n=1) and the background noise of the computer fan caused some problems in smaller living situations (n=1). Other concerns included the uncertainty of data transmission (n=3) and the limited portability of the device (n=1). Suggestions to improve the system were given in two studies and consisted of adding a blood pressure monitor, ensuring the transmission of clinical data and giving real time feedback.

DISCUSSION

This systematic literature review provided a comprehensive description of the methodologies of home telemonitoring interventions in COPD and summarized the findings related to patients' adherence and satisfaction with the use of telemonitoring systems. The majority of the articles were published from 2010 to the present, suggesting that telemonitoring interventions are a relatively new field in COPD research. Protocols of the telemonitoring studies were similar in several aspects such as the training provided to patients and the process of data collection and transmission. Studies diverged on the type of technology used, telemonitoring duration, and on the provision of prompts, reminders and/or feedback.

Training was usually provided in the initial home visit. However, this training may not have been enough to allow easy use of the systems, as many difficulties were encountered.

With respect to data collection, most studies lacked information about whether data had to be inserted manually or if the process was automatic, hindering study replication. Furthermore, some of these studies required data collection/transmission at a specific time of the day or more than once a day. These options were related to lower compliance rates in one study [31]. The results suggest that the moment and frequency of data collection/transmission should be flexible to meet patients' preferences and specific needs. However, the optimal frequency of data collection/transmission has not yet been defined in the literature.

Information on the type of technology used was lacking in some studies. Generally, a main device was connected to one or more peripheral devices. Most studies did not provide systems with options for adjusting them to each patient, making the use of those systems difficult. Some patients identified difficulties in manipulating the devices and in viewing the information provided on screen [31]. According to the review by Botsis and Hartvigsen [40], telemonitoring systems should fulfill the following criteria: i) be easy to use; ii) operate without interruptions; and iii) provide security and confidentiality of data collected. These criteria were not fully addressed in the included studies, since patients were not always comfortable about using the

technology to monitor their health condition. Furthermore, the difficulties felt by patients may have been a contributor to the high dropouts found in some studies, as suggested by Sanders and co-workers in their study exploring the factors related to the non-adherence to telemonitoring interventions [16]. To overcome these difficulties, it has been suggested that patients should receive training over a period of several days to help them learn to use the new technology and, therefore, optimize its use [41]. As the success of a telemonitoring system depends on how well it serves the needs of the target population [41], assessment of patients' acceptance of the system may also be useful to avoid dropouts and ensure patients' compliance. According to the American Telemedicine Association [42], evaluating and tailoring technology systems to specific user populations may contribute significantly to reduce *technophobia* among potential users.

Despite the usability problems, most patients reported that the system provided them with a better understanding of their disease and helped them to recognize the earlier signs of an exacerbation. These findings support the belief that telemonitoring may improve self-management of the disease [43]. According to Bourbeau et al. [44], self-management refers to the various tasks that a person carries out for management of their condition, in order to control their disease and improve their well-being. By helping patients to be aware of their symptoms and act in case of exacerbations, home telemonitoring may have facilitated patients' self-management. Furthermore, patients felt secure and reassured when using the system, because they knew that they would be contacted if deterioration occurred. The worsening of symptoms associated with COPD exacerbations is usually present for days before hospital admissions [24]. Thus, home telemonitoring may be a valuable tool to detect these changes sooner and allow an earlier intervention to reduce the severity of exacerbations. This is particularly important since exacerbations contribute to the deterioration of patients' clinical status [3].

The results of this review showed that patients were overall satisfied with the telemonitoring systems. This is an encouraging finding, since one of the aims of home telemonitoring is to explore the potential of the monitoring services to provide a continuum of care and, therefore, patients' satisfaction must be high for successful innovations to achieve a significant change in practice patterns. However, this positive impact may be questionable and even overestimated, since the included studies used poorly constructed instruments. According to previous literature [5], the concept of patient satisfaction is still not well defined and validated instruments are lacking.

Limitations

The present study has several limitations that need to be acknowledged. First, the study was restricted to English, Portuguese and Spanish languages. Although six records written in other languages were excluded, they could be relevant for the scope of the review. Second, this review included studies which were not specific for patients with COPD but had a sub-group of patients with this disease, and/or studies with different interventions (telemonitoring alone versus telemonitoring plus other health care components). This may have contributed to the differences found between studies. Nevertheless, this was deemed necessary to gather all information about the methodologies used in home telemonitoring for COPD. Finally, patients' satisfaction was explored regardless of clinical outcomes and healthcare utilization. Thus, it was not possible to assume that more satisfied patients were those with improved outcomes and reduced healthcare utilization.

Recommendations for future telemonitoring interventions

This review points out important methodological aspects that should be considered by researchers and healthcare professionals when developing home telemonitoring interventions for patients with COPD, and it provides recommendations for future interventions:

- The inclusion of more training sessions may facilitate patients' education on the use of the systems;
- Assessment of patients' needs, characteristics and acceptance of the telemonitoring technology should be considered prior to its implementation, as it may help adjusting the intervention to the target population;
- Studies should consider the inclusion of easy-to-use technology for patients with COPD, including those with disabilities;
- The frequency of data collection and transmission should be flexible to improve adherence to telemonitoring interventions. As the optimal frequency of data collection/transmission has not been set yet, future research should also explore this topic;
- The potential of telemonitoring interventions to change patients' self-management behavior, as well as its associations with patient outcomes and healthcare utilization, should be explored to improve the evidence on this topic;
- Patients' satisfaction with the use of systems should be further explored using more robust and validated instruments. Alternatively, a thorough qualitative analysis can be conducted to enable an in-depth understanding of patients' satisfaction and the use of that information to improve future technology designs.

CONCLUSION

Home telemonitoring interventions are a relatively new field in COPD research. Findings suggest that these interventions, although promising, still need to be adjusted to ensure their suitability to the target population. This study provides important recommendations for future

telemonitoring interventions, such as the inclusion of additional training sessions to facilitate patients' education on the use of the systems and the assessment of patients' characteristics and acceptance of the technology prior to its implementation. These adjustments are essential before the widespreading of telemonitoring can occur. Future research should also investigate the impact of these interventions on patients' self-management behavior and satisfaction, and explore their associations with patient outcomes and healthcare utilization.

Statement on conflicts of interest

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Table 1 - **Main characteristics and description of the technology used in the studies.**

First author (year)	Study design	Country	Participants	Type(s) of intervention(s) or comparator(s)	Telemonitoring duration	Description of technology
Antoniades (2012)[32]	RCT	Australia	44 patients with moderate to severe COPD and with ≥1 hospital admissions/year randomized in 2 groups: IG (n=22) and CG (n=22).	IG: home telemonitoring; CG: usual care.	12 months	Laptop computer with peripherals: blood pressure cuff and stethoscope, pulse oximeter, pneumotachograph, electrocardiogram touch plate and thermometer.
Chau (2012)[31]	RCT	Hong Kong	53 older people with moderate to very severe COPD randomized in 2 groups: IG (n=30) and CG (n=23).	IG: home telemonitoring plus in-home nurse visits with provision of education. CG: in-home nurse visits with provision of education.	2 months (mean duration 54.36 days)	Mobile phone with a touch-screen monitor and peripheral devices: oximeter and respiratory rate sensor.
Dale (2003)[39]	UBA	United Kingdom	55 patients with COPD.	Home telemonitoring plus additional telephone questions.	3 months	Oximeter and home weight scale.
Dinesen	RCT	Denmark	111 patients with severe or very	IG: home telemonitoring plus in-	4 months	Telemonitor device. Other devices

(2012)[27], Haesum (2012)[28], Jensen (2012a)[29], Jensen (2012b)[30]			severe COPD randomized in 2 groups: IG (n=60) and CG (n=51).	home exercises plus a monthly video meeting. CG: in-home exercises.		(not connected to the main device): weight scale, blood pressure monitor, oximeter, spirometer and step counter (in Dinesen (2012) and Haesum (2012)).
Kim (2012a) [23], (2012b) [24]	Non-equivalent multiple-group UBA	Korea	144 patients with COPD randomly allocated in 3 groups: IG1 (n=78), IG2 (n=36) and IG3 (n=30).	IG1: home telemonitoring; IG2: home telemonitoring plus education plus mobile phone service; IG3: home telemonitoring plus education plus video phone teleconsultation.	6 months	Integrated platform with peripherals: spirometer, oximeter and electronic stethoscope.
Koff (2009)[33]	RCT	United States of America	40 patients with COPD grades 3 and 4 according to the Global Initiative for Chronic Obstructive	IG: home telemonitoring plus education plus usual care. CG: usual care.	3 months	Health Buddy® device. Other devices (not connected to the main device): oximeter, pedometer and

			Lung Disease criteria [3].			mini-spirometer.
Lewis (2010a)[25], (2010b)[26]	RCT	United Kingdom	40 patients with moderate to severe COPD randomized in 2 groups after undertaken pulmonary rehabilitation: IG (n=20) and CG (n=20).	IG: home telemonitoring during 26 weeks and usual care in the following 26 weeks. CG: usual care for 52 weeks.	6 months	Hand-held telemonitor (Docobo® Health HUB) to display questions and a peripheral oximeter. A manual thermometer was also provided.
Paré (2006)[34]	NRCT	Canada	30 patients with severe COPD assigned in 2 groups: IG (n=20) and CG (n=10).	IG: home telemonitoring; CG: usual home care.	6 months	Web phone with a touch-screen monitor and a modem.
Sicotte (2011)[38]	NRCT	Canada	46 patients with severe COPD assigned in 2 groups: IG (n=23) and CG (n=23).	IG: home telemonitoring; CG: usual home care.	Mean±SD of 146.7±72.3 days	Web phone with a touch-screen monitor.
Sund (2009)[37]	UBA	United Kingdom	20 patients with moderate to severe COPD.	Home telemonitoring.	6 months	Mobile phone with a touch-screen and a peripheral spirometer. 2 software packages to enter data about symptoms and spirometry.
Trappenburg	NRCT	Netherlands	165 patients with moderate to	IG: home telemonitoring plus	6 months	Health Buddy® device with 4 large

(2008)[36]		severe COPD: IG (n=101) and CG (n=64).	education plus usual care; CG: usual care.		buttons to present questions and education.
Ure (2012)[35]	UBA	27 patients with moderate to severe COPD.	Home telemonitoring.	2 months	Touch-screen computer and peripherals: Bluetooth-linked oximeter and spirometer.

UBA - Uncontrolled before-and-after study; NRCT - non-randomized controlled trial; RCT – Randomized controlled trial; NA – no available information; COPD – chronic obstructive pulmonary disease; IG – intervention group; CG – control group; SD – standard deviation.

Table 2 - Patients' training and specificities of data transmission and management.

First author (year)	Training to use the system	Reminders, prompts and/or feedback	Data transmission	Data management	Detection of health deterioration
Antoniades (2012)[32]	In the initial home visit. Ongoing in-home support available, if required.	On-screen prompts to complete the measurements and questionnaire.	Via a telephone line to a central server.	A nurse monitored the data on weekdays.	Significant changes triggered a contact to a physician/nurse or to the patient for further assessment.
Chau (2012)[31]	In the initial home visit, provided by a nurse, with return demonstration.	Medication and pursed-lips breathing reminders with a feedback function.	Via a radio service to an online network platform on a base station.	A nurse monitored the data.	Immediate action taken when changes in clinical data occurred (not specified).
Dale (2003)[39]	In the initial home visit, provided by a nurse.	NA	Via a telephone line to a clinical response center.	A nurse monitored the data on a daily basis.	Clinical changes could lead to further assessment or treatment. A physician could be contacted for decision-making.
Dinesen (2012)[27], Haesum	In the initial home visit, with advice on how to exercise.	NA	Through a secure line using wireless to a healthcare center/hospital and stored	Healthcare professionals monitored the data.	Healthcare professionals could give advice (not specified).

(2012)[28], Jensen (2012a)[29], Jensen (2012b)[30]			in patient's database.		
Kim (2012a) [23], (2012b) [24]	At the hospital, with return demonstration, and then at home. Ongoing in-home support available, if required.	NA	Via a cable modem or digital subscriber lines.	NA	NA
Koff (2009)[33]	In the initial home visit, provided by a nurse, with education about the normal clinical parameters.	Advice to contact the coordinator when classified as *red flags.*	Via a telephone line to the databank, each night.	The coordinator monitored the data in the following morning of data transmission.	Patients automatically stratified into 3 color-coded groups and contacted if persistent red/yellow flags appeared. A red flag or a patient call led to the contact of the primary care physician.

Lewis (2010a)[25], (2010b)[26]	In the initial home visit (~1h per patient).	NA	Via a free-phone landline to a central server, at 02h00 daily. Transmission failures were followed by a call or a message on the screen after 7 days (2010a) or 24h (2010b).	Healthcare professionals monitored the data.	Detection of health deterioration triggered an automatic email message to healthcare professionals, who called the patient (on weekdays).
Paré (2006)[34]	In the initial home visit, provided by a nurse.	Alerts and advice when readings fell outside pre-set values.	Over the internet.	A nurse monitored the data on a daily basis.	Data outside pre-set values triggered an automatic alert to patients and the nurse, who contacted the patient or the physician for decision-making.
Sicotte (2011)[38]	NA	Alerts and advice when readings fell outside pre-defined values.	Over the internet, in real time.	NA	Data outside pre-set values triggered automatic alerts to a surveillance center and a nurse called the patient.
Sund (2009)[37]	In the initial home visit, with an information sheet and return demonstration.	Prompts to attach the spirometer to the main device.	To research center, in real time. Transmission failures for 2 days were followed	Data monitored by the research team, based on daily time-score plots	Exacerbations automatically detected by a red line on the time-plots. Patients were called to start

	A helpline was available.		by a call.	about symptoms and FEV_1.	treatment with pre-provided medications.
Trappenburg (2008)[36]	NA	Each answer received immediate feedback from the device: praise or encouragement to try again.	Via a telephone line to Health Hero's data center.	Respiratory nurses monitored the data on weekdays.	Data automatically stratified and color-coded. Nurses received alerts and contacted the patient and/or notified a pulmonary physician (if needed).
Ure (2012)[35]	NA	NA	Via a secure broadband link to a call center. Transmission failures were followed by a call.	Staff monitored the data.	Staff contacted the patient or physician on weekdays according to an algorithm. Patients received an action plan and emergency supply of medication to commence as soon as an exacerbation was recognized. Physicians provided clinical care at weekends.

NA – no available information; FEV_1 – Forced expiratory volume in 1 second.

Table 3 – Type and frequency of data collection.

First author (year)	Symptoms	Oxygen saturation	Spirometry	Heart rate	Temperature	Weight	Blood pressure	Respiratory rate	Medication	Other reports*	Frequency
Antoniades (2012)[32]	●	●	●		●	●	●		●		Daily, at the same time
Chau (2012)[31]		●		●				●			3X/day on weekdays
Dale (2003)[39]		●		●		●					Daily
Dinesen (2012)[27], Haesum (2012)[28], Jensen (2012a)[29], Jensen (2012b)[30]	●	●	●	●		●	●				According to prescription
Kim (2012a) [23], (2012b) [24]	●	●		●							Daily
Koff (2009)[33]	●	●	●						●	●	Daily morning on weekdays
Lewis (2010a)[25],	●	●		●	●				●		2X/day, at a

(2010b)[26]											specific period
Paré (2006)[34]	●			●						●		Daily
Sicotte (2011)[38]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Daily
Sund (2009)[37]	●			●						●	●	Daily evening
Trappenburg (2008)[36]	●									●	●	Daily
Ure (2012)[35]	●	●		●		●						Daily

NA – no available information. *Other reports: lung and heart sounds [24], electrocardiogram data [32], number of steps in the 6-minute walking test [33] and questions regarding patients' knowledge about COPD [33, 36].

Table 4 – Patients' satisfaction with the telemonitoring system.

First author (year)	Measures of patients' satisfaction	Results of patients' satisfaction
Antoniades (2012)[32]	Non-validated questionnaire related to: ease of use of the system; adequacy of technical support; system usefulness for disease management; overall satisfaction.	- Easy-to-use system (94%); - Good technical support (100%); - Useful to manage the disease (82%); - Overall satisfaction (88%).
Chau (2012)[31]	*Quantitative data:* Self-developed satisfaction questionnaire (1-5 Lickert scale, 5 being the highest level of satisfaction) related to: ease of use; level of confidence in using the system; acceptability; usefulness; satisfaction with nurse support. *Qualitative data:* Open-ended comments.	*Quantitative data* (% or mean±SD): - Overall satisfaction (91%); - Adequate explanation (86.3%) and understanding (3.50±1.10); - Usage difficulties (2.45±0.80); - Mediation reminders (60%); - Automated healthcare advice (50%) and nurse support (100%) reassuring; - Useful to manage the disease (54.5%); - Recommend to others (3.14±089). *Qualitative data:* - Facilitated timely care and access to professionals to help decide on the best action; - Reminders about medication not helpful because patients remembered to take it.

		Difficulties found: - Action taken when unexpected characters were displayed (n=5); - Instability of data transmission; - Small display screen, words, push buttons and power supply; - Use of the touch screen, due to decreased sensation and fine motor control; - Emergency call button too sensitive; - Need of help from caregiver to transmit the data; - Use of the belt of respiratory rate sensor (dyspnea, cold water in the winter); - Short-lived duration batteries with long time needed to charge. Suggestions: add a blood pressure monitor.
Dale (2003)[39]	Satisfaction questionnaire approved by the local research and medical ethics committee.	- Easy-to-use equipment; - Health condition well managed; - Monitoring service reassuring (no quantitative data reported).
Kim (2012)[24]	*Quantitative data:* Tool developed by the research team to measure attitude toward the system (4-point Lickert scale questions, from "*strongly agree*" to "*strongly disagree*"): user satisfaction; intention	*Quantitative data: Most patients were "satisfied"* or "*very satisfied*" with the systems. "*Agree*" or "*strongly agree*" options were higher for the topics: - Physical aspect (n=136); - Ease to use (n=129);

	to use in the future; preferred cost. *Qualitative data:* Open-ended questionnaire.	- Treatment improvement (n=140) and communication with physician (n=139); - Recommendation to others (n=128). *Qualitative data:* <u>Difficulties found:</u> - Selection of the precise area to apply the device; - Incorrectly connection of the device or error of the server; - Learning to use the video phone and adjusting the volume; - Limited portability of the device. <u>Suggestions</u>: Ensure data transmission, give real-time feedback and include blood pressure monitors.
Koff (2009)[33]	Questionnaire about satisfaction with individual pieces of the equipment (1-10 Lickert scale: 10 being the highest level of satisfaction).	Satisfaction was very high for all equipments (mean scores 9.6 to 8.5), except for the pedometer (4.5), which was not accurate for some patients with gait impairments.
Lewis (2010a)[25]	NA	Most patients found it "*helpful"* or "*very helpful*" (88%); 1 patient "*neither agreed nor disagreed*" that it was useful; 1 patient found it "*inconvenient*".
Paré (2006)[34]	Questionnaire about satisfaction completed by telephone (4-point Lickert scale: 4 being the highest level of satisfaction) and related to: ease of use;	Results (mean±SD): - Easy-to-use web phone (3.47±1.18); - Training (3.76±0.75) and vocabulary used (3.65±0.86);

	technical support; usefulness.	- Problems solved within 24h (3.57±1.09); - Sense of security (3.35±1.22); - Useful for the adoption of new practices to stabilize health condition (3.65±0.86).
Sicotte (2011)[38]	Validated scale of patient satisfaction (5-point Lickert scale: 5 being the highest level of satisfaction). Validated scale of the benefits of telemonitoring (5-point Lickert scale, 1=very little to 5=very good).	Overall satisfaction (mean±SD, 4.6±0.8): - Information quality (4.6±0.5), usefulness (4.2±1.4), presentation (4.9±0.4) and understanding (4.6±0.7); - Data confidentiality and security (4.4±1.0); - Ease of use (4.8±0.4) and learning (4.4±0.9); - Frequency of use (4.9±0.3); - Technical performance (4.2±0.8); <u>Perceived benefits (mean±SD):</u> - Reassurance (4.2±1.2); - More quickly detection of health deterioration (3.6±1.3) and action when it occurred (4.1±1.3); - Medication taken as prescribed (2.5±1.7).
Ure (2012)[35]	Face-to-face interviews about acceptability of the system, specifically: installation; training; use;	Most patients found the system easy to use and useful: - Earlier recognition of exacerbations;

	disease management; benefits about care, health management, recognition of symptoms and feelings; concerns; confidentiality; communication with healthcare professionals; recommended changes.	- Facilitated access to professional advice; - Confidence to respond to health deterioration; - Reassurance. <u>Difficulties found:</u> - Background noise of the computer fan caused problems in smaller living situations; - Uncertainty of data transmission.

NA – No available information; SD – standard deviation.