International Journal of Technology Assessment in Health Care

cambridge.org/thc

Home-based telerehabilitation software systems for remote supervising: a systematic review

Mohammad Hosseiniravandi[1], Amir H Kahlaee[2], Hesam Karim[1], Leila Ghamkhar[3] and Reza Safdari[1]

[1]Department of Health Information Management, School of Allied Medical Sciences, Tehran University of Medical Sciences (TUMS), Tehran, Iran; [2]Department of Physical Therapy, University of Social Welfare and Rehabilitation Sciences, Tehran, Iran and [3]University of Social Welfare and Rehabilitation Sciences, Tehran, Iran

Assessment

Cite this article: Hosseiniravandi M, Kahlaee AH, Karim H, Ghamkhar L, Safdari R (2020). Home-based telerehabilitation software systems for remote supervising: a systematic review. *International Journal of Technology Assessment in Health Care* **36**, 113–125. https://doi.org/10.1017/S0266462320000021

Received: 22 February 2019
Revised: 28 December 2019
Accepted: 11 January 2020
First published online: 10 March 2020

Key words:
Telerehabilitation; Telemedicine; Patient Monitoring; Home Care Services; mHealth

Author for correspondence:
Reza Safdari,
E-mail: rsafdari@tums.ac.ir

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Objectives. In the past decade, with the ever-increasing growth of information and communication technologies, telerehabilitation, especially home-based rehabilitation (HBR), has been widely considered by researchers. Many software systems are developed to address HBR programs, which includes various functionalities. The aim of this study is to review the functional features of these systems designed for remote supervising of HBR programs.
Methods. Scopus, PubMed, EMBASE, ISI Web of Science, Cochrane Library, IEEE Xplore Digital Library, and ProQuest databases were searched for English-language articles published between January 2008 and February 2018 to retrieve studies reported an home-based telerehabilitation software system aiming to remotely supervise HBR program.
Results. A total of fifty studies that reported twenty-two unique systems met the inclusion criteria. Various functional features were identified including but not limited to exercise plan management, report/statistics generating, patient education, and task scheduling. Disorders or diseases addressed by these systems could mainly be grouped into five categories: musculoskeletal, neurological, respiratory, cardiovascular, and other health-related problems. Usability and acceptability, and clinical/patient outcomes were the most reported outcomes and data analysis was used by the majority of included studies to measure the outcomes.
Conclusions. Systems developed for supervising of HBR program are diverse. However, preliminary results of this review revealed that these systems share more or less common functionalities. However, further research is needed to determine the requirements, structure, and effectiveness of these systems in real-life settings.

Every year, many people suffer from impaired physical functions (strength, balance, and movement) because of a variety of reasons including neurological disorders, musculoskeletal pains (highly prevalent), surgeries, aging, unexpected injuries, and so on. This impaired population subsequently requires rehabilitation services (1, 2). Meanwhile, the social and economic costs of not being at work due to illness and inability to work are also significant (3, 4).

Nowadays, patients go through a period of short-term illness rapidly and are discharged from hospitals faster than in the past. This is mainly due to the time constraints and economic considerations faced by today's healthcare organizations. However, many of these patients still require rehabilitation services to completely recover from illness. Furthermore, such services are often associated with substantial costs and the patients sometimes have to make multiple trips to the rehabilitation center during the treatment process (5). On the other hand, the capacity of rehabilitation services in primary care is limited due to human resources issues (6). Today, it is very common to continue rehabilitation therapy at home, which is called home-based rehabilitation (HBR).

In recent years, many studies have focused on implementing HBR programs for a wide range of acute and chronic conditions including but not limited to cancer, stroke, cardiovascular disease, diabetes, and musculoskeletal disorders. The main challenge faced by many of the HBR programs is how accurately and adequately do the patients follow the orders and perform prescribed exercises at home in the absence of a therapist. Studies show that two thirds of patients do not properly perform exercises at home. Improper HBR activities may lead to postponed treatment outcomes and could worsen the condition or lead to re-injury over time (7, 8). Fortunately, telerehabilitation systems have so far offered various solutions to overcome such issues.

Telerehabilitation can be broadly defined as the application of information and communication technologies to provide rehabilitation therapy to remote people (9–11). In order to address HBR programs, a variety of systems have been designed with different approaches, purposes, and capabilities enhanced with a variety of sensors, virtual reality technologies,

https://doi.org/10.1017/S0266462320000021 Published online by Cambridge University Press

robots, and motion detection tools such as Kinect, Lip Motion, Nintendo Wii, and so on. In the current study, all of these systems are briefly called home-based telerehabilitation systems or HBTR systems.

Studying HBTR systems from the technical point of view provides us with better insights and helps to improve such systems in the future. Several reviews have been carried out on the HBTR systems covering different aspects (12–14). However, to the best of our knowledge, there has been no research that has reviewed functional features of HBTR software systems developed to remotely supervise HBR programs. Remote supervising in this context is referred to as the opportunity of giving/getting feedback to/from patients and to manage rehabilitation therapy from remote.

We aimed to conduct a systematic review of the HBTR software systems designed and used in the literature during the last decade. Specific objectives included: (a) to identify the scope of the HBTR software systems employed by the literature in the recent decade about remotely supervise HBR programs; and (b) to identify functional features of such systems and to outline common functionalities shared among these systems.

Materials and Methods

The review process followed the PRISMA guideline (15).

Data Sources and Search Strategy

Searches for papers written in English, from January 2008 to February 2018, were conducted using Scopus, PubMed, EMBASE, ISI Web of Science (Core Collection), Cochrane Library, IEEE Xplore Digital Library, and ProQuest databases. In addition, the reference lists of all included studies were checked. Google Scholar was also searched for additional literature.

We prepared the search terms using the PICO approach (see Supplementary Table 1). As the search aimed to be sensitive and exhaustive, we employed a search strategy combining search terms for population (e.g., home combined with rehabilitation, physiotherapy, exercise therapy, physical therapy, kinesiotherapy, physical activit*, exercise train*) and interventions (e.g., supervis*, telesupervis*, tele supervis*, monitoring, telemonitoring, tele monitoring, telerehabilitation, tele rehabilitation combined with system, software, apps, application, online, on-line, web base*, Internet, mobile, phone, telephone, cellphone, smartphone, tablet, personal digital assistant). We also used MeSH and Emtree indexed keywords in PubMed and EMBASE, respectively (see Supplementary Table 2).

Study Selection

Inclusion criteria:

(1) Given the aim of this study, which was to review HBTR software systems for remote supervision, the target population was considered to be all individuals who remotely receive rehabilitation services through a software system.
(2) According to the aim of this study, in order to comprehensively review functional features of the HBTR software systems for remote supervision reported by the last decade published literature, studies using any design methods and with any outcomes using specified qualitative or quantitative measures (validated or not) were included.

Exclusion criteria:

(1) We considered remote supervision as telecommunication with patients, giving and/or getting therapeutic feedback, and remote control of the HBR program. Therefore, HBTR software systems without telecommunications, remote feedback, and HBR control, were excluded.
(2) A software system is fundamentally different from a hardware system in terms of structure and characteristics, design, implementation, and evaluation processes. Therefore, in the current study, we focused solely on HBTR software systems. The studies that investigated hardware systems such as robots, rehabilitation tools/devices, and sensors were excluded. However, studies that used such systems/technologies alongside an HBTR software system as a part of the system were included.
(3) Because we aimed to review HBTR software systems, general-purpose software including video conferencing tools, games, and health apps available on the market were excluded. This type of software is not only used for HBR programs, but also used for any other purposes. However, studies that used such tools alongside an HBTR software system to improve remote supervision were included.

After removing duplicates, three of the authors independently screened records based on titles and abstracts and then marked irrelevant records. A record would be excluded if it marked by at least two of the reviewers. All remaining papers were further investigated through their full-text for excluding the irrelevant studies. Disagreements were resolved through review team discussion.

Data Extraction and Analysis

All extracted data were entered into the included studies summary table. Demographic data and technical information were extracted from the included studies. Data extracted from each eligible study include study design, sample size, comparison if used by the study, primary outcome, outcome measure, health problem targeted by the study, type of feedback provided by the system, and the system functional features. The data were extracted by a purpose-made electronic form containing all the above-mentioned items.

Data analysis started with an overview of the study and functional features of the HBTR software system followed by the tabulation of extracted data. Due to the heterogeneous nature of the functionalities across the HBTR software systems, a narrative approach was used to synthesize the data. The functional features of an HBTR software system were narratively extracted according to the act of the system. Similar features were put into a category as a representative of the overall functionality. The categories were not pre-existing but the thematic synthesis was undertaken to make each category as follows.

All features that expressed how to manage rehabilitation exercises including creating exercises, changing exercise parameters (e.g., frequency, duration, and speed), adding or removing exercises from the HBR program named “Exercise plan management”; any kind of tasks or activities scheduling in the system considered as “Task scheduling”; any kind of data statistics, reports, and analysis provided by the system titled “Report/statistics generation”; any type of patient training and instructions whether in visual, textual, video, or guideline format called “Patient education”; managing user accounts and the data access rights named “User

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control"; text/voice messaging titled "Message transferring"; recording rehabilitation activities/exercises by patients in audio, image, or video format to provide a treatment feedback considered as "Exercise recording"; video communication through the system called "videoconferencing"; any type of patient-to-patient communications through the system whether in video, audio, or text messages or sharing/publishing experience and general posts named "Virtual community"; patient's connections with other therapists or therapist-to-therapist communications for treatment purposes considered as "Tele-consultation"; and finally, any kind of therapist recorded notes about the patient treatment process named "Recording clinical notes."

For an easier referral and analysis of the data, all included studies and reported systems have been numbered separately. Throughout this study, references to the studies and the systems will be made according to these numbers.

Because the aim of this study was to systematically review and comprehensively scope the functional features of the HBTR software systems reported by the literature of the recent decade, the quality assessment of the included studies was not carried out. However, we categorized the studies based on study design into four categories in order to report the types of studies conducted in this field since the last decade (see Supplementary Table 3). In this review, we didn't aim to evaluate the impact/effectiveness of reviewed systems or quality of the included studies or to draw any conclusion or generalization based on these studies. Our main focus was placed on identifying functional features of the HBTR software systems and reporting the status of such systems during the last decade.

Results

The search retrieved 4,172 records initially. After a stepwise process of screening titles, abstract, and then full-text articles against the defined eligibility criteria, we identified forty-seven studies to be included. The included studies reported on twenty-two discrete HBTR software systems (see Figure 1). In most cases, a system was reported by several studies, for example, system 1 was reported by ten out of forty-seven (21 percent) studies (see Table 1).

Overview of Included Studies

Overall, the included studies covered 1,139 people. Twenty-four out of forty-seven (51 percent) studies recruited patients; eleven (23 percent) studies addressed healthy people, and five out of forty-seven (11 percent) included both patients and healthy people and reported related outcomes. Testing the system prototype was the most prevalent subject, carried out by 28 percent of the studies. We grouped studies into five categories according to health conditions including musculoskeletal system and connective tissue-related conditions (studies 1–13); nervous system and sense organ-related conditions (studies 14–31); respiratory system-related conditions (studies 32–37); cardiovascular system-related conditions (studies 38–42); and general health-related conditions such as aging people fitness and strengthening exercises (studies 43–47). Nine HBTR software systems (systems 1, and 8–15) reported by twenty-five out of forty-seven studies, were designed for neurological conditions. Of these, system 1 could be used for musculoskeletal (studies 1–6) and strengthening exercises (study 43) as well. Stroke (six out of eighteen studies) and multiple sclerosis (six out of eighteen studies) were the most frequent health problems targeted by two thirds of the systems. All systems in the respiratory conditions category were designed for chronic obstructive pulmonary disease (COPD). Among the systems reported for multiple health problems (e.g., systems 1, 2, 10, and 16), system 1 was the only system that addressed the health conditions of multiple categories. The other systems were mainly used only for the health problems of a specific category.

Study Design and Study Aims

We categorized study designs broadly into four types as follows (see Supplementary Table 3):

- Effectiveness (or efficacy) studies (eight studies, 17 percent) including randomized controlled trials (RCTs) and quasi-experimental studies. These studies aimed to establish the HBTR software systems' effectiveness for patient outcomes comparing to other types of care received (such as usual care and conventional rehabilitation therapy or support) (e.g., studies 14 and 32).
- Evaluation studies (seven studies, 15 percent) including non-randomized, uncontrolled, or single-group before–after studies. These studies tended to pilot-test the HBTR software systems' effectiveness for pre-specified patient outcomes within a group of patients (e.g., studies 6 and 18).
- Feasibility or usability studies (ten studies, 21 percent) including post-use surveys or studies evaluating the usability of the HBTR software system. This group of studies aimed to establish the ease of use and perceived acceptability of the HBTR software systems (e.g., studies 10 and 27).
- Other studies (twenty-two studies, 47 percent) included mixed-method studies that reported documentation of the development process or description and pilot-testing of an HBTR software system or its prototype. Using questionnaires and/or interviews to collect users' feedback were examples of studies commonly employed in this category (e.g., studies 2 and 24).

Study Outcomes and Measures

The outcomes reported by the included studies varied widely and different measures/tools were used as well. The objective of these studies varied across the four main categories of study designs. Regarding the outcome, there were five main types including usability and acceptability (e.g., satisfaction, ease of use, and acceptance), clinical/patient outcomes, performance of the HBTR system, system description/development process documenting, and patients' adherence (e.g., usage rate and/or motivation for using system) which were respectively reported by twenty, twenty, thirteen, eight, and twelve out of forty-seven studies. Although some studies had considered various outcomes, 55 percent of reviewed studies reported only outcomes of a kind such as clinical/patient outcomes (six out of forty-seven studies; e.g., studies 14, 20, and 34), usability and acceptability (four out of forty-seven studies; e.g., studies 10, 17, and 30), performance or function of designed system (eleven out of forty-seven studies; e.g., studies 2, 7, and 26), and development process of or description of the system (five out of forty-seven studies; e.g., studies 9, 29, and 42). However, usability and user satisfaction and clinical/patient outcomes which each established by twenty out of forty-seven studies were the most common outcomes reported by included studies. The data analysis, system analysis, and the system usability scale tool were the most commonly used

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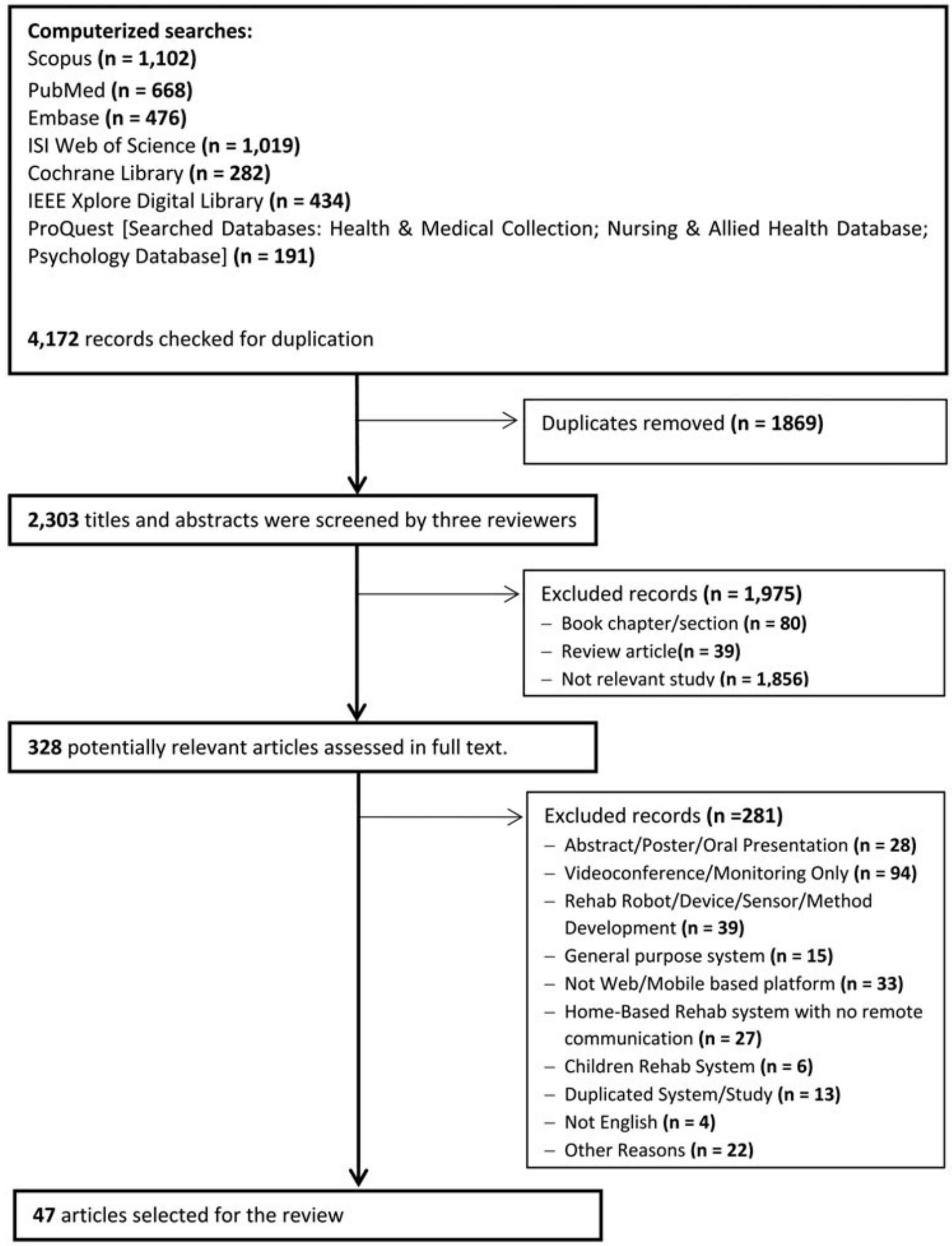

Figure 1. Study selection (PRISMA diagram).

measures/tools across reviewed studies, addressed by twenty-two, seven, and six out of forty-seven studies, respectively.

Effectiveness/efficacy studies had reported both usability and satisfaction and clinical/patient outcomes almost equally, which were addressed by five and six studies, respectively. Of these, studies 14, 33, and 39 were carried out only on clinical/patient outcomes. The measures used in these studies varied widely and each study used outcome-specific tools. For example, using peak oxygen uptake (VO2peak), EQ5D, and HADS; and Jette Late Life Functional and Disability Instrument (LLFDI) to respectively measure MI (study 44) or stroke (study 16) patient outcomes.

Evaluation studies (e.g., studies 6, 19, and 40) also commonly reported clinical/patient outcomes. Seven studies (1, 6, 18, 20, 25, 37, and 38) reported clinical/patient outcomes. From these studies, five also reported other outcomes such as usability and satisfaction (studies 1, 6, and 18) and patient adherence or usage of the HBTR system (studies 25 and 37).

Feasibility and usability studies had focused more on usability and satisfaction outcomes (eight out of forty-seven studies) compared to the other types of study designs. The pre-intervention/baseline measurements were often not considered in feasibility/usability studies. Instead, these studies primarily aimed to establish the perceived acceptability or user satisfaction in using the HBTR system (eight out of ten feasibility/usability studies) through questionnaires or analysis of usage data (e.g., studies 10, 16, and 35). The questionnaire was commonly used to glean insight into the usability, usefulness, utility, likeability, acceptability of the HBTR system, and how patients used it in a real-life context.

Finally, studies using mixed methods not fitting any of the above categories were grouped into the fourth category called "other studies." These studies (e.g., studies 2, 7, 19, and 28) had commonly documented the development process, description, and initial testing of the HBTR system (system prototype). In

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Table 1. Summary of included studies

Study no.	Year (ref)	System no.	Target health problem	Study design	Comparison (if used)	Sample size	Primary outcome	Outcome measure
Studies on the musculoskeletal system and connective tissue-related conditions								
1	2015 (16)	1	Hip fracture	Pre-post evaluation	N/A	10	Impact of the system; satisfaction; patient adherence	SF-36; CES-D; LEFS; YPAS; CSQ-8; MMSE; MBI; data analysis
2	2013 (17)	1	Upper and lower limb rehabilitation	Prototype test	N/A	N/A	System function	Data analysis
3	2012 (18)	1	Mobility limitations	Feasibility study	N/A	9	Acceptance; clinical impact of the system; patient adherence	BBS; T25FW; 6MWT; CSQ-8; MOS
4	2012 (19)	1	Upper extremity problems	Prototype test	N/A	7	System function	Data analysis
5	2012 (20)	1	Disabling impairments	Prototype test	N/A	8	System function	Data analysis
6	2012 (21)	1	Mobility limitations	Pre-post evaluation	N/A	9	Patient's functional outcome; satisfaction; patient adherence	T25-FW; 6MWT; BBS; MOS; CSQ-8
7	2015 (22)	2	Frozen shoulder	Prototype test	N/A	N/A	System function	Data analysis
8	2017 (23)	2	Frozen shoulder	Prototype test	N/A	5	System function	Data analysis
9	2013 (24)	3	Frozen shoulder	Development study	N/A	N/A	Description of the system	System analysis
10	2014 (25)	4	Hand and wrist impairment	Usability study	N/A	46	Acceptance	Questionnaire
11	2014 (26)	5	Hand and wrist impairment	Prototype test	Data captured from normal subjects	12	System function	Data analysis
12	2012 (27)	6	Lower Extremity Therapy	Prototype test	N/A	21	System function	Data analysis
13	2017 (28)	7	Hip replacement surgery	Development and prototype test	N/A	3	System function and description	Data and system analysis
Studies on nervous system and sense organ-related conditions								
14	2015 (29)	8	Stroke	RCT	Usual care	100	Life task's social activity participation	LLFDI
15	2016 (9)	9	Stroke and cerebral palsy	Prototype test	N/A	5	System function	Data analysis
16	2014 (30)	10	MS	Usability study	N/A	10	Usability	SUS
17	2014 (31)	10	MS	Usability Study	N/A	30	Usability	SUS

(*Continued*)

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Table 1. (*Continued.*)

Study no.	Year (ref)	System no.	Target health problem	Study design	Comparison (if used)	Sample size	Primary outcome	Outcome measure
18	2008 (32)	1	MS	Pilot evaluation	N/A	12	Clinical impact; acceptability	T25FW; 6MWT; BBS; MSWS-12; MAS; MSSE; MOS; CSQ-8
19	2011 (33)	1	MS	Development study	N/A	N/A	System development	Data analysis
20	2014 (34)	11	ABI	Single case evaluation	N/A	1	Patient performance	Questionnaire
21	2013 (35)	11	ABI	Secondary data analysis	N/A	4	Satisfaction; patient performance	Questionnaire
22	2014 (36)	12	MS	Feasibility RCT	Usual care	30	Usability; satisfaction; timed 25 foot walk	Telephone interview; questionnaire
23	2017 (37)	12	SCI	Pilot RCT	Usual care	24	Satisfaction; 6 min Walk test	Telephone interview; questionnaire
24	2013 (38)	13	Multiple neurological conditions	Development and usability study	N/A	48	Usability and acceptability	Questionnaire
25	2014 (39)	13	Multiple neurological conditions	Cohort study	N/A	45	Treatment intensity; patient adherence	Data analysis
26	2014 (40)	14	DS	Prototype test	N/A	2	System function	Qualitative data analysis
27	2014 (41)	15	Stroke	Feasibility study	N/A	24	Usability; arm motor function	SUS; FM; ARAT
28	2014 (42)	15	Stroke	Development and feasibility study	N/A	23	Usage; usability	Usage data; SUS
29	2014 (43)	15	Stroke	Prototype test	N/A	20	Arm, wrist and hand function; usage	FM; usage data
30	2015 (44)	1	MS	Feasibility study	N/A	10	Usability; acceptance	Questionnaire
31	2015 (45)	15	Stroke	Feasibility study	N/A	24	Training duration; usability; motivation	SUS; IMI; Data analysis
Studies on respiratory system-related conditions								
32	2014 (46)	16	COPD	RCT	Usual care	29	Usage; satisfaction	Data analysis; questionnaire
33	2016 (47)	17	COPD	RCT	Standard care	120	Combined number of hospitalizations and emergency department presentations	Incidence density
34	2017 (48)	17	COPD	Feasibility study	N/A	10	Long-term exercise maintenance; clinical effects; quality of life; use of hospital resources	6MWD; CAT; EQ-5D; hospitalizations and outpatient visits

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35	2016 (49)	17	COPD	Usability study	N/A	10	Satisfaction; patient adherence	Qualitative data analysis
36	2013 (50)	17	COPD	Feasibility study	N/A	10	Number of hospital admissions; usage	Data analysis
37	2016 (51)	18	COPD	Pilot evaluation	N/A	167	Patient adherence; perceived impact	Questionnaire
Studies on cardiovascular system-related conditions								
38	2014 (52)	19	Cardiovascular system	Comparison study	CPX	50	ECG; heart rate; breathing frequency	Data analysis
39	2017 (53)	19	CAD	RCT	CCR	118	Exercise capacity; anxiety and depression	VO_2 peak; EQ5D; HADS
40	2017 (54)	19	CAD	RCT	CCR	[Same sample of study 39]	Acceptability and usefulness; patient adherence	Questionnaire; data analysis
41	2014 (55)	20	Cardiovascular system	Development study	N/A	N/A	System description	System analysis
42	2014 (56)	20	Cardiovascular system	Development study	N/A	N/A	System description	System analysis
Studies on general health-related conditions								
43	2015 (57)	1	Strengthening exercise	Prototype test	N/A	5	System function	Data analysis
44	2016 (58)	21	Older adults' fitness	Quasi-randomized study	A basic version of the system	36	Usability and acceptability; usefulness; nature of social interactions	SUS; questionnaire; qualitative analysis of data
45	2011 (59)	22	Older adults' fitness	Prototype test	N/A	4	System function	Data analysis
46	2012 (60)	22	Older adults' fitness	Development study	N/A	N/A	System description	System analysis
47	2013 (61)	22	Older adults' fitness	Prototype test and Post-use evaluation	N/A	37	System function; acceptance; usability	Data analysis; questionnaire

N/A, not applicable; SF-36, 36-item short-form; CES-D, Center for Epidemiologic Studies Depression Scale; LEFS, Lower Extremity Functional Scale; YPAS, Yale Physical Activity Survey; CSQ-8, Client Satisfaction Questionnaire; MS, multiple sclerosis; ABI, acquired brain injury; SCI, spinal cord injury; DS, Down's syndrome; MMSE, Mini Mental State Examination; BMI, modified Barthel index; BBS, Berg Balance Scale; T25FW, timed 25-foot walk; 6MWT, 6-min walk test; MOS, medical outcomes study patient adherence measure; LLFDI, Jette Late Life Functional and Disability Instrument; SUS, System Usability Scale; MSWS-12, 12-Item MS Walking Scale; MAS, Modified Ashworth Scale; MSSE, MS Self-Efficacy Scale; FM, Fugl–Meyer; COPD, chronic obstructive pulmonary disease; ARAT, Action Research Arm Test; 6MWD, 6-min walking distance; CAT, COPD assessment test; EQ-5D, EuroQol 5 dimensions; CPX, conventional cardiac exercise; CCR, conventional cardiac rehabilitation; CAD, coronary artery disease; VO_2 peak, peak oxygen uptake.

these studies, the most important consideration was the performance of the systems (reported in thirteen out of twenty-two studies). In this sense, the system users were frequently involved in the system development process. Five out of twenty-two studies (23 percent) had merely described or documented the system development process.

HBTR Software Systems

Overall, twenty-two unique HBTR software systems for remote supervision of the HBR programs were reported by the included studies (see Table 2). The majority of these systems provided patients and therapists with real-time (nineteen out of twenty-two systems; systems 1–11, 13–16, 18–20, and 22) and periodic feedback (seventeen out of twenty-two systems; systems 2, 4–8, 10–12, 14–18, and 20–22) respectively. Systems 12, 16, and 21 provided the patients with periodic feedback. Of these, system 16 also addressed real-time feedback. In system 17, the type of feedback provided to the patients was unclear. The only systems that provided therapists with real-time feedback were systems 3 and 18. System 18 could also provide periodic feedback. However, the way in which systems 1, 9, 13, and 19 provided the therapists with feedback was unclear. Twenty-seven percent of the systems were capable of providing reminders and alerts to the users.

In terms of patient data collection (here we considered questionnaires or video recording as manual and vital signs or movement detectors as automatic data collectors), there were fourteen automatic data collecting systems (systems 1–6, 8, 9, 14, 15, 18, and 20–22) and three were manual (systems 12, 13, and 17). Motion sensors and accelerometers were used in the majority (84 percent) of the automatic data collection systems. Five systems (systems 7, 10, 11, 16, and 19) collected patient data both automatically and manually. In order to check the progress of the HBR program remotely by the therapist, logs of activities recorded by the system (activities performed by the patient using the HBTR system) were used in twenty out of twenty-two systems. Seven of these systems also employed other methods such as system-provided questionnaires or checklists, which were answered by the patients often after each task's completion (systems 7, 10, 16, 19, and 21), video recording or image capturing (system 11), remote (systems 9 and 10), or face-to-face (system 10) visits. However, in systems 12 and 17, this was merely addressed by the system-provided questionnaires.

The type of communication in 23 percent of the systems (five out of twenty-two systems) was store-and-forward, in 36 percent of the systems (eight out of twenty-two systems) communication was online. Approximately 41 percent of the systems (nine out of twenty-two systems) were able to communicate both online and store-and-forward. The transferred data format in 58 percent of the systems was textual (including data from the questionnaire, motion sensors, and vital signs data, logs of the system, and exchanged text messages).

Functional Features of HBTR Software Systems

Overall, eleven functional features were obtained from HBTR software systems reported in the literature of the last decade. This includes exercise plan management, report/statistics generation, patient education, message transferring, task scheduling, user control, clinical note recording, videoconferencing, exercise recoding, teleconsultation, and virtual community.

Although the methods of managing exercises and reporting varied widely across reviewed HBTR software systems, all of these systems had somehow managed the rehabilitation exercises by adding, removing, or changing exercises or modifying the exercise parameters, for example, frequency, duration, and degree of difficulty as well as providing the required statistics and reports. The next most commonly used feature was providing patients with treatment education, employed by fifteen out of twenty-two (68 percent) reviewed systems (systems 1, 3, 5–14, 16, 21, and 22). However, other features were considered by less than one third of the reported systems. Transferring audio/text messages through the system (systems 1, 7, 10, 15, 16, 18, and 21), scheduling tasks (systems 2, 8, 13, 16, 18, 19, and 21), and user control (systems 3, 7, 12–15, and 18) were each used by 32 percent of the systems. Providing video communication was considered in four out of twenty-two systems, three of which (systems 8, 9, and 10) were deployed for neurological conditions and one (system 18) for COPD in the respiratory diseases category (see Table 3). The ability to record clinical notes by the therapists (used by systems 8 and 20) and exercises by the patients (employed by systems 10 and 11) as well as sharing experiences and communicating with other users through the system (systems 20 and 21) were each considered by only 9 percent of the HBTR software systems. The only system that provided teleconsultation was system 16. Two categories, that is, neurologic and respiratory categories were the richest in terms of functional features that respectively 82 percent and 73 percent of the acquired functional features employed by systems were in these two domains.

Discussion

To the best of our knowledge, this is the first systematic review about the HBTR software systems for remote supervising focusing on functional features with a broad range of the HBR programs. The conducted search was comprehensive of 4,172 records. We identified and included fifty papers, which reported twenty-two unique HBTR software systems. The number of papers published during the last decade, especially that 64 percent of studies published in the last 5 years suggests that the HBTR software systems for remote supervision of HBR programs are growing rapidly. Overall, eight studies were seeking to test the effectiveness or efficacy of such systems; the remaining studies (83 percent) primarily used uncontrolled designs, investigating on evaluations, feasibility, and acceptability of the HBTR software systems, or descriptions of these systems' development. This all suggests that although fast-evolving, the field is still in its infancy and the main focus of researches placed on system innovation and usability evaluation.

Considering the fact that the HBR programs are an integral part of today's rehabilitation therapy (62–64) and given that the treatment is carried out through regular therapeutic exercises (65, 66), which are required to be performed properly (25, 67), the majority of systems reviewed were primarily developed for treatment and education. However, system innovation seems not to be the same in different health areas. For example, in neurological and respiratory rehabilitation fields more complete systems have been introduced compared to other areas. It could be due to the nature of targeted health problems as well as the domain and/or users (e.g., patients and therapists) related requirements. Such requirements are an integral part of software system design and critical to the success of interactive systems (68, 69). There are some differences among reviewed HBTR software

Table 2. Features of the included HBTR software systems

System no.	Health problem	Feedback to Therapist	Feedback to Patient	System features
1	• Hip fracture • Upper and lower limb rehabilitation • Mobility limitations • Disabling impairments • MS • Strengthening exercises	N/S	R	• Message transferring • Exercise plan management • Patient education • Report/statistics generation
2	Frozen shoulder	P	R	• Exercise plan management • Report/statistics generation • Task scheduling
3	Frozen shoulder	R	R	• User control • Exercise plan management • Patient education • Report/statistics generation
4	Hand and wrist impairment	P	R	• Exercise plan management • Report/statistics generation
5	Hand and wrist impairment	P	R	• Exercise plan management • Patient education • Report/statistics generation
6	Lower extremity therapy	P	R	• Exercise plan management • Report/statistics generation • Patient education
7	Hip replacement surgery	P	R	• User control • Message transferring • Exercise plan management • Report/statistics generation • Patient education
8	Stroke	P	R	• Exercise plan management • Patient education • Clinical note recording • Report/statistics generation • Task scheduling • Videoconferencing
9	• Stroke • Cerebral palsy	N/S	R	• Exercise plan management • Patient education • Report/statistics generation • Videoconferencing
10	Multiple sclerosis	P	R	• Message transferring • Exercise plan management • Exercise recoding • Patient education • Report/statistics generation • Videoconferencing
11	ABI	P	R	• Exercise plan management • Exercise recoding • Patient education • Report/statistics generation
12	• MS • SCI	P	P	• User control • Exercise plan management • Patient education • Report/statistics generation
13	Multiple neurological conditions	N/S	R	• User control • Exercise plan management • Patient education • Report/statistics generation • Task scheduling
14	DS	P	R	• User control • Exercise plan management • Patient education • Report/statistics generation

(*Continued*)

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Table 2. (*Continued.*)

System no.	Health problem	Feedback to: Therapist	Feedback to: Patient	System features
15	Stroke	P	R	• User control • Message transferring • Exercise plan management • Report/statistics generation
16	COPD	P	P and R	• Message transferring • Exercise plan management • Patient education • Report/statistics generation • Task scheduling • Tele-consultation
17	COPD	P	N/S	• Exercise plan management • Report/statistics generation
18	COPD	P and R	R	• User control • Message transferring • Exercise plan management • Report/statistics generation • Task scheduling • Videoconferencing
19	• Cardiovascular system • CAD	N/S	R	• Exercise plan management • Report/statistics generation • Task scheduling
20	Cardiovascular system	P	R	• Exercise plan management • Clinical note recording • Report/statistics generation • Virtual community
21	Older adults' fitness	P	P	• Message transferring • Exercise plan management • Patient education • Report/statistics generation • Task scheduling • Virtual community
22	Older adults' fitness	P	R	• Exercise plan management • Patient education • Report/statistics generation

N/S, not specified; R, real-time; P, periodic; MS, multiple sclerosis; ABI, acquired brain injury; SCI, spinal cord injuries; DS, Down's syndrome; COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease.

systems in terms of employing some functional features. These features were mainly established by less than one third of the systems. This difference may also be concerned with the domain-related issues and/or the user-specific requirements.

In addition to the three most common functional features (exercise plan management, reporting, and patient education), there were also many similarities in systems reviewed in terms of data collection methods (automatically data collection established by more than 85 percent of the systems), recording the progress of patient treatment (using log of activities employed by 90 percent of the systems), and respectively providing therapist and patient with periodic (more than three quarters of the systems) and real-time (more than 85 percent of the systems) feedback. Contrary to the observed differences in reviewed systems, the similarities may be due to the purpose of these systems, which is remotely supervising of the HBR program. In other words, it may be possible to derive a set of functional features from the commonalities seen in the majority of these systems in order to design a general-purpose system capable of supervising a variety of HBR programs.

Automatic patient data collection could be an advantage for an HBTR software system in terms of the accuracy and simplicity of the data gathering process. On the other hand, providing the therapist with periodic feedback could address the time constraints. Concerning patient education, providing patients with real-time feedback could be helpful to avoid possible mistakes made by patients although doing rehabilitation exercises at home. Moreover, using the patient's activities recorded by the system could be fairly good for tracking treatment progress and/or patient's performance. However, this is suggested by the extent to which these features are employed by systems reviewed and further studies are needed in this field.

Strengths and Limitations

This review was conducted according to PRISMA guidelines. We included all study designs in order to comprehensively scope the HBTR software systems for remote supervision of HBR programs. In this review, the main focus was placed on the functional features of these systems, which helps to better understand what

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Table 3. Functional features addressed by the HBTR software systems according to the health problem categories

	No. of HBTR systems used in					
Functional features	Musculoskeletal	Neurological	Respiratory	Cardiovascular	General health	Total (systems)
Exercise plan management	7	9[a]	3	2	3[a]	22
Report/statistics generation	7	9[a]	3	2	3[a]	22
Patient education	5	8[a]	1	0	3[a]	15
Message transferring	2	3[a]	2	0	2[a]	7
Task scheduling	2	4	1	0	0	7
User control	2	4	1	0	0	7
Videoconferencing	0	3	1	0	0	4
Clinical note recording	0	1	0	1	0	2
Exercise recoding	0	2	0	0	0	2
Virtual community	0	0	0	1	1	2
Tele-consultation	0	0	1	0	0	1
Total (features)	6	9	8	4	5	

[a]One duplicated system (system 1 from musculoskeletal category).

such systems do in order to remotely supervise HBR programs. We also synthesized the data in cross tables which facilitates comparison. However, as the review solely included papers written in English, publications in other languages were omitted, which might affect the results. Also, HBTR software systems designed and developed may not have been reported as a scientific study (e.g., systems used in clinical settings). This is a well-known phenomenon in a field, which is driven arguably by commercial or real-world developers as opposed to academic or clinical researchers (70–72). In this review, we extracted the functional features of the HBTR software systems reported by the literature, highlighting the similarities and differences between these systems. However, the necessity of each of these features could not be explained by this study.

Future Directions

This review extracted functional features of the HBTR software systems and outlined their similarities. However, more research is needed to better understand such systems, their functionalities, and the effectiveness of such functionalities on patient's treatment outcomes. It is therefore recommended that this research is taken to the next level, which could include studying the hardware and device required by an HBTR software system, real-world implemented systems, structure, and effects of these systems in real-world settings. This could be a major step forward in designing a comprehensive HBTR software system incorporating features obtained in such studies, which beyond health issues could be used for a wide variety of patients and scenarios.

Conclusion

Overall, the review of HBTR software systems aiming remote supervising of HBR programs reported by the literature indicates that these systems share more or less common functionalities promising comprehensive HBTR systems. However, research within this field is still in its infancy. A better understanding of such systems could enhance the optimal design of HBTR systems leading to improved HBR programs and facilitated remote supervision.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0266462320000021.

Acknowledgments. The authors wish to acknowledge the clinical research development center of Rofeideh rehabilitation hospital.

Conflict of interest. The authors have nothing to disclose.

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