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Technology applications to improve health outcomes and self-management in patients with arthritis

Mobile technologies are proliferating rapidly in medicine and provide opportunities for patient education and behavior change interventions. Technology-based interventions have the potential to overcome barriers to adherence, are accessible and entertaining thereby increasing interest in participation. This article provides an overview of new technology-based educational and behavioral interventions used to manage arthritis symptoms and promote healthy behaviors such as online education and self-management programs, mobile applications, and virtual reality-based rehabilitation. We also highlight a new area for technology applications in arthritis, exergaming, based on evidence from other chronic illnesses. Given the limited controlled studies in this area, data will be summarized by topic area highlighting the effectiveness of various interventions, their challenges, opportunities and areas for future research.

Keywords: arthritis • health promotion • mobile health • rehabilitation • technology

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Background

Behavioral health interventions are designed to change health-related behaviors. Behavioral health interventions may target individuals at high risk for a particular health outcome by targeting healthy lifestyle behaviors such as exercise, diet or medication adherence. They may also impact the environment by improving access to gyms, healthy meal choices in restaurants, health screenings, and/or public policy (e.g., smoking bans and taxes on liquor, among others) (Figure 1). Unfortunately, lifestyle health behaviors are difficult to change because they require active and conscious engagement of the individual, as well as motivation to change familiar habits and practices. Behavior change also requires deferring gratification of the effort involved as the benefits of behavior change may take months or even years to occur. Regardless of the target of the health behavior intervention, interventions that are grounded in theory are most effective [1]. Table 1 describes some of the more commonly used behavioral theories and models, many of which have strong evidence for effectiveness.

This article provides an overview of the current literature on technology-based behavioral interventions for arthritis management. Given the recent proliferation of technology in arthritis-based self-management and rehabilitation interventions, the literature on specific topics is limited with many articles focused on the design and development of these interventions versus clinical trials of efficacy. Therefore, this article aims to present the array of new technology-based interventions from internet-based self-management programs to virtual reality (VR) infused rehabilitation to exergaming (gaming for exercise) and describe the current data on their effectiveness, challenges and opportunities. When possible, information will be summarized in a systematic manner.

Methods

For this review, Medline, PubMed, EMBASE, CINAHL, AMED, PsychInfo and the Cochrane Library were searched

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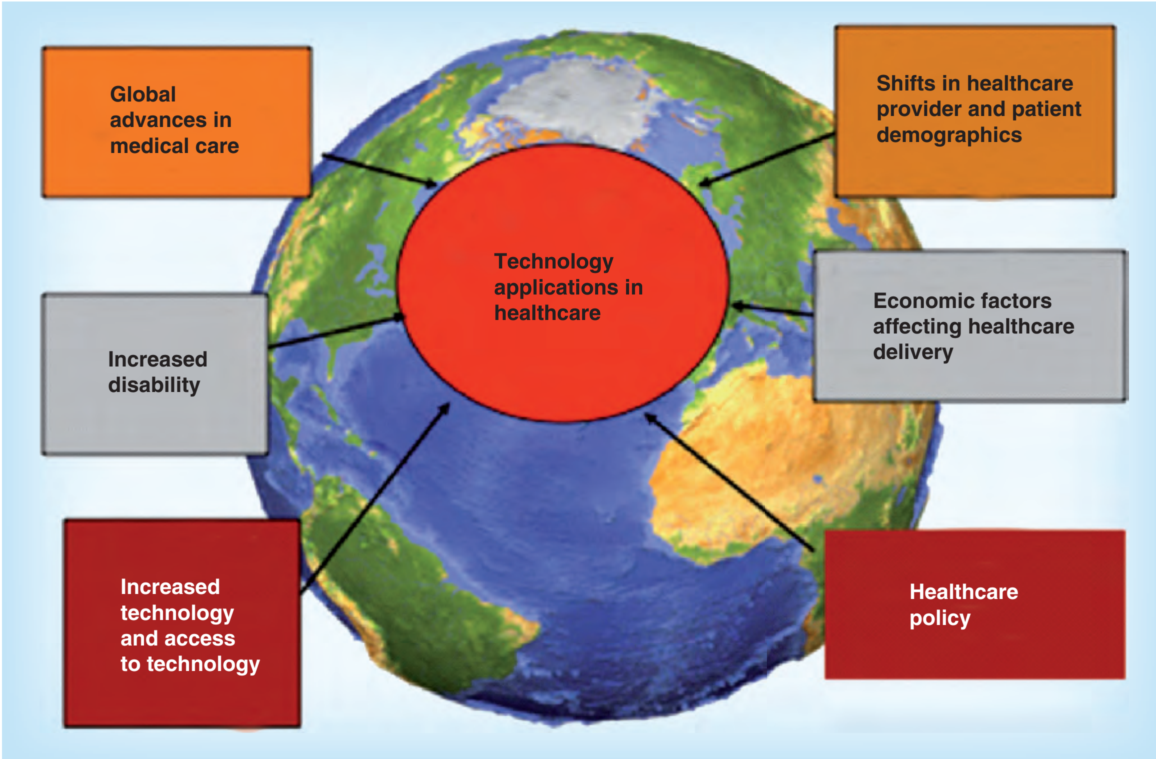

Figure 1. External influences on technology and health.

from 2006 and up to December 2013 using the key terms 'patient education', ' self-management ', 'technology' and arthritis'. Search terms were expanded to 'internet', 'rheum$', 'rehabilitation', 'self- management', 'self care', 'gaming' 'telemedicine', physical activity' and 'arthritis'. Topic areas covered reflect current advances in technology-based behavioral and rehabilitation interventions to promote health and independence. Given the limited number of clinical trials, all articles addressing self-management interventions, patient education, VR, physical activity, telemedicine and gaming/exergaming were included regardless of article type (descriptive, developmental/ technology paper, cohort, and so on) if they were in published in English. Articles are described and summarized under specific subheadings to present a general overview of what is known in each area. Given there were no arthritis-related exergaming programs for children this literature review covers exergaming for children with chronic illness.

Internet-based education & self-management programs in arthritis

Definition of self-management intervention & benefits of traditional self-management interventions in arthritis

Literature on traditional face-to-face arthritis educational and self-management interventions yield positive health benefits such as better symptom control and improved quality of life [11,12]. Educational programs provide patients with information about arthritis, as well as publicly available resources (e.g., Arthritis Foundation). Self-management programs are designed to help individuals manage their symptoms, treatments, physical, psychosocial and lifestyle consequences related to living with a chronic condition [11]. Self-management interventions extend beyond merely the provision of information to promote active patient engagement to enhance health and to manage symptoms of arthritis. Iversen *et al.* reported [11] successful self-management interventions (SMIs) delivered face-to-face include the following characteristics: use of a group format grounded in behavioral theory (most commonly social cognitive theory [9] and cognitive behavioral theory [2]); individually tailored programs, standardized patient materials, and weekly supervised exercise sessions. Data indicate SMIs provide short-term benefits of up to 9 months following the intervention [11].

Technology & SMIs

Technology-based SMIs provide the promise of more efficient, broad reaching, and potentially motivating strategies [13,14]. Current technologies for SMIs include online interventions, mobile applications (i.e., text messaging, video messaging, voice calling, social media such as Facebook and Twitter and mobile monitoring), as well as gaming and technologically–based rehabilitation interventions and monitoring systems [13,14]. The 2013 Pew Internet and American Life Project's Online Health Survey [15] reports more than half of all Americans searched the internet for health information and greater than a third of respondents reported using the internet for self-diagnosis. The internet provides access to countless sources of health information (e.g., websites such as WebMD, MDadvice, MedicineNet and NetDoctor), most focused on diagnoses, diet, physical activity, alcohol use, and smoking. However, some websites provide inaccurate or misleading information, so the choice of sites should be monitored.

Kohl *et al.* [16], summarized data from 41 studies and reported the use of internet to elicit behavior change is small, variable and not sustainable. Additionally, the authors noted that most users of internet-based data are female, well educated, Caucasian and living in high income countries. The recent 2013 Pew Internet Survey of internet use and users [15] supports Kohl *et al.*'s findings. Clearly, the typical user of internet data is in a privileged position relative to healthcare, and still has difficulty with adherence. As technology continues to be adopted worldwide, these limitations should be noted and addressed in the design of future interventions and research to ensure better comprehensibility, usability and access to all. Ossebaard and colleagues [17] examined the usability and impact of a national internet portal to promote health among adults with chronic illness and their caregivers. The team conducted semi-structured interviews and focus groups recruiting patients with arthritis, asthma and diabetes and their caregivers to ascertain how they used the portal for information-seeking, self-management, and decision-making regarding their or their significant others' health condition. Information gleaned from this study highlighted the need to develop better navigation support and to provide more disease-specific information. While patients and families found the portal useful for providing information it was less effective for self-management and decision-making. Data from this study was used to modify the design of the national portal (e.g., better navigation through the site and more tailored disease information).

To ascertain what patients wanted and needed from a self-management website, Tradeau and colleagues [18] recruited 32 patients with arthritis and 12 arthritis practitioners. Participants engaged in 1-h telephone interviews to discuss the content of online materials. Patients and practitioners categorized and rated 88 unique statements about the self-management website. From these 88 statements, six themes emerged including: tools to manage pain; future of arthritis pain-related research; disease and pain education; physical activity; daily living/what can be done to modify pain; and communication/support such as emailing questions to practitioners. The data suggested patient and providers agreed on content for online arthritis education and self-management. However, patients desired more information about disease progression, while practitioners felt patients needed more information on medication adherence. van ser Vaart *et al.* [19] employed a cross-sectional study of 484 randomly selected patients from a large hospital-based rheumatology clinic to examine current content of internet-based materials for adults with arthritis and factors associated with online support services. Approximately half (47%) of patients completed the survey that contained items about intentions to use internet to obtain disease-

Table 1. Description of select behavioral theories and models commonly used in behavioral health interventions.

Behavioral Interventions	Description	Ref.
Cognitive behavioral therapy	Based on Cognitive Model of Emotional Response – a concept, which states that our thoughts cause our feelings and behaviors, not external things	[2]
Behavior reinforcement	Stimulus–response, reinforcement of desirable behaviors (i.e., Weight Watchers)	[3]
Health belief model	Patient beliefs drive change	[4]
Mindfulness	Meditation-based; focus attention/awareness	[5]
Transtheoretical model	Conceptualizes intentional behavior change – series of stages with strategies	[6]
Theory of planned behavior	Links beliefs, attitudes and behavioral intention	[7,8]
Social cognitive theory	Knowledge acquisition directly related to observing others within social contexts	[9]

Data taken from [10].

related information, care and support services, e-consultation, symptom monitoring, and electronic medical records (EMRs). Most patients (82%) used the internet to search for arthritis information and to access their medical records. Many reported they intended to use the additional online support services. However, no significant differences existed between demographic features of patients and use of online resources. These two studies [18,19] demonstrate that patients with arthritis use internet resources to learn about their arthritis and to access personal information.

In a systematic review of 11 randomized controlled trials, McDermott *et al.* [14] reported a lack of evidence to substantiate the superiority of internet-based SMIs over traditional SMIs. The authors noted that internet-based SMIs provided positive health outcomes compared with no intervention. However, this systematic review included only one study involving patients with arthritis. Table 2 provides a description of the studies of internet-based SMIs designed for adults with arthritis and their corresponding outcomes [20–23]. These studies varied with respect to sample sizes, duration and intensity of intervention. All studies compared the intervention to usual care or wait list control. Whetstone *et al.* [20] found the use of a brief online educational and behavioral program led to greater use of joint protection techniques, an improved outlook on life and hopefulness about the prognosis of rheumatoid arthritis (RA). Lorig *et al.* [21] and Shigaki *et al.* [23] used a randomized controlled design and demonstrated significant and substantial improvements in a variety of outcomes. Both studies reported long-term increases in self-efficacy and quality of life or global health. While the evidence for internet-based SMIs is limited, preliminary studies suggest acceptance and utility of internet-based SMIs for adults with arthritis. More research is needed to compare the effectiveness of traditional SMIs to internet-based SMIs on health outcomes, and to identify subgroups of patients who can benefit from these interventions.

Internet-based interventions to improve physical activity in adults with arthritis

There are limited studies of internet-based physical activity interventions in adults with arthritis [24–29]. Among the published literature there is a focus on assessing the usability and feasibility of this mode of SMI among healthy individuals and those with chronic illnesses. Factors found to affect engagement in physical activity using an internet-based program include: ease of navigation through the site, trust in the program, dependability and functionality of the site, social support and perceived support from the team who developed the online intervention [13,24,26–27]. Barriers to success included: medically complex health conditions, increased age, perceived lack of guidance with the program, poor motivation and/or depressed mood and increased value placed on human interaction [25]. In a recent focus group study reporting patient perceptions regarding physical activity monitoring in adults with RA, Tierney *et al.* [28] reported the use of monitoring devices was acceptable to patients.

Four studies [24,26–29] examined health outcomes of internet-based physical activity interventions in arthritis using a mix of study designs, duration and subjects. Bossen and colleagues [25] enrolled 199 patients with hip or knee osteoarthritis (OA; aged 50–75 years) who were allocated to the intervention group in a large randomized controlled nonblinded trial of a self-paced 9-week internet physical activity program (Join2move) versus wait list control. The intervention was based in the behavior graded activity theory. At 3 months the intervention group improved in physical function (difference: 6.5 points; 95% CI: 1.8–11.2) and positive self-perceived effect (odds ratio: 10.7, 95% CI: 4.3–26.4). There was no difference in physical activity scores. At 12 months, there were no effects for function and self-perceived effect but the intervention group reported engaging in more physical activity.

Another randomized controlled trial examined the effectiveness of two internet-based physical activity programs for adults with RA [24]. Van Den Berg *et al.* [24] enrolled 116 adults with RA who were physically inactive and randomly allocated them to one of two groups. One group was an individually guided internet-based physical activity program (IT) combined with bicycle ergometer and group contacts. The other group was an internet-based physical activity program, which included only general information on exercises and physical activity (GT). Patients in the IT program submitted weekly reports on physical activity and their program was modified accordingly. Assessments were made at 6, 9 and 12 months. At follow-up, the proportion of adults with RA who were physically active was significantly greater for the IT group at 6 months (Rx: 38 vs 33%) and 9 months (35 vs 11%; $p = 0.05$). Patients in the IT group also demonstrated higher rates of exercise at moderate intensity (30 min per session, 5×/week) than those in the general program at 6 months (35 vs 13%) and 9 months (40 vs 14%; $p < 0.001$). At 12 months, differences between groups regarding moderate intensity exercises persisted (34 vs 10%; $p = 0.005$). Thus, self-reported physical activity engagement appeared to be significantly impacted by an individually tailored and monitored program versus general information on physical activity. There were no differences with respect to disease activity, quality of life, or physical activity as measured by the activity monitors.

Table 2. Studies of internet-based self-management and physical activity interventions in adults with arthritis.

Author (year)	Design and sample; mean age (years); % women; arthritis	Recruitment source	Intervention, duration, booster, comparison group	Theory used (if any)	Follow-up	Significant outcomes	Ref.
Self-management interventions							
Whetstone *et al.* (1985)	RCT; n = 35; RA	Rheum	Rx: Received computer-based education and behavior change strategies. Patients completed the lesson at their convenience, taking from one to four sessions, with a mean duration of 107 min (range: 81–204) C: Usual care	–	N/A	Follow-up varied between 2 and 6 weeks. Patients in the Rx group reported greater use of joint protection techniques ($p = 0.018$), changes in the amount of rest time ($p = 0.043$), improved outlook on life ($p = 0.007$) and increased sense of hopefulness regarding their prognosis ($p = 0.001$) compared with the control group. No difference in treatment adherence	[20]
Lorig *et al.* (2008)	RCT; n = 855; OA 64%; RA 28%; FM 52%; other arthritis 14%; 52 years; 60% female	CV OV; drop-out: 6 months: 25%; 12 months: 24%	Rx: Internet-based ASMP log-on 1–2 h ≥3×/week for 6 weeks: self-tests; read information; post action plans, participate in discussion board; tailored exercise program; arthritis Helpbook. No booster C: Usual care	SCT	6 and 12 months	12 months: IASMP demonstrated significant improvements in pain, activity limitation, global health, self-efficacy, less health distress. OA-only group (n = 292): significant changes in outcomes as above plus improvements function and fatigue RA-only group (n = 144): significant improvements seen only in pain, activity limitation, and global health. FM only (n=86): no differences in any outcome	[21]
Shigaki *et al.* (2008)[†]	Cohort, secondary analysis of RCT; n = 30; RA	Nationwide OV; subjects part of wait list control in primary study	Rx: 10-week cognitive-behavioral self-management program with peer-support	SCT CBT	N/A	Primary outcomes: social interactions (median 32 log-ins). Qualitative review of discussion board posts demonstrated subjects spent most time accessing educational materials, posting on discussion board and e-mail. Posts reflected feeling of supportiveness being understood, and bonding among subjects	[22]

[†]Study is a subset of another published study.
[‡]While the study design was not stated, it is assumed to be SCT.
ASMP: Arthritis Self-Management Program; BGA: Behavior graded activity; C: Comparison group; CBT: Cognitive behavioral theory; CDSMP: Chronic Disease Self Management Program; CLBP: Chronic low back pain; CV: Community volunteers; EIA: Early inflammatory arthritis; FM: Fibromyalgia; N/A: Not applicable; NS: Not stated; OA: Osteoarthritis; OV: Online volunteers; ORTHO: Orthopedic clinic; PA: Physical activity; PC: Primary care; PsA: Psoriatic arthritis; RA: Rheumatoid arthritis; RDQ: Roland Morris Disability Questionnaire; Rheum: Rheumatology outpatient departments; Rx: Intervention; SCT: Social cognitive theory; SMART: Mail delivered Arthritis Self-Management Program; SMP: Self-management program; VA: Veterans Affairs Hospitals.

Table 2. Studies of internet-based self-management and physical activity interventions in adults with arthritis (cont.).

Author (year)	Design and sample; mean age (years); % women; arthritis	Recruitment source	Intervention, duration, booster, comparison group	Theory used (if any)	Follow-up	Significant outcomes	Ref.
Shigaki *et al.* (2013)	RCT; n = 106; RA; 50 years; 93% female	Nationwide OV	Rx: 10-week online program using secure website (RAHelp.org), which contained weekly online self-management modules plus social networking reinforced with weekly phone calls from clinician who also monitored website C: Wait list	SCT CBT	9 m	At follow-up: large differences in self-efficacy (ES = 0.92; p < 0.0001); quality of life (ES = 0.66; p = 0.003) 9 months: differences in self-efficacy and quality of life remained strong (ES = 0.92; p < 0.0001 and ES = 0.71; p = 0.04, respectively)	[23]
Interventions to promote PA							
Van den Berg *et al.* (2006)	RCT; n = 160; RA; 49 years; 61% female	Rheum	Rx: individually tailored internet-based PA program plus bicycle ergometer and group contacts. Weekly exercises consisted of strengthening, ROM, and cycling (60–68% max predicted heart rate) 5×/week with email adherence reports C: Internet-based PA program plus general information on exercise and PA	NS	6m, 9m and 12 m	Report of PA at follow-up at 6 months Rx group = 38 vs 33%) 9 months Rx group = 35 vs 11%; p = 0.05). IT higher exercise at moderate intensity (30 min per session, 5×/week) than those in the general program (6 months = 35 vs 13%; 9 months = 40 vs 14%; p < 0.001). 12 months differences between groups regarding moderate intensity exercises persisted (34 vs 10%; p < 0.005). No differences for disease activity or quality of life	[24]

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ASMP: Arthritis Self-Management Program; BGA: Behavior graded activity; C: Comparison group; CBT: Cognitive behavioral theory; CDSMP: Chronic Disease Self Management Program; CLBP: Chronic low back pain; CV: Community volunteers; EIA: Early inflammatory arthritis; FM: Fibromyalgia; N/A: Not applicable; NS: Not stated; OA: Osteoarthritis; OV: Online volunteers; ORTHO: Orthopedic clinic; PA: Physical activity; PC: Primary care; PsA: Psoriatic arthritis; RA: Rheumatoid arthritis; RDQ: Roland Morris Disability Questionnaire; Rheum: Rheumatology outpatient departments; Rx: Intervention; SCT: Social cognitive theory; SMART: Mail delivered Arthritis Self-Management Program; SMP: Self-management program; VA: Veterans Affairs Hospitals.

Table 2. Studies of internet-based self-management and physical activity interventions in adults with arthritis (cont.).

Author (year)	Design and sample; mean age (years); % women; arthritis	Recruitment source	Intervention, duration, booster, comparison group	Theory used (if any)	Follow-up	Significant outcomes	Ref.
Bossen *et al.* (2013)†	Mixed methods cohort; n = 20; hip or knee OA; 50–75 years; sedentary	Subset of patients from RCT, only those allocated to intervention group who completed 6 of 9 modules	Rx: Internet and theory-based self-guided, self-paced 9-week physical activity program (Join2move), contains automatic functions (website messaging and automatic emails). Builds on subject's favorite recreational activity	BGA	6 and 12 weeks	At 6 weeks: pain scores were significantly different between groups (5.3–6.6; p = 0.04), but this difference not evident after 12 weeks. There was no difference in physical activity scores. Subjects enjoyed exercising at their own pace, liked the convenience of the program. Lack of personal guidance, insufficient motivation, presence of physical problems, and low mood were reasons for nonusage. Absence of human involvement in the program was viewed as a disadvantage. Program was accepted; effective in reducing pain	[25]
Bossen *et al.* (2013)	RCT; n = 199; hip or knee OA; 50-75 years; sedentary	OV plus recruited via newsletters	Rx: Internet and theory-based self-guided, self-paced 9-week physical activity program (Join2move), contains automatic functions (website messaging and automatic emails). Builds on subject's favorite recreational activity C: Wait list control	BGA	3 and 12 months	Both short-term and long-term results positive with respect to physical activity, physical functioning, self-perceived effect	[26]
Krein *et al.* (2013)	Parallel group; RCT; n = 299; CLBP	VA	Rx: Subjects received uploading pedometer, access to a website for automated walking goals, feedback, motivational messages, and e-community social support C: Usual care	NS SCT‡	6 and 12 months	ITT and CC performed primary outcome was RDQ at 6 and 12 months. At 6 months, average RDQ scores were 7.2 for Rx group compared with 9.2 for usual care, an adjusted difference of 1.6 (95% CI: 0.3–2.8; p = .02) for the complete case analysis and 1.2 (95% CI: -0.09 to 2.5; p = 0.07) for the all-case analysis. A *post-hoc* analysis of patients with baseline RDQ scores ≥4 revealed even larger adjusted differences between groups at 6 months, but at 12 months the differences were no longer statistically significant	[27]

†Study is a subset of another published study.
‡While the study design was not stated, it is assumed to be SCT.
ASMP: Arthritis Self-Management Program; BGA: Behavior graded activity; C: Comparison group; CBT: Cognitive behavioral theory; CDSMP: Chronic Disease Self Management Program; CLBP: Chronic low back pain; CV: Community volunteers; EIA: Early inflammatory arthritis; FM: Fibromyalgia; N/A: Not applicable; NS: Not stated; OA: Osteoarthritis; OV: Online volunteers; ORTHO: Orthopedic clinic; PA: Physical activity; PC: Primary care; PsA: Psoriatic arthritis; RA: Rheumatoid arthritis; RDQ: Roland Morris Disability Questionnaire; Rheum: Rheumatology outpatient departments; Rx: Intervention; SCT: Social cognitive theory; SMART: Mail delivered Arthritis Self-Management Program; SMP: Self-management program; VA: Veterans Affairs Hospitals.

Krein and colleagues [27] recruited 229 veterans with chronic low back pain from Veterans Administrations Clinics and employed a randomized controlled trial to ascertain whether an internet-based program combined with pedometer assessment of walking could reduce chronic low back pain-related disability. Subjects were randomized to either an uploading pedometer and internet-based program that integrated periodic feedback, goals reinforcement, motivational messages, and social support via an e-community or usual care. Patients in the usual care also received an uploading pedometer but no feedback or access to the program website. Assessments were made at 6 and 12 months. A complete case and all-case analysis were conducted using linear mixed effects models to assess differences between study groups at both time points. At 6 months, the intervention group reported better function (average Roland Disability Questionnaire scores) compared with the control group. *Post-hoc* analysis indicated even larger statistically significant adjusted differences between groups at 6 months among patients with baseline Roland Disability Questionnaire scores greater than or equal to 4, but this difference disappeared by 12 months. These data demonstrate an online automated physical activity intervention was effective in reducing low back disability in the short-term.

These trials of internet-based physical activity interventions suggest internet programs are well accepted and yield short-term benefits for physical activity engagement in adults with arthritis. Two studies used behavioral theories to inform their intervention (note, while Krein did not specifically report using social cognitive theory, elements of the program such as social support, represent aspects of this theory) and yielded promising results.

Exergaming to promote heath outcomes in adults

Definition of exergaming & applications in chronic illnesses

As opposed to video games that are performed for enjoyment, exergaming refers to video games played on a television, computer or projector that captures motion and serves as a form of exercise to increase energy expenditure. Exergaming is considered a venue to augment rehabilitation, and can be incorporated into rehabilitation interventions to encourage movement or to promote physical activity [30,31]. Exergaming provides an opportunity for greater access to care by reducing physical barriers (transportation issues) and medical costs, potentially enhancing patient adherence through entertaining activities and enables individuals to monitor their progress via online documentation of exercise [31].

Gaming platforms include VR systems, computers mounted on exercise equipment and commercially available home video game consoles (e.g., Nintendo WiiFit, Sony PlayStation, Kinect and so on). Motion-monitoring systems allow control of onscreen activity and include hand-held accelerometers and gyroscopes, haptic and video-capture technology. There are both commercially available games as well as games developed specifically for health and rehabilitation [30–33]. Games may be immersive, or nonimmersive. Games are generally designed using an iterative process, which includes five stages: contextual inquiry, value specification, testing of design prototypes, operationalizing and, finally, summative system evaluation [30]. A well-tailored system can be developed through this iterative process and will ideally use input from an interprofessional team with individuals from the target patient population. [32]

The majority of exergaming studies for adults with chronic conditions include individuals who have suffered a stroke [34]. Plow and colleagues [34] reviewed 25 studies (either published or in press) using a standardized methodology. Studies were published between 1980 and July 2011 for adults with disabling conditions. The majority of studies examined the acceptability and functionality of the exergames but only four were randomized controlled trials. They concluded that research on exergaming is still in its infancy. More recent studies have examined the effectiveness of exergaming in healthy adults (both young and old) to improve balance [35–37], to ascertain metabolic equivalents of games [38] and to improve overall fitness and engagement in physical activity. [39] Miyachi and colleagues [38] recruited 12 adults to identified the energy expenditure associated with a commercially available exergaming system (WiiFit). Adults played a series of games including (golf, bowling, tennis, baseball, boxing) and WiiFit Plus activities such as yoga). In total, 67% of games were classified as light intensity (<3 metabolic equivalents) and 23% were classified as moderate intensity (3–6 metabolic equivalents). These data can be used to help consumers and patients accurately report physical activity levels and select appropriate games to meet their personal goals.

To date, only a handful of systems have been developed for adults with arthritis [32–33,40–41] and one study [41] has examined the use of exergames. Yuen [41] recruited 15 women with systemic lupus erythematosis and used a simple prepost design to examine the effectiveness of WiiFit on reducing fatigue and weight. Subjects were asked to use the exergame system 30 min per session, three times per week for 10 weeks. At the end of the trial, statistically significant improvements were noted for fatigue (10-point decrease on fatigue severity scale; $p = 0.002$) and weight loss (decrease of 2 kg). Srikesavan *et al.* [40] are examining the acceptability and effectiveness of a task-oriented exergaming system for adults with RA or OA using a single-blinded randomized controlled trial. Thirty adults with RA or OA affecting the hand will be randomly allocated to either: task-oriented training or conventional hand exercise. This trial is underway. Metsis and colleagues [32] are conducting a proof of concept trial to test the efficacy of a multifaceted exergaming system (RPLAY), combining elements of individual feedback with e-community. This theory-based cyberphysical system (uses components of social cognitive theory) is intended to preserve functional range-of-motion and cardiovascular health in persons with RA through promotion of physical activity. Breugelmans *et al.* [33] are assessing the use of a biosensor-based video game in adults with RA using modifications to the gaming interface to address common issues such as wrist and finger pain and synovitis, poor joint function, weak prehension and high prevalence of carpal tunnel syndrome. The system combines an eye tracking device with cyber glove technology. The gaming activities replicate common activities of daily living to allow users to develop strength and dexterity during an engaging and challenging game.

Exergaming for adults with chronic conditions appears to provide beneficial health outcomes and is acceptable to patients. Within the field of arthritis, exergame development is underway but only one study has formally assessed outcomes in a small pilot group. This area of research is expected to expand considerably in the next few years and provides promise for greater access to exercise and behavioral therapy to those currently limited by environmental barriers (access to transportation and so on).

Gaming interventions to promote self-management in children

Research demonstrates that video games are helpful therapeutic and educational techniques for children with chronic illness. There are no published studies or game systems reported for children with arthritis. Thus, this section will describe what is known about gaming for children with chronic illnesses and relate these findings to potential benefits for children with arthritis.

Ten studies [42–51] were identified that described 16 different video games for children with chronic conditions such as Type 1 diabetes, asthma, sickle-cell anemia, cancer, cerebral palsy, and cystic fibrosis [42–51]. These video games were specifically designed for each chronic illness and addressed their unique education, self-management, self-efficacy, entertainment, communication and social application needs. The majority of the games were designed for younger children (75% for ages of 7–14 years). Six studies measured changes in disease knowledge; five measured changes in self-management (self-care behaviors and adherence); four changes in self-efficacy and two measured changes in communication/social applications. In addition, five studies measured the level of enjoyment and entertainment for children during play. Specifics regarding game content, game design, theory, statistics, and outcomes for each game can be found in Table 3. Four games were particularly unique. These games demonstrated improvements in education/knowledge of disease, self-management, self-efficacy, entertainment, or communication and social skills. For example, the 'Egg Breeder' game [42], designed for children newly diagnosed with Type 1 diabetes aims to improve understanding and management of diabetes.

Throughout the game, players breed and nurture a diabetic egg through provision of correct food types, exercise, and insulin doses, based on plasma glucose levels. The goal is to hatch a healthy chick. Depending on how well the player has maintained plasma glucose levels during the breeding period, varying degrees of healthy to unhealthy eggs will hatch. Researchers tested the game for entertainment, usability, and clinical usefulness. Data indicated that 25.9% of children strongly agreed the game was entertaining. A total of 60% found the game clinically useful. Results demonstrate the potential value and benefit of using entertaining video games to educate children with chronic illness about their disease [42].

Another study examined commercially available exergames (e.g., Wii tennis, Wii bowling, Wii boxing, Disney Grooves Dance Dance Revolution [DDR]) to assess whether active video games are useful in promoting physical activity and rehabilitation therapies for children with cerebral palsy [46]. Children used a Wii remote in their dominant hand to simulate tennis and bowling movements. In Wii boxing, children used both upper extremities, with a Wii remote and nunchuk. For DDR, the children had a dance mat, a Wii remote and nunchuk, requiring the use all four extremities. Energy expenditure, perceived exertion, and self-reported enjoyment were measured. Energy measures were lower at baseline levels prior to playing, than during any of the games ($p \leq 0.002$). Games involving both the lower body and upper body (DDR) or which had high frequency movements of both arms (Wii boxing) demonstrated significantly higher energy measures than games requiring the use of one arm (Wii bowling). The median score for enjoyment was 4.5 out of 5, which suggests that the children enjoyed playing the games. Moderate physical activity levels were

Table 3. Studies of gaming for children with chronic illness, content, design and health outcomes.

Author (year)	Chronic illness	Name of game	Game content	Outcomes measured	How it was measured	Ref.
Yoon and Godwin (2007)	Sickle cell disease	Sickle-cell Slime-o-rama	Sickle cell disease facts, taking care of your health, and disease management	Level of knowledge, confidence of self management	Pretest/post-test	[49]
Aoki *et al.* (2004)	Type 1 diabetes mellitus	Egg Breeder	Relationship among plasma glucose, insulin prescription, food, and exercise	Entertainment, usability, and clinical usefulness	14 question post-test survey answering from 5 = strongly agree to 1 = strongly disagree	[42]
		Detective	Player must choose the correct food or insulin dose to keep the detective's blood sugar at an appropriate level. Short quizzes embedded regarding management of Type 1 diabetes along route. Correct answer allows player to take a short cut and get closer to catching the criminal. When blood sugar levels are not handled in an appropriate time frame, screen fogs up to signify that vision can be affected by unmanaged blood sugar	Edutainment, usability, and clinical usefulness	14 question post-test survey answering from 5 = strongly agree to 1 = strongly disagree	
		Build-up Blocks	Which food to be selected in a variety of situations	Edutainment, usability, and clinical usefulness	14 question post-test survey answering from 5 = strongly agree to 1 = strongly disagree	
Fuchslocher *et al.* (2011)	Type 1 diabetes mellitus	Balance-Platform 'jump and run' game	Player has to control his blood sugar by eating food and taking insulin. Food choices get harder as game advances	Diabetes-related self efficacy, enjoyment of the game, children's perceived similarity to the game character, correlation between self-efficacy and participants' experienced similarity to the game character	Questionnaire with rating scales	[45]

Table 3. Studies of gaming for children with chronic illness, content, design and health outcomes (cont.).

Author (year)	Chronic illness	Name of game	Game content	Outcomes measured	How it was measured	Ref.
Kato (2010)	Asthma	Bronkie the Bronchiasauras	Avoiding asthma triggers and answering educational questions to proceed in the game	Self-concepts, social support, knowledge, self-care behaviors, self-efficacy	Not stated	[48]
		Spiro game	A device measures and gives a readout of breathing function for spirometry. The game teaches children to differentiate between inhalation and exhalation, and teaches them how to control their breathing	Lung function, spirometry	Spirometry measures	
	Pediatric cancer	Re-Mission	Treatments (destroying cancer cells through chemo and radiation), combat side effects (pain, nausea, infection, constipation)	Treatment effectiveness, knowledge of cancer and self-efficacy to manage cancer	Level of chemotherapy in their blood, how often prophylactic antibiotic medications were taking	
	Diabetes	Packy and Marlon	Monitoring glucose levels, taking insulin as needed, diet	Self-efficacy for diabetes self-management, amount of communications with parents, self-management behaviors	Not stated	
Bingham *et al.* (2012)	Cystic fibrosis	Ludicross and Creep Frontier	Breath activating game to enhance secretion removal by incorporating a digital spirometer, enhance lung function, and prevent exacerbations of cystic fibrosis. Made to help improve adherence and self-management	Adherence and engagement to airway clearance techniques in relation to their sense of competence, self-determination, and autonomy. Improvement in FEV1	20-min questionnaire	[43]
Farrell *et al.* (2011)	Hygiene	E-bug Junior	An avatar is shrunk to fit inside the human body where she/he interacts with helpful and harmful cartoon microbes	Knowledge game of learning objectives	Pre- and post-level (of the game) questions	[44]
Huss *et al.* (2003)	Asthma	Wee Willie Wheezie	Navigate Willie through his home environment by avoiding asthma triggers and giving Willie the correct amount of certain medications to manage his asthma either when he cannot avoid a trigger or when he has an exacerbation	Lung function (measured by FEV1, FEV1 percent predicted, PEFR, PEFR percent predicted), quality of life scores specifically for symptoms (measured by the PAQQL), emotions, and overall quality of life (measured by the PAQQL), severity of asthma (measured via PAQQL scores plus FEV1 percent predicted), and asthma and air control knowledge	Pre-/post-test measurements of FEV1, FEV1 percent predicted, PEFR, PEFR percent predicted, PAQQL, emotions, PAQQL plus FEV1 percent predicted, and asthma and air control knowledge	[47]

Table 3. Studies of gaming for children with chronic illness, content, design and health outcomes (cont.).

Author (year)	Chronic illness	Name of game	Game content	Outcomes measured	How it was measured	Ref.
Burdea *et al.* (2013)	Cerebral palsy	Airplane	Use the Rutgers Ankle CP system to fly an airplane through a series of targets, which the PT controls using a computer program. Long games for ankle endurance, fast flying airplanes to improve motor control, turbulence/ vibrations to practice overcoming disturbances	Primary: impairment (DF/PF torques, DF initial contact angle and gait speed), function (GMFM), and quality of life (Peds QL); Secondary: game performance (game scores as reflective of ankle motor control and endurance)	Pre-/post-test measurements of DF/PF torques, DF initial contact angle and gait speed, GMFM, Ped QL, and game score	[50]
		Breakout 3D	Control a paddle to rebound balls towards a brick wall trying to break the bricks. Game can varied for different skill levels based on ball speed and size and number of bricks	Primary: impairment (DF/PF torques, DF initial contact angle and gait speed), function (GMFM), and quality of life (Peds QL); Secondary: game performance (game scores as reflective of ankle motor control and endurance)	Pre-/post-test measurements of DF/PF torques, DF initial contact angle and gait speed, GMFM, Ped QL, and game score	
Wyatt *et al.* (2013)	Asthma	Okay With Asthma	Encourages users to describe their feelings and asthma support systems as they interact with a prewritten narrative and then add text to create their own stories. OKWA v2 uses similar but more refined techniques for supporting interactivity	Self-management, education, communication, knowledge	Post-test questions	[51]
Howcroft *et al.* (2012)	Cerebral palsy	Wii bowling, Wii tennis, Wii boxing, DDR Disney Dance Grooves	Player uses the Wii remote in dominant hand for Wii bowling, a nunchuk and the Wii remote for boxing, and the nunchuk, Wii remote, and dance pad for dancing. Player simulates the motions of bowling, boxing and dancing shown on screen	Energy expenditure, upper limb muscle activations, upper limb kinematics, self- reported enjoyment, perceived exertion	Portable cardiopulmonary testing unit, single differential surface electrodes, an optical motion capture system, the Physical Activity Enjoyment Scale (PACES)	[46]

found in 15% of children playing Wii bowling, 23% in Wii tennis, 62% in DDR, and 54% in Wii boxing. A total of 8% of children reached vigorous levels of physical activity using Wii boxing. This study illustrated that active video games can promote moderate physical activity for children with mild cerebral palsy [46]. Whether similar outcomes are possible for children with arthritis is unknown but appears promising.

Most studies of exergaming examine enjoyment of game, adherence to medical treatment, self-efficacy and knowledge. In total, 60% of studies used pre-/post-tests to measure knowledge, self-management, and medical measurements (e.g., spirometry and chemotherapy blood levels). Some studies restricted the time children were able to play during treatment sessions. Among studies that reported length of play, the time varied from 15 to 60 min at a time, with an average of 26 min. Each game used different techniques to engage children in play: 31.2% used an avatar, 25% used an animal figure, 18.8% used quizzes, 12.5% used physical activity feedback, and 12.5% used controlling a race car or airplane. Games that used animals (75%) tended to report the highest level of improved outcomes whereas, among games using avatars improvements were noted 40% of the time. Most games (75%) incorporated motivational tactics such as passing levels to move on, keeping the avatar or animal healthy and alive, and physically seeing improvement with changes in your avatar's play.

Video gaming as a therapeutic treatment for children with chronic illness is fairly new. Most games address self-management, knowledge and self-efficacy and appear to be effective in improving these outcomes. Game designs varied with respect to computer interfaces, computer representations (avatar vs animal) motivational tactics, and length of play. The efficacy of exergaming for children with arthritis is unknown. However, design elements evident in games for children with other chronic conditions may prove informative for the development of exergames for children with arthritis.

mHealth & arthritis management

Technologic advances and the proliferation of smartphones have led to easy access of information and new developments in mHealth. Approximately, 1 billion smartphones and tablets are in use globally; some sources estimate that this will reach 2 billion by 2014 [52]. Nearly two-thirds of cell phone owners use their phone to go online [15]. Mobile health applications or mHealth are defined as "medical and public health practice supported by mobile devices" [53] such as mobile phones, patient-monitoring devices (e.g., accelerometers), personal digital assistants, and other wireless devices, which may involve the use of voicemail, short messaging service (SMS) or use more complex functionality such as global positioning systems. Smartphone technology allows applications to locate the nearest park to promote physical activity, and to connect through social media such as Facebook or crowd sourcing [54]. The immediate feedback, ability to connect with social networks and observe others activities (through pictures and online monitoring) provides the social reinforcement, cues to action and social modeling evident in the social cognitive theory [9].

Despite the staggering proliferation of healthcare applications, (estimated at over 40,000) [15], there is limited data on the role of mobile health applications to improve health outcomes. A recent report from the IMS Institute for Healthcare Informatics provides an overview and analysis of 40,000+ healthcare applications available for download. This enormous undertaking provides some guidance for healthcare providers and consumers regarding the content, validity, and functionality of these applications. In this section, studies using mHealth interventions for persons with arthritis are reviewed [15].

Cole-Lewis *et al.* [55] and Fjeldsoe and colleagues [56] evaluated the impact of mobile text messaging to promote behavior change and disease management. In their systematic review, Cole-Lewis *et al.* [55], summarized data from 12 randomized or quasi-experimental controlled trials published prior to June 2009 that used text messaging as the primary intervention. Five studies used text messaging for disease prevention and seven for disease management. Various message frequencies and intervention periods were used but studies did not examine long-term outcomes. Of nine studies deemed sufficiently powered, eight supported the use of text messaging to promote behavior change. Fjeldsoe *et al.* [56] conducted a systematic review of studies published between January 1990 and March 2008 using SMS as the primary intervention to promote health behavior change. Fourteen studies met the inclusion criteria. Four studies focused on changing a lifestyle behavior such as smoking cessation and ten on disease self-management. The authors found significant positive short-term effects on behaviors in 13 of 14 studies. Aspects of SMS interventions which influenced behaviors included: tailoring of content, who initiated the SMS, and amount of interaction with the study team.

Behavioral interventions to improve physical activity are effective in managing arthritis. Most of these used counseling, group exercise and behavioral reinforcement [57]. An emerging area of research is the use of accelerometers, which are devices used to capture body movement via gyroscopes. Data can be used to ascertain metabolic equivalents to categorize amount of physical activity/sedentary behavior for individuals with arthritis. Studies have examined the validity of self-reported physical activity questionnaire using these devices [58,59] developed protocols to more accurately measure physical activity in persons with arthritis [59] and to objectively measure change in physical activity over time and after interventions [60]. This is a fertile area of research in arthritis and other conditions which rely on activity for disease prevention and/or management.

VR, active assistant technology & telemedicine

VR technology creates controllable, interactive, multisensory environments that allow measurement of human behavior and provide motivation for participation. There are two formats for VR: nonimmersive and immersive. Nonimmersive VR uses modern computer and console games systems providing a 3D graphic environment either on a flat screen monitor, a projection system or TV. This system allows the user to navigate through the VR environment and interact with the environment. Whereas, Immersion VR "combines computers, head-mounted displays, body tracking sensors, specialized interface devices and real-time graphics to fully immerse the user in a computer-generated simulated world that changes in a natural way with head and body motion" [61,62]. Applications of VR in healthcare include: medication adherence, patient counseling, rehabilitation and physical activity promotion. Studies examining the use of rehabilitation-based VR systems focus primarily on adults and children with neuromuscular conditions and note that games that incorporate strong design elements (e.g., patient input into design components) are the most effective [62,63]. Three studies have been published using VR in arthritis [64,65]; one is still underway [66]. Alhalabi [64] examined the use of VR to employ imagery therapy for adults with RA. In his paper, he describes the development of the system and outcomes of the VR pilot testing. Patients were allocated to one of two groups: control (usual care) or VR (usual care plus VR imagery). Data suggested patients in the VR group reported reduced stress, better sleep and mood state [64]. Botella *et al.* [65] describe the use of a VR-based program for adults with fibromyalgia. Six women with fibromyalgia were recruited and participated in ten group sessions of cognitive behavioral therapy using a virtual environment. At 6 months, patients reported improved affect and use of coping strategies, as well as reduced pain and mood. In a systematic review of nonimmersive VR for rehabilitation, Smith *et al.* [63] analyzed the results of 16 randomized controlled trials including patients with stroke, cardiopulmonary conditions, cerebral palsy, OA, and balance disorders. Most studies did not include patients with arthritis. The authors concluded that nonimmersive VR is a useful adjunct to rehabilitation but there is no evidence to suggest nonimmersive therapy alone is effective.

Automated & active assistive technology for health behaviors

Beyond internet self-management programs, there is a vast array of technologies available to address medication adherence [67]. Automated medication tracking systems, known as technology assistant systems, are available as mechanisms to prompt for and record medication use with embedded sensors (withdrawal of pills from containers) [68]. These devices are used in many venues including hospitals, nursing facilities and homes [69–71]. Newer wireless interfaces advance this technology and serve as local intelligence. Personal computers can be updated with instructions for the client, medical staff can use the internet to retrieve and access data, computers can provide daily reminders and monitor whether instructions are followed. Thus, technology can target the individual, environment and provider. Patient interfaces can include prompts for behaviors, allow for recording of symptoms, provide a forum for discussion with the provider and correlate activity related to medication adherence.

Kennedy *et al.* [69] analyzed the results of 41 studies to determine how active assistive technology (AAT) influences health behaviors. Active assistance technology was defined as any technology involving automated processing of health or behavior change information that is ongoing as the user interacts with the technology. The authors found most research focused on dynamic adaptive systems to tailor health messages, embodied conversational agents to promote education, and systems to monitor and recognize behaviors. Many studies addressed physical activity promotion. Empathy and relational behavior were predominant research themes in systems for behavior change and few studies focused on interactive education and self-monitoring. They concluded more work is needed to examine the capabilities of technology to promote behavior change and incorporate interdisciplinary teams to best identify and develop successful systems.

Within hospital systems, a new technology currently being examined is the virtual discharge nurse and patient self-management system [71]. This system reviews discharge instructions with the patient using synthetic speech, allowing for acquisition of information with electronic medical records. It uses an avatar that portrays attributes of patients to walk patients through the discharge instructions and to promote learning and self-management [71].

Telerheumatology uses, strengths & challenges

Telehealth/telemedicine is defined as remote access to medical professionals and has the potential to increase access to rheumatologists for patients with arthritis. This technology has been used successfully in cardiology but is still novel in rheumatology. A recent report [72] on the application of telemedicine in rheumatology identifies three major strengths. These are: improved patient access to rheumatology care, reduced costs and travel time (for patient and provider) and ability to promote communication among the interprofessional team. Challenges evident with the use of telerheumatology include: ensuring provision of quality care, maintaining patient satisfaction (due to decreased personal contact) and financial impact to provider (how to bill for services). Other challenges are medicolegal issues associated with transmission of medical data across technology, the need for secure lines to protect confidentiality, and training for technical staff. Despite the challenges, telemedicine holds promise regarding greater access to skilled rheumatologic care.

Conclusion

Multiple factors are driving integration of technology into health. Today, consumers use their smartphones to access online health information and most have at least ten applications downloaded on their phones. With over 40,000 health applications available [15] and little control over the quality, usability and applicability of mobile applications, consumers can get overwhelmed and confused by data, some of which might be inaccurate. Most published studies in arthritis examine the use of web-based interventions to promote self-management and physical activity. Results suggest internet-based education and self-management programs are more effective than no intervention but appear to be similar in impact to person-to-person SMIs.

mHealth includes a multitude of interventions from text messaging, voice messaging, global local systems, and personal monitoring devices. mHealth messaging via texting appears to be compatible with theories of health promotion such as the theory of planned behavior [7,8] and social cognitive theory [9], as they integrate social support (crowd sourcing and so on), cues to action, and incorporate patient beliefs and attitudes. The majority of studies of mHealth applications have been conducted in persons with diabetes. Among studies in arthritis, some text messaging programs exist and newer studies are incorporating the use of accelerometers to objectively assess physical activity. These interventions should not be considered stand alone interventions, rather they are best suited to augment current care. Studies also indicate that regardless of the technology used, theory-based technological interventions are the most successful at promoting and maintaining health behaviors and self-management.

Health-related games are most often studied in persons with neuromuscular disorders. Limited studies address the use of gaming for persons with arthritis, though novel games are currently being tested. Games allow for the integration of social support/social networks, as well as ecological models through the use of e-communities and social feedback. While exergaming for children has been studied in various chronic conditions, these have not been evaluated for children with arthritis. However, information from these studies can be gleaned from the literature regarding successful design elements and approaches to motivating children to engage in play. VR systems can simultaneously provide motivation and ability to simulate daily activities but these studies are in the early stages so conclusions about their effectiveness for promoting behavior change and self-management in persons with arthritis are limited. AATs are used to monitor, inform and enhance patient adherence to medical treatment and exercise. A vast arrange of AATs exist. AATs have the potential to address barriers to care and provide new learning opportunities for patients. The use of avatars with the virtual discharge systems may help facilitate communication between patients and providers, as the system has the capacity to create avatars that resemble patient attributes (e.g., race, age and gender). They may also be used to address issues of health and functional literacy. AATs may enhance provider-patient communication by allowing more time for providers to discuss patient questions. Studies of their effectiveness are needed.

Telemedicine/telehealth holds the promise of greater patient access to rheumatologic care. Telemedicine also presents unique challenges and strengths and studies are warranted to test the feasibility and effectiveness in the myriad of health settings. Despite the mode of delivery of technology-based health interventions it is paramount to garner the expertise of an interprofessional team (mix of providers, engineers and consumers) to develop the most patient-centric, useful, feasible and modifiable systems.

Future perspective

Given the expanding market in health applications, more formal and standardized methods to ascertain the quality of mHealth applications are warranted. Future studies should address the development of a universal assessment rubric that is consumer friendly to help patients navigate the mobile applications minefield. Telemedicine and AATs studies in rheumatology will help to identify strategies to address barriers to their use and give patients and providers more options for routine monitoring of health status, physical activity and adherence. Individuals with expertise in outcome assessment and behavioral science need to become more engaged in design and implementation of technology-based interventions to determine the impact of these programs as well as to identify which subgroups of individuals who will benefit from technology-based interventions to promote health.

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Executive summary

- Health and technology applications are on the rise and consumers need guidance on which ones to use and how to navigate through them.
- In-person self-management interventions (SMIs) and physical activity promotion programs have been effective for persons with arthritis.
- Internet-based SMIs and physical activity promotion programs are more effective than no interventions and appear to be equivalent to in-person programs. They provide an added benefit of creating more access, convenience and potentially greater cost–effectiveness. However more studies are needed to substantiate these claims.
- Regardless of the technology, technologically-based interventions are more likely to be adopted when they have greater versatility, are based in behavioral theory and engage an interdisciplinary team in their design.
- Fewer studies on the use of games and virtual reality systems exist for arthritis self-management and physical activity than for other conditions or interventions.
- Active assistive technology and telemedicine are relatively new technologies in the field of rheumatology and offer the promise of greater access, and the ability to reduce barriers to care.

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