

EFFICACY OF CONNECTED DEVICES IN PROMOTING PHYSICAL ACTIVITY AND REHABILITATION AMONG PATIENTS WITH RHEUMATOID ARTHRITIS AND SPONDYLOARTHRITIS: A SYSTEMATIC REVIEW

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Abstract. Objective: The main objective of the study was to evaluate the efficacy of connected devices in promoting physical activity and rehabilitation among patients with IRD. Secondary outcomes were to assess their effects on disease activity, fatigue, and quality of life. **Data sources:** Key words related to connected devices, physical activity, rehabilitation, and inflammatory rheumatic diseases (IRD) (rheumatoid arthritis, spondyloarthritis, psoriatic arthritis) were used to search for intervention trials published as articles and abstracts in the databases MEDLINE, Web of Science, Scopus, American College of Rheumatology (ACR) abstract archive and European Alliance of Associations for Rheumatology (EULAR) abstract archive. No restrictions were applied in terms of publication date. **Study selection:** Interventions consisting of connected devices used for promoting physical activity and rehabilitation were included. Studies reporting the following primary or secondary outcomes were included: physical activity measurements, function of a limb region, and performance-based physical function tests. Studies reporting only disease activity outcomes or only evaluating feasibility of connected programs were excluded. **Data Extraction:** Data from each report were extracted by two researchers independently. The obtained data were narratively summarized. **Data Synthesis:** The search identified 584 studies and 15 met the inclusion criteria. The study designs were: randomized controlled trials ($n = 9$), non-randomized intervention trials ($n = 3$), cross-sectional study ($n = 1$), prospective observational study ($n = 1$), and a case-control study ($n = 1$). Promoting physical activity using a wearable device was improved significantly in one study. Among 9 studies assessing rehabilitation, a significant improvement was found in four studies for hand strength, in 2 studies for cardiorespiratory fitness, and in 2 studies for muscle endurance. Two of the 3 studies focusing mobility showed a significant increase for intervention groups. **Conclusion:** The present study indicates that connected devices are simple and safe tools to improve mainly performance-based physical function in patients with IRD. However, further studies with larger population sizes and a longer follow-up period are needed to make reliable conclusions.

Key words: telerehabilitation, wearable electronic devices, connected healthcare, rheumatoid arthritis, spondyloarthritis

INTRODUCTION

The burden of inflammatory rheumatic diseases (IRD) especially Rheumatoid arthritis (RA) and Spondyloarthritis (SpA) increased significantly, affecting millions of patients worldwide [1, 2]. They are responsible of chronic pain, joint damages with osteoarticular destructions, and deterioration of physical functioning which may reduce the health related quality of life (HRQoL) (less autonomy and dependence) and decreasing the work productivity [3]. In association with musculoskeletal diseases, IRD are estimated to be the second cause of functional disability [4]. This impairment reduces physical activity and increases sedentariness.

Physical activity is defined as “any bodily movement produced by skeletal muscles which results in

energy expenditure. Exercise is a subset of physical activity in that it is planned, structured, repetitive and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective” [5]. The World Health Organization (WHO) recommends “at least 150-300 minutes of moderate-intensity aerobic physical activity or at least 75-150 minutes of vigorous-intensity aerobic physical activity; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week” [6]. It is commonly recommended as non-pharmaceutical intervention. Physical activity plays a crucial role in general population and especially in patients with IRD. In this context, the European League Against Rheumatism (EULAR) recommends physical activity for patients with IRD [7].

For that, health care professionals should actively promote physical activity at diagnosis of inflammatory arthritis and throughout the disease course [8]. However, authors estimate that 60% of patients with IRD are away from those recommendations [9].

Physical activity may have an important preventive effect, as well as therapeutic and rehabilitative ones. It is associated with a decrease in cardiovascular risk, pain, and inflammation [10, 11]. A meta-analysis published by Billet et al. emphasizes that exercise improved HRQoL, function, and pain among patients with RA [12]. Moreover, sedentary behavior is associated with poor HRQoL in patients with SpA [13].

In fact, the promotion of physical activity and rehabilitation function for patients with IRD is a key challenge faced by medical professionals. Those interventions can be performed individually or in groups and should include behavioral change techniques in order to promote long-term adherence [14]. However, in addition to the lack of motivation, there is a lack of access to supervised community-based centers because of the important number of patients suffering from disability. This matter was raised during the COVID-19 pandemic because of restricted access to health care services, self-isolation and home quarantine [15]. Therefore, the need to develop other methods providing home-exercises and rehabilitation programs was identified to improve patient's adherence and motivation. It was necessary to found accessible tools to reduce sedentary behavior at home, to encourage patients to be more active in their daily life, continue their rehabilitation programs, and self-manage their disease [16]. Recently, modern technologies have revolutionized the health field worldwide. Connected devices such as Smartphone applications, web-interventions, and wearable devices have been widely used for health care promotion especially in cardiovascular diseases and recently in IRD [17-19]. Activity trackers were used to promote or to monitor physical activity, performance-based physical and rehabilitation. Recently EULAR published guidance on important aspects that should be considered for the development, evaluation and implementation of applications for self-management of IRD [20].

In fact, many studies including a meta-analysis have shown that home-based physical activity interventions and telerehabilitation were as efficient as specialized center interventions and conventional rehabilitation [21-23].

However, scarce information and limited evidence about the effectiveness of wearable devices

in promoting physical activity and rehabilitation among IRD patients are available. Therefore, there is a better need to summarize information about devices, different protocols, and their outcomes for this specific population. To the best of authors' knowledge, there is no systematic review assessing the effect of wearable devices on physical activity and rehabilitation among patients with IRD.

Therefore, the aim of the current study was to perform a systematic review on the efficacy of wearable devices on promoting physical activity and rehabilitation among patients with IRD. Secondary outcomes were to assess their effects on disease activity, fatigue, and quality of life.

METHODS

The updated version of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement was used for the structure of this systematic review [24]. Ethical approval was not required, since this research was a systematic review of published articles.

Eligibility criteria

Intervention trials published as articles and abstracts involving rheumatic disease patients (RA, SpA, psoriatic arthritis) were included. Scientific texts published in a different language than English and French were excluded. No restrictions were applied in terms of publication date.

Interventions consisting of connected devices (games, smartphone applications, websites ...) used for promoting physical activity and rehabilitation were included.

Studies reporting outcomes regarding physical activity measurements (steps per day, physical activity questionnaires...) and rehabilitation evaluation: function of a limb region (mobility indexes, range of motion, muscular strength...), and performance-based physical function tests were included. Studies reporting only disease activity outcomes or only evaluating feasibility of connected programs were excluded.

Information sources

A research on MEDLINE, Web of Science, Scopus, American College of Rheumatology (ACR) abstract archive and EULAR abstract archive for relevant studies was performed. These databases were last searched on January 31st, 2024.

Search strategy

The search strategy consisted in intersecting key words related to the concepts of interest: con-

nected elements, physical activity and rehabilitation, and rheumatic disease. The search terms were chosen after discussion within the research team. A MeSH search in MEDLINE and a manual search in all the previously mentioned databases were performed. The following search terms were used for the identification of studies including the use of connected elements: Mobile Applications [MeSH], Software [MeSH], Smartphone [MeSH], Exergaming [MeSH], Virtual Reality Exposure Therapy [MeSH], Virtual Reality [MeSH], Telerehabilitation [MeSH], Telemedicine [MeSH], Wearable Electronic Devices [MeSH], Wearable technology, Telehealth, smart healthcare, and Connected healthcare. To identify studies targeting physical activity and rehabilitation, we used the search terms Exercise [MeSH], Warm-Up Exercise [MeSH], Physical Conditioning, Exercise Therapy [MeSH], Physical Fitness [MeSH], and physical activity questionnaire. Studies targeting rheumatic disease population were identified using the following search terms: Spondylarthritis [MeSH], Spondylitis, Ankylosing [MeSH], Spondyloarthropathies [MeSH], Arthritis, Psoriatic [MeSH], Arthritis, Rheumatoid [MeSH], and spondyloarthritis. Afterwards, reference lists of the included studies were screened for relevant publications.

Selection process

Search results were extracted into a Microsoft Excel spreadsheet. Study selection was performed by two independent researchers (HE, BDS). If there was a disagreement, the record was assessed by a third investigator (BTA). After removing duplicate articles, the first step of the selection process was title screening, followed by abstract screening, and finally full-text screening. Abstracts derived from the same study as a selected article and reporting similar results were excluded in favour of the article.

Data collection process and data items

Data from each report were extracted by two researchers independently. The following data were extracted from the included studies: authors, country of the study, year of publication, study design, inclusion and exclusion criteria, population, numbers of IRD patients and control groups, age, and sex of participants. As for rehabilitation, the following were collected: target, type of intervention, frequency, setting, duration of the intervention, follow-up, outcomes, and findings. The device of connected intervention was described.

Study risk of bias assessment

Quality assessment of included studies was performed using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies [25]. This tool evaluates 6 different domains: Selection bias, Study design, Confounders, Blinding, Data collection methods, and Withdrawals and drop-outs. Each domain is rated as strong, moderate, or weak. Based on the rating of each domain, an overall study quality was assigned to each study (strong, moderate, weak). The rating "Strong" was assigned to studies having no weak-rated domain. Studies having one weak-rated domain were rated as "Moderate." Studies were rated as "Weak" if they had two or more weak ratings. Each study was rated by two authors independently. In case of disagreement, consensus was reached through discussion within the research group.

Synthesis methods

A meta-analysis was not conceivable because of the disparity of the included studies in terms of intervention characteristics, and outcome measures. As a result, the obtained data were narratively summarized.

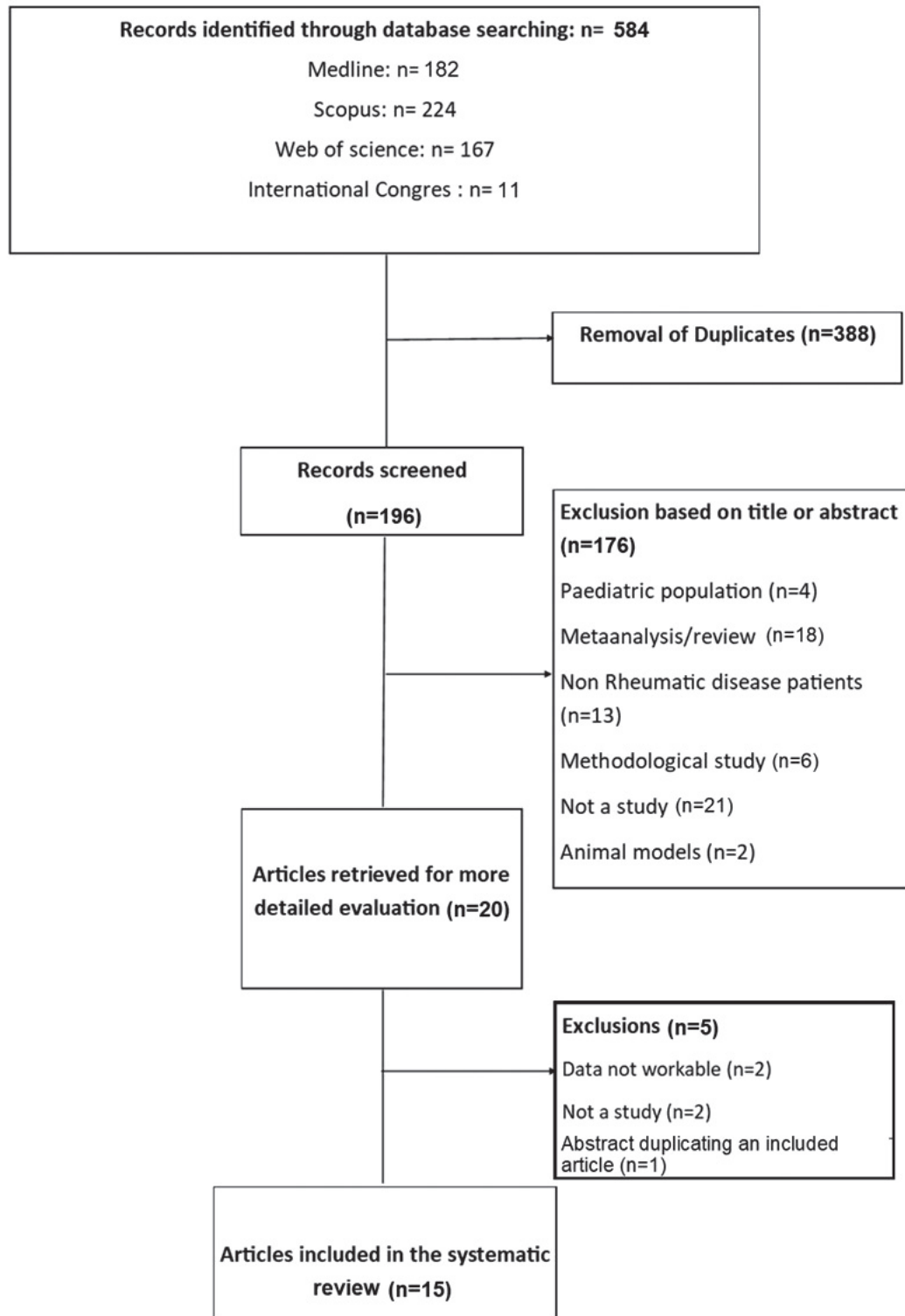
RESULTS

Study selection

The initial electronic search yielded 584 articles through the following databases: MEDLINE, Scopus, Web of science, and the international congresses. After removing duplicates from the initial search, a total of 196 articles were screened by two independent medical doctors. Screening based on title and abstract excluded 176 articles and left 19 articles to be screened in full text. Of those 19 articles, 15 studies that met the inclusion criteria of this systematic review were identified. Reasons for exclusion are shown in the flow diagram (Figure 1). The list of eligible studies was sent to an expert in the field for verification.

Risk of bias in studies

Two studies were rated as "strong," eight as moderate, and five as "weak". The highest number of weak ratings was found in the "selection bias" and the "blinding" domains. The "Study design," "confounders" and "data collection methods" domains had the highest number of strong ratings. The details of the methodologic assessment of included studies are described in Table 1.



Flow diagram for systematic review

Figure 1. Flow diagram for systematic review

Table 1. Methodologic quality assessment with EPHP tool for quantitative studies

Study	Selection bias	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Global rating
Pani D et al. (2014) Italy [19]	Weak	Moderate	Not applicable	Moderate	Weak	Strong	Weak
Zernicke J et al. (2016) Germany [17]	Moderate	Strong	Strong	Moderate	Strong	Strong	Strong
Wang Y et al. (2022) China [26]	Weak	Strong	Strong	Weak	Strong	Strong	Weak
Rodríguez Sánchez-Laulhé P et al. (2022) Spain [27]	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong
Tierney M et al. (2015) Ireland [28]	Weak	Moderate	Not applicable	Weak	Weak	Strong	Weak
Li LC et al. (2020) Canada [16]	Weak	Strong	Moderate	Weak	Strong	Strong	Weak
Jacquemin C et al. (2018) France [29]	Moderate	Moderate	Strong	Moderate	Weak	Strong	Moderate
Katz P et al. (2018) USA [30]	Moderate	Strong	Strong	Weak	Strong	Strong	Moderate
Haglo H et al. (2021) Norway [31]	Weak	Strong	Strong	Moderate	Strong	Moderate	Moderate
Piga M et al. (2014) Italy [32]	Weak	Strong	Strong	Weak	Strong	Moderate	Weak
Allam A et al. (2015) Switzerland [33]	Strong	Strong	Strong	Weak	Strong	Strong	Moderate
Lorig KR et al. (2008) USA [34]	Weak	Strong	Strong	Moderate	Strong	Moderate	Moderate
Tada et al. (2022) Japan [35]	Strong	Moderate	Not applicable	Weak	Strong	Strong	Moderate
Labat et al. (2022) France [36]	Moderate	Strong	Strong	Weak	Moderate	Moderate	Moderate
Paul et al. (2024) UK [37]	Strong	Moderate	Not applicable	Weak	Moderate	Moderate	Moderate

Study characteristics

The included studies were published between 2008 and 2024. Ten of them were conducted in Europe (France, Spain, Italy, Germany, Norway, Ireland, and United Kingdom) [17, 19, 27-29, 31-33, 36, 37], two in USA [30,34], one in China [26], one in Japan [35], and one in Canada [16]. Of the included studies, nine were randomized controlled trials (RCT), three were non-randomized intervention trials, one was a cross-sectional study, one was a prospective observational study, and one was a case control study.

At the end of follow-up, the total study population size was 1769. The mean age was specified in 11 articles and ranged from 31.20 to 61.86 years [16, 17, 19, 26, 27, 29, 30, 32, 33, 36, 37]. One study specified the median age that was 66 years (Inter-Quartile Range (IQR) : 59-74) [35]. The mean disease duration was specified in 8 articles and ranged between 6.7 and 14.8 years [17, 26, 29-33, 37]. One study specified the median disease duration that was 5.3 years (IQR: 1.1-11.5) [35].

Twelve studies included RA patients with a population size of 900, a mean/median age ranging from 53 to 66 years, and a mean/median disease duration ranging from 5.3 to 14.8 years [16, 17, 19, 27-35]. Five studies included SpA patients (n = 308) of which two studies included axial SpA (axSpA) patients (n = 124) [29, 37], two studies included ankylosing spondylitis (AS) patients (n = 163) [26, 36], and one study included 21 SpA patients with no precision of the disease subtype [31]. The mean age and disease dura-

tion of SpA patients ranged from 31.2 to 52.3 years and from 10.1 to 16.2 years, respectively. Three studies represented outcome results of a combined population regardless of the diagnosis;

Lorig et al. included 866 patients with at least one of the following diagnoses: RA, fibromyalgia (FM) and osteoarthritis (OA) [34], Jacquemin et al. included 157 patients with RA (n = 83) and axSpA (n = 74) [29], and Haglo et al. included 40 patients with RA (n = 12), SpA (n = 21), and systemic lupus erythematosus (SLE) (n = 7) [31].

Physical activity was targeted by 8 studies [16, 28-30, 33, 35-37] while 10 studies focused on performance-based physical function [17, 19, 26-28, 31-35] and 4 studies targeted mobility [19, 26, 32, 37]. Two studies targeted both physical activity and performance-based physical function [28, 35] and one study targeted both physical activity and mobility [37].

The used connected elements were smartphone applications in 4 studies [26, 27, 29, 31], a web-based intervention in 3 studies [33, 34, 37], a sense-wear armband (SWA) device in 2 studies associated with a web application [16, 28], an activity tracker in two studies [29, 36], a Fitbit and a Fitbiz in one study [16], a novel telemonitoring device in 2 studies [19, 32], a Wii console in one study [17], a wearable triaxial accelerometer in one study [35], and a pedometer with a brochure in one study [30]. The intervention period lasted from one week to 12 months.

Characteristics of the included studies and the description of the wearable devices were detailed in Table 2.

Table 2. General information and study characteristics

Authors (Year)/ Country	Population (n =)	Mean age (years)	Inclusion criteria	Exclusion criteria	Target	Devise	Frequency/ Intervention period	Monitoring	Follow-up period
Li LC et al. (2020) Canada [16]	RA (n = 86) Immediate group (n = 43) Delay group (after 10 weeks) (n = 43)	53 54	– A confirmed diagnosis of RA – Having an email address and daily access to internet – Able to attend an in-person session	– Previous use of physical activity wearable Devices – To consider unsafety to be physically active without health professional supervision	The upper and lower bound of intensity and duration and mean of MVPA (min/day)	– A Fibit Flex2 and a FIViz, a new web-based application – SenseWear Mini for 7 days at each assessment, a multi-sensor monitor worn over the triceps 24 hours a day	Week 1-8 (immediate group) Week 10-17 (delay group)	Bi-weekly phone calls by PT	27 weeks
Katz P et al. (2018) USA [30]	RA (n = 120) 120 completed the study – Education only group – Pedometer group – Pedometer + step targets group	54	English-Spanish speaking, able to attend 3 in-person research visit	BMI < 20 kg/m ² , currently engaging in regular exercise, nonambulatory or presence of a condition limiting the ability to walk	Increase activity	An educational brochure and a guided discussion –Pedometer (Jawbone up)	NS	Contact patients Every 2 weeks (by phone or email)	21 weeks
Heglo H et al. (2021) Norway [31]	RA, SpA, SLE (n = 40; 12 RA, 21 SpA, 7 SLE) AG: self-administered HIIT guided by an application (n = 19; 4 RA, 11 SpA, 4 SLE) SG: standard supervised HIIT group (n = 21; 8 RA, 10 SpA, 3 SLE)	NS	NS	Unstable cardio-vascular disease, pulmonary disease, diabetes type I, pregnancy, not owning a smartphone, planned surgeries influencing the training or testing,	Cardiorespiratory fitness, commonly assessed as maximal oxygen uptake ($\dot{V}O_{2max}$)	Smartphone application with written and standardized preprogrammed audio instructions, automated email halfway in the training period	2 training sessions per week on nonconsecutive days, 34 min per session	NS	10 weeks
Piga M et al. (2014) Italy [32]	RA (n = 20) – Experimental arm (n = 10) – Control arm (n = 10)	56	Dreiser's index score ≥ 6 with stable medications for 3 months.	Irreversible anatomical damage, active arthritis, and digital ulcers. DAS28 > 2.6	Home rehabilitation exercises for the hand: hand strength, the maximum hand abduction and the ROM of MCP joints.	Recovery of Movement and Telenmonitoring portable device monitoring software interface, Calls + booklet *control arm: only booklet	5 days per week for 12 weeks, each session lasting a maximum of 50 min (45 min for control arm).	Calls for experimental arm	12 weeks
Allam A et al. (2015) Switzerland [33]	RA (n = 155) *Experimental groups: G1 (n = 30): access to informational sections only, G2 (n = 29): plus access to social support sections G3 (n = 28): access to only the gaming G4 (n = 28);access to everything *Control group (n = 40): no website access	57	No participation in another experiment or research study before Sufficient competence to use the website and internet access, No other major chronic illness), speaking Italian	NS	Physical activity	ONESELF website with Gamification	Freely access	NS	4 months

Authors (Year)/ Country	Population (n =)	Mean age (years)	Inclusion criteria	Exclusion criteria	Target	Device	Frequency/ Intervention period	Monitoring	Follow-up period
Lorig KR et al. (2008) USA [34]	RA, OA, FM patients 441 patients randomized to intervention (28.3% RA) 425 patients randomized to usual care (26.6% RA)	NS	≥ 18 years of age; a diagnosis of OA, RA, or fibromyalgia; could not have been in active treatment for cancer for 1 year; no previous participation, had access to a computer	NS	Coping with RA especially in one's everyday life	Internet-based Arthritis Self- Management Program	For each of 6 weeks, participants (approximately 25 per workshop) were asked to log on at least 3 times for a total of 1-2 hours and to participate in the weekly activities.	NS	12 months
Jacquemin C et al. (2018) France [29]	RA (n = 83), axSpA (n = 74) Healthy controls (n = 20)	45	> 18 years; Internet access; mobile phone or tablet compatible with the mobile activity tracker.	NS	Physical activity: number of steps per day, proportion of morning steps over a day	Wearing an activity tracker (Withings Activity Pop connected by Bluetooth, at least every 2 days, to a mobile phone application) every day for 3 months.	NS	NS	90 days
Pani D et al. (2016) Italy [19]	10 RA patients (10 systemic sclerosis patients were also included)	55.5 [39-74]	NS	NS	Hand rehabilitation	A novel telerehabilitation device with remote monitoring capabilities	5 sessions per week	NS	12 weeks
Zernicke J et al. (2016) Germany [17]	RA (n = 30) G1: starting with a conventional home-based physical exercise program, 15 RA patients, 100% females G2: starting with a predefined animated exercise program by using the Wii game console, 15 RA patients, 67% females	G1: 59 ± 9 [45-69] G2: 52 ± 8 [34-65]	Patients' global assessment <30 mm under therapy with a bDMARD	Patients only on cDMARD therapy	Physical activity	Wii game console	3 sessions per week, 30 minutes per session, 12 weeks for each treatment arm	Semi-structured face to face interviews	12 weeks
Wang Y et al. (2022) China [26]	AS (n = 55) G1: Controle group, receiving usual AS care, 28 patients, 77% males G2: Intervention groups, 26 patients, 75% males	G1: 31.2 ± 6.3 G2: 33.2 ± 6.2	Fulfillment of the criteria for AS (1984 Modified New York criteria) Age between 18 and 60 years stable drug treatment in the preceding month ASDAS between 1.3 and 3.5	– cardiovascular disease at high risk – Cervical vertebral bridges Surgery within the preceding 6 months – bDMARDs used in the preceding 3 months – Regular exercise in the preceding 3 months Factors leading to the inability to receive regular exercise rehabilitation	Physical activity	Smartphone application	2. 30 min/day, 5 days/ week 3. 60 min/day, 3 days/ week	Uploading pictures taken after each session by the patient.	16 weeks

Authors (Year)/ Country	Population (n =)	Mean age (years)	Inclusion criteria	Exclusion criteria	Target	Device	Frequency/ Intervention period	Monitoring	Follow-up period
Rodríguez Sánchez- Laulhé P et al. (2022) Spain [27]	36 RA patients (58 hands) G1: control group, 22 (41 hands), 59% females G2: intervention group, 14 (28 hands), 64% females	G1: 61.86 ± 10.76 G2: 57.64 ± 7.25	- age ≥ 18 years - RA of the hands, wrists, or fingers, based on the ACR guidelines - Disease duration of at least two years - report current pain and disability in the hands or wrists - possessing a smartphone with internet access	- previous hand fracture or surgery - waiting for upper limb surgery - steroid injection in the month before recruitment - pregnancy - cognitive problems that may preclude the completion of the study protocol	Hand and wrist rehabilitation	Smartphone application	15-20 min/day, 4 days/week	Adherence charts were sent via the application to a cloud database	3 months
Tierney M. et al. (2013) Ireland [28]	RA (n = 25)	NS	Fulfilling ACR criteria for RA diagnosis	NS	Physical activity	senswear armband IPAQ	7 days	NS	7 days
Tada et al. (2022) Japan [35]	RA (n = 85)	Median (IQR) 66 (59,74)	Age ≥ 20 years Fulfilling ACR criteria for RA diagnosis	Severe renal dysfunction, heart failure, neurological diseases, malignancy, other collagen diseases, myogenic disease, or surgically implanted metal	Physical activity, Muscle function	a wearable triaxial accelerometer	7 days	NS	7 days
Labat et al. (2022) France [36]	AS (n = 108) NTG: non-tracker group, n = 53, 67.9% females TG: tracker group, n = 55, 72.7% females	NTG : 50.7 ± 14 TG : 52.3 ± 13.6	Age > 18 years Understanding the objectives and constraints of the study SpA according to the ASAS criteria Lived in Nice or in a 20- km area Certified as having no contraindication to perform physical activities such as swimming or Nordic walking.	coronary artery disease moderate-to-severe heart failure uncontrolled hypertension myocarditis pericarditis endocarditis lung disease any contraindication to PA inability to go to the activity venue undergoing supervised PA in a club or with a sports coach, pregnancy or breastfeeding	Physical activity	wearable activity tracker (Garmin Vivofit 4)	Twice a week with an additional weekly coach-supervised PA session after 24th week	NS	36 weeks

Authors (Year)/ Country	Population (n =)	Mean age (years)	Inclusion criteria	Exclusion criteria	Target	Device	Frequency/ Intervention period	Monitoring	Follow-up period
Paul et al. (2024) UK [37]	axSpA (n = 50) 54% females	50 ± 12	confirmed axSpA for more than one year access to the internet at home	already exercising regularly (three or more times per week) joint replacement within the last six months comorbidities that may interfere with taking part in a regular exercise programme currently participating in another clinical trial	Physical activity, mobility	website	30 minutes 5 days per week	Data recorded on the website	12 months

AS: Ankylosing Spondylitis, SpA: Spondyloarthritis, axSpA: axial SpA, RA: Rheumatoid Arthritis, OA: Osteoarthritis, FM: Fibromyalgia, SLE: Systemic Lupus Erythematosus, ASDAS: Ankylosing Spondylitis Disease Activity Score, DAS28: Disease Activity Score, bDMARD/cDMARD: biologic/conventional disease modifying antirheumatic drug, MVPA: moderate/vigorous physical activity, HIIT: aerobic high-intensity interval training, PT: physiotherapist, ROM: range of movement, BMI: Body mass index, AG: application group, SG: standard supervised group, G1-2: group 1-2, MCP: metacarpophalangeal, NS: not specified

Results of individual studies and synthesis of results

Results of the intervention studies on primary and secondary outcomes are summarized in Table 3.

Primary outcomes

Primary outcomes consisted of the physical activity outcomes and rehabilitation outcomes, which included mobility, physical function, and performance.

Physical activity

All the 8 studies targeting physical activity focused on overall physical activity. The study populations included patients with RA in 4 studies, AS in two studies, axSpA in one study, and RA and axSpA in one study. Assessment tools to evaluate the effectiveness of wearable devices in promoting physical activity were: number of daily steps, intensity and daily time of activity, gait speed, duration of moderate/vigorous physical activity (MVPA), and the International Physical Activity Questionnaire (IPAQ). Connected elements were: Fit Bit Flex and SWA, Withings Activity Pop, wearable activity tracker (Garmin Vivofit 4), a wearable triaxial accelerometer, Pedometer, and a web-based intervention.

Wearable devices revealed positive outcome in the study of Katz et al. [30]. These researchers reported significantly step increased counts in RA patients using pedometer (PED)-based intervention compared with RA patients receiving therapeutic education.

Li LC et al. showed significantly higher mean time spent in MVPA and daily steps at week 9 in RA patients using Fitbit Flex2 and a SWA device compared to control group but not significantly higher at weeks 17 and 26 [16]. Likewise, Jacquemin et al. demonstrated similar number of steps per day in RA and axSpA patients using an activity tracker compared to healthy controls at 3 months [29]. Alam et al. found an increase in mean minutes spent on exercise over time for RA patients with access to the social support sections and gaming using a web-based intervention [33]. However, Tierney et al. did not identify correlations between all items of the short form IPAQ after 7 days of ordinary daily activity of RA patients monitored by a SWA armband [28].

Rehabilitation

There were 9 studies interested in rehabilitation for improving performance-based physical function via wearable devices among rheumatic disease patients. Different studied fields were: hand strength, cardiorespiratory fitness, and muscle endurance.

Table 3. Study outcome measures and their results

Authors/ Year	Study design	Intervention	Primary Outcome measures		Other secondary measures	Results
			Assessment tools	Findings		
Li LC et al. (2020) [16]	RCT	In-person session to plan: *Immediate Group: Education and counseling by a PT, used a Fitbit and a web-application with 4 follow-up calls from the PT. *Delay Group: same intervention (weeks 10-17) Assessment: Baseline, Week 9, 18 and 27. — Individual physical activity plan on FitViz	— The upper and lower bound of intensity, duration and mean of MVPA (min/day) — Mean daily time in purposeful activity — Average daily steps	— At 9 weeks: A significant higher mean time spent in MVPA for the Immediate Group — At weeks 17 and 26: a larger but statistically non-significant intervention effects — A trend favoring the Immediate Group was found in time spent in purposeful activity and daily steps	— Mean daily time in sedentary behavior. — Self-Reported Habit Index	— Time spent in sedentary behaviours: A trend favoring the Immediate Group — Pain and self-reported walking habit: statistically significant difference for Immediate group
Katz P et al. (2018) [30]	RCT	Weekly average number of daily steps Other activities (swimming, cycling, walking, Pilates)	Weekly average number of daily steps	Intervention groups significantly increased step counts from baseline to Week 21 The proportions of PED and PED+ groups achieved a doubled health activity with no significant differences with EDUC.	Promis Fatigue Short form, PHQ-8 HAQ RADAI	Fatigue: a reduction trending for the PED+ group by 21 weeks. PROMIS and PHQ-8: general improvement for all groups with a statistically significant improvements for the PED and PED+ groups. — HAQ: improved significantly within the PED and PED+ groups — RADAI: relatively stable between baseline and week 10, and then decreased significantly between week 10 and week 21 for PED and PED+ groups
Haglo H et al. (2021) [31]	RCT	HIIT	Cardiorespiratory fitness assessed as maximal oxygen uptake (VO_{2max}) percentage of VO_{2max} : Oxygen uptake (VO_2) from the first 3 and last 3 HIIT sessions	— AG and SG performed sessions with an intensity of 85%-90% of VO_{2max} with no difference between the groups. — No difference in improvement of VO_{2max} was apparent between the groups.	HRQoL	— Three HRQoL dimensions improved in both groups with no significant difference. — Dimensions of general health, physical functioning, and emotional well-being increased in the SG with no differences.
Piga M et al. (2014) [32]	RCT	*Experimental group: 4 strengthening and 3 mobility exercises *Control arm: 3 strengthening and 3 mobility exercises	Hand strength (grip and pinch) measured through a sphygmomanometer. The maximum hand abduction and the ROM of MCP joints for both hands measured through a goniometer.	— Experimental arm: statistically significant results on both grip and pinch strength. — Patients in experimental and control arms obtained good results on MCP ROM for both hands.	HAQ, FIHOA VAS DAS28	— FIHAO and HAQ: a statistically significant improvement over time in the experimental group with no significant difference between groups — VAS decrease in experimental arm without a significant difference with controls. — DAS28: a reduction of for the experimental arm patients.

Authors/ Year	Study design	Intervention	Primary Outcome measures		Other secondary measures	Results
			Assessment tools	Findings		
Allam A et al. (2015) [33]	RCT	Time spent on physical activity during a week	The time spent on physical activity in the last week on a scale from 0 = never to 5 = more than 3 hours per week. The number of minutes spent on exercise from 0 to 180 minutes.	Mean minutes spent on exercise increased over time for patients with access to the social support sections and gaming.	Health care utilization	Health care utilization: a significant decrease for patients in the social support group and patients in the social support plus gaming group
Lorig KR et al. (2008) [34]	RCT	Aerobic exercise	Aerobic exercise (minutes/week) Stretching and strength exercise (minutes/week)	No significantly difference between groups	Health status Self-efficacy Health care utilization	At 1 year, the intervention group significantly improved in 4 of 6 health status measures and self-efficacy. No significant differences in health care utilization.
Jacquemin C et al. (2018) [29]	Case control study	No intervention	Physical activity was assessed by the number of steps per day.	Controls tended to be more active than patients. There was no statistically significant difference between patients with RA and axSpA in physical activity levels or patterns.	-	-
Pani D et al. (2016) [19]	non-randomized, single arm, intervention trial	Isometric exercises: hand pinch, hand grip, finger pinch (opposition to the thumb), rotation (screwing with the fingers) Dynamic exercises: hand extension, rotation (fast manipulation), finger tapping (piano-like)	Hand algo-functional Dreiser Index ROMf ROMw Grip strength CTorque ATorque	Significant sustained improvement of all outcome measures.	Hands' acral temperature	Significant increase in acral temperature after exercise
Zernicke J et al. (2016) [17]	Non-randomized, two-arm, crossover pilot study	Wii-group: At least 12 Yoga exercises, 11 muscle-strength exercises, 7 balance games and 6 aerobic exercises Conventional home-based physical exercise group: strength training (10 exercises), coordination (2), joint mobility (10) and relaxation (9)	muscles strength* 6-MWT respiratory tests (peak expiratory flow)	12-week evaluation: Significant improvement of muscle strength in both groups Significant improvement of the mean 6-MWT in both groups No significant effects on respiratory tests -> No significant difference between both groups on all outcomes	HAQ-DI SF36 PtGA (using a 100 mm visual analogue scale)	No statistically significant difference at week 12 and 24 in and between both groups in the mean changes of HAQ-DI, SF36 and PtGA results
Wang Y et al. (2022) [26]	Randomized, two-arm pilot controlled trial	1. In-person counseling sessions and supervised training sessions 2. Home-based aerobic exercises: brisk walking or running 3. Functional home-based exercise: posture, range of motion, resistance, stability, and stretching exercises	Cardiorespiratory fitness: HRmax, the VO_{2max} Body composition: lean body mass, percentage of body fat, and visceral fat area; evaluated using a non-invasive bioelectrical impedance analysis method range of motion of the cervical spine and hip joints measured with a smartphone app lumbar muscle endurance assessed with back extensor and flexor endurance tests	Between-group differences were significant favoring the intervention group for all outcomes.	ASDAS(CRP), BASDAI, PtGA, PhGA, BASFI, BASMI, ASAS HI, SF-36.	Between-group differences for change from baseline were significant favoring the intervention in ASDAS(CRP), BASDAI, PtGA, PhGA, BASFI, and BASMI. SF-36: significant beneficial effects were detected in physical function, bodily pain, general health, and vitality in the intervention group.

Authors/ Year	Study design	Intervention	Primary Outcome measures		Other secondary measures	Results
			Assessment tools	Findings		
Rodríguez Sánchez-Laulhé P et al. (2022) [27]	single-blinded randomized controlled trial	warm-up routine, mobility, stretching, and strengthening exercises	- Michigan Hand Outcome Questionnaire (MHQ) - Grip strength (dynamometer) - pinch strength (pinch gauge) - Upper limb function (shortened version of the Disabilities of the Arm, Shoulder, and Hand questionnaire)	Significant time-group effect for the total MHQ score and subscales overall hand function, work performance, pain, and satisfaction. No significant effect for the subscales activity of daily living and aesthetic. No significant effect on grip and pinch strength and on upper limb function.	- Pain and stiffness intensity -	- No significant effect on pain and stiffness intensity -
Tierney M. et al. (2013) [28]	Cross-sectional study	Ordinary daily activity of patients	- Physical activity: IPAQ-SF - total energy expenditure measuring via SWA output - MET-minutes per week and Sitting Time.	No large correlations between any aspect of the SWA and any aspect of the short form IPAQ	-	-
Tada et al. (2022) Japan [35]	non-randomized, single arm, prospective observational study	Ordinary daily activity of patients	- Daily calories expended for walking and for housework - Exercise for walking and for housework (MET-minutes per week) - Number of steps 3 minutes walk test - Grip strength - Power, speed, and stabilizing time of lower limbs and trunks	Walking, housework, and total exercise were positively correlated with grip strength, walking speed, power, and speed. Walking speed (except for house work exercise), and power were independently related to exercise.	mHAQ, DAS28-ESR locomotive syndrome (5-question Geriatric Locomotive Function Scale), frailty	Walking, housework, and total exercise were negatively correlated with age, mHAQ, DAS28-ESR, locomotive syndrome, and frailty. Locomotive syndrome, frailty, and mHAQ (except for housework exercise for the two last factors) were independently related to exercise. Total daily exercise and number of steps were significantly lower in the moderate and high disease activity group. Lower number of steps was associated with a higher risk of frailty and locomotive syndrome
Labat et al. (2022) France [36]	RCT	2 weekly physical activity sessions of the participant's choice with Nordic walking encouraged and a training to avoid positions or activities that could aggravate the disease Weekly activity SMS reminders A supplementary 1 hour of coach-supervised PA after week 24	6-MWT - IPAQ-SF (rejected for missing data)	Significant increase in 6-MWT between W0 and W12, W24, and W36 without significant difference between the 2 groups	Number of flares, BASDAI SF-36	No difference between groups in number of moderate and persistent flares between W0 and W12, W24, or W36. Significant decrease in number of flares in both groups between W0 and W12 Nonsignificant decrease in BASDAI in both groups between W0 and W12, W24, and W36 SF-36: Significant increase in role limitation (physical) domain between W0 and W24 in TG Significant increase in role limitation (emotional) domain between W0 and W12 in TG

Authors/ Year	Study design	Intervention	Primary Outcome measures		Other secondary measures	Results
			Assessment tools	Findings		
Paul et al. (2023) UK [37]	Single arm, prospective, interventional cohort study	Specific exercise goals were agreed between the participant and the physiotherapist Participants were encouraged to undertake an exercise program up to five days per week for 30 min per day	– 6-MWT, PA assessed by an accelerometer (steps/day, walking time, sitting/lying time), EQA-18, EMI-2	Significant improvements in 6-MWT at M6 and M12 No significant difference in PA, EQA-18 or EMI-2	BASDAI, BASFI, ASQoL, WPAI:SpA, EQSD, BASMI, and M12	Significant increase in mental health domain between W0 and W24 in TG and W0 and W36 in NTG Significant increase in general health domain between W0 and W12 in NTG Significant increase in bodily pain domain between W0 and W12 in both groups Significant improvements of BASDAI, BASMI, EQSD-IAS, ASQoL at M6 and M12 Significant improvements of EQSD index (quality of life) and WPAI activity impairment subscale at M6

MVPA: moderate/vigorous physical activity, MET: Metabolic Equivalent of Task, PED +: Pedometer + step targets group, EDUC: Educational group, PHQ-8: Questionnaire depression scale, HAQ: Health Assessment Questionnaire, HAQ-DI: Health Assessment Questionnaire Disability Index, RADA: Rheumatoid Arthritis Disease Activity Index, ROM: range of movement finger flexo-extension; ROMw: ROM wrist flexo-extension, C Torque: clockwise rotation torque, A Torque: anticlockwise rotation torque, 6-MWT: 6-min walk test, SF36: Short Form 36-Item questionnaire, PtGA: patient's global assessment, HRmax: maximal heart rate, VO2 max: maximal oxygen uptake, ASDAD(CRP): Ankylosing Spondylitis Disease Activity Score using C Reactive Protein, BASDAI: Bath Ankylosing Spondylitis Disease Activity Index, PhGA: physician global assessment, BASFI: Bath ankylosing spondylitis functional index, BASMI: Bath Ankylosing Spondylitis Metrology Index, ASAS HI: Spondyloarthritis International Society Health Index, MHQ: Michigan Hand Outcome Questionnaire, IPAQ: international physical activity questionnaire, IPAQ-SF: IPAQ short form, SWA: sensewear armband, HILT: aerobic high-intensity interval training, AG: application group, SG: standard supervised group, HRQoL: Health-related quality of life, μ : Bodily pain, vitality, social functioning), ROM: range of movement, MCP: metacarpophalangeal, FHOA: Functional Index of Hand OA, mHAQ: modified HAQ, axSpA: axial spondyloarthritis, p: significance level, *: muscle groups were neck extensors, neck flexors, shoulder abductors, elbow extensors, elbow flexors, 3-point grip strength, hip flexors, knee extensors and knee flexors, RCT: Randomized controlled trials, VAS: pain visual analog scale, PT: physiotherapist

– Muscle Strength

There were 4 studies targeting muscle strength performance among patients with IRD. There were 3 case-controlled studies, and one was a single arm intervention. Three studies focused on hand strength and one study targeted nine groups of muscles of the neck, shoulders, elbows, grips, hips, and knees. Wearable devices used were: care hand application available on smartphones, sphygmomanometer, telerehabilitation device with remote monitoring capabilities, and Wii console. There were 2 studies that have employed performance-based physical function questionnaires assessing hand strength [19, 27].

A significantly increase in muscle strength was noted in all studies [19, 27, 32]. Indeed, Piga et al. reported a significant increase in grip and pinch strength measured through a sphygmomanometer in experimental group than controls [32]. As for the single arm study, Hand algofunctional Dreiser's index of patients with RA and grip strength have shown a significant improvement after a 12-week of hand rehabilitation program [19].

In the study conducted by Zernicke J et al., there was a significant improvement of strength in nine groups of muscles (neck, shoulder, elbow, grip, hip, knee) at 12-week with no significant difference between both RA groups receiving home-based animated physical activity program using a Wii console versus conventional home-based physical exercise program [17].

Similarly, Rodríguez Sánchez-Laulhé et al. noted a significant time-group effect for the total Michigan Hand Outcome Questionnaire (MHQ) score ($p = < 0.01$) and especially for his following subscales: overall hand function ($p = 0.04$), work performance ($p = 0.006$), pain ($p < 0.001$), and satisfaction ($p = 0.06$) [27]. However, there was no significant time-group effect for pinch strength and grip strength after 3 months of hand rehabilitation programs with no significant effect for the shortened version of the Disabilities of the Arm, Shoulder, and Hand questionnaire (QuickDASH) [27].

– *Cardiorespiratory fitness*

Cardiorespiratory fitness among IRD patients was investigated in 3 papers. Assessment tools were maximal oxygen uptake (VO₂max), respiratory tests, and 6-minute walk test (6-MWT).

Following home-based programs targeted by mobile applications resulted in a significant improvement of respiratory tests and VO₂max in 2 studies [26, 31]. In fact, Wang et al. found a significant between-group differences for change from baseline of VO₂max favoring the intervention group of Ankylosing Spondylitis (AS) after 16 weeks [26]. However, after 6 supervised high-intensity interval training (HIIT) sessions guided by an application for RA and SpA patients, the increase of VO₂max from baseline was not significant compared to control groups [31].

Walk tests were also improved in a RA group using a home-based animated physical activity program via a Wii console without a significant difference between experimental and control group [17].

– *Muscle endurance*

Improving muscle endurance has been researched in 4 studies. Connected devices were: web-based interventions (two studies), smartphone application (one study), and a SWA armband (one study). The effectiveness of a connected program was proven in two studies.

Wang et al. found significant improvement in back extensor endurance test favoring the intervention group of AS patients undergoing a home-based physical activity program guided by a smartphone application for 16 weeks [26]. The same result was concluded by Allam et al. [33] who showed that the mean time spent on self-training was higher for RA patients with access to social support and gaming ($p = 0.02$) compared to control group with no website access.

However, Kate et al. did not find a significant difference between exposed and non-exposed RA patients on time spent on aerobic, stretching, and strength exercises monitored by internet self-management program for exposed patients [34]. Tierney et al. published closed negative findings in RA patients regarding the total energy exposures assessed by a SWA armband during ordinary daily activities for a week [28].

– *Mobility*

Mobility was assessed in 3 studies including range of motion (ROM) of cervical spine, hip joints, ROM of the hand, the fingers, and the wrist. In the following study, there were significant differences for the ROM of cervical lateral flexion and hip abduction between-group, favouring the intervention group of AS patients undergoing a home-based physical activity

program guided by a smartphone application for 16 weeks [26]. Similarly, there was a significant improvement in ROM of fingers and wrist of patients with RA, after a 12-week hand rehabilitation program using a novel telerehabilitation device with remote monitoring capabilities [19]. However, in the study conducted by Piga et al, there was an improvement in hand ROM for RA patients monitored by portable device without a significant difference with controls [32].

Secondary outcomes

An overview of the studies examining secondary outcomes such as disease activity, fatigue, and functional impairment is presented in Table 2.

Disease activity

Six studies were interested in searching the impact of wearable devices on disease activity among rheumatic disease patients: RA ($n = 3$), AS ($n = 2$) [26, 30, 32, 35, 36]. Different wearable devices were Pedometer, triaxial accelerometer, a wearable activity tracker, telemonitoring portable device, and a smartphone application. The follow-up duration ranged from 12 weeks to 36 weeks. The used disease activity scales were the Disease Activity Scale 28 (DAS 28), and the Rheumatoid Arthritis Disease Activity Index (RADAI) for RA patients and the Ankylosing Spondylitis Disease Activity Score using C Reactive Protein (ASDAS-CRP), the Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), and number of flares for SpA patients.

In RA, the use of wearable devices improved the disease activity in two studies. Devices were a Pedometer and a telemonitoring portable device. In fact, Katz et al. showed that the RADAI improved in Pedometer group and Pedometer + step targets group after 10 and 21 weeks of intervention [30]. In the other study, authors noted a reduction in the DAS 28 in RA patients using telemonitoring portable device for hand rehabilitation (1.8 at baseline to 1.4 at week 12) [32]. However, authors did not find a significant difference with controls.

Regarding AS, the use of a wearable device improved disease activity parameters in one study without a significant difference with controls. Indeed, disease activity parameters decreased significantly for patients with AS undergoing wearable assisted home based exercises from baseline to 16-week follow-up ($p = 0.03$ for ASDAS, $p = 0.004$ for BASDAI) [26]. Labat et al. found a significant decrease in number of flares after a 12-week physical activity program assisted by a wearable activity tracker [36]. However, there was no significant difference compared to the non-tracker group.

Health-related quality of life, fatigue, and pain

Five studies were interested in assessing the impact of wearable devices on health-related quality of life for patients with RA. In fact, in the study conducted by Katz et al., the Health Assessment Questionnaire (HAQ) improved significantly in the experimental group compared to controls after 21 weeks of physical activity program monitored by a pedometer [30]. Similarly, there was a statistically significant improvement of the HAQ after 12 weeks of home rehabilitation exercises for the hand using a telemonitoring portable device but without a significant difference with control group [32]. Unlike Zernicke et al. who have not found a significant change after 24 weeks of physical activity targeted by a Wii console [17]. In axSpA patients, Paul et al. found a significant improvement of quality of life indexes 6 and 12 months after an exercise program guided by a website [37].

According to fatigue, there was a statistical trend for the Pedometer group to reduce fatigue scores more than the Educational group by 21 weeks in the study conducted by Katz et al. [30]. For Li LC et al., there was not a significant improvement between both RA groups (delayed and immediate group) after the use of a SWA [16].

As for pain, there were 3 studies assessing the improvement of pain via wearable devices using the Visual Analogue Scale (VAS). There was a statistically significant adjusted mean difference in the VAS in one study [16]. However, pain decreased in experimental arm without a significant difference with controls in one study [32], and there was no significant effect on pain and stiffness intensity in another [27].

DISCUSSION

Our systematic review investigated whether wearable devices could promote physical activity and rehabilitation in patients with IRD. There are few studies in the literature investigating the effect of those tools on IRD patients. For that, in this paper, we tried to summarize different studies in order to draw a conclusion.

The findings showed the increase of physical activity parameters with a significant difference between interventional and non-interventional groups in only one study. Regarding performance-based physical function, there were improvements of hand strength, cardiorespiratory fitness, and muscle endurance for most exposed groups to wearable devices. As for mobility, joints motions were also improved after the exposed period. Wearable devices had also

positive outcomes on disease activity, pain, fatigue, and on health-related quality of life.

Disability and functional impairment are frequent among patients with IRD [38, 39]. They are caused by pain and limitation of joint mobility [40, 41]. They lead to alteration of work productivity and to dependence [42]. Physical therapy and exercises are recommended for patients with IRD except flares and are often prescribed in order to improve the physical function [43]. However, following a well-defined physical therapy intervention program and adhering to physiotherapist sessions are not always obvious [44].

In this context, wearable devices were developed to promote physical function and to encourage patients with rheumatic diseases to apply to at-home exercises in order to enhance their quality of life. There are some controversies regarding the gain obtained from these interventions.

Indeed, a recent review showed significant efficacy of eHealth-supported home exercise interventions on improvements of pain, physical activity, and quality of life in patients with osteoarthritis of the knee [45]. Another one showed the efficacy of physical therapy given by telerehabilitation on shoulder pain and disability [46].

Telematic behavioral modification techniques were also effective options for the management of anxiety and depressive symptoms in patients with chronic musculoskeletal pain [47].

However, a meta-analysis of Randomized Controlled Trials conducted by Xie et al. did not find evidence of internet-based rehabilitation to improve physical function among patients with osteoarthritis [22].

The application of those devices has certain limitations, which can reduce their effect. There are different conditions related to the patient such as comorbidities or to the device himself. In fact, in a recent Systematic Review and Meta-Analysis, telematic behavioral modification techniques did not seem to be effective on reducing the stress among patients with chronic musculoskeletal pain [47]. As for adherence, a recent systematic review with meta-analyses showed that digital rehabilitation programs were effective at improving therapeutic exercise adherence for patients with musculoskeletal conditions at intermediate follow-up, but not at short- and long-term follow-up [48]. Patient satisfaction is also an important condition that may influence patients' adherence to wearable devices. Indeed, Amin et al. provided in their systematic review some evidence of satisfaction with Telerehabilitation among patients with musculoskeletal disorders [49]. The cost is considered as another condition related to the use of wearable

devices. In fact, home-based exercises using wearable devices may be expensive for some ones. However, some studies showed cost saving per patient of £38.57 related to telehealth and telerehabilitation services for physical therapy for people with musculoskeletal conditions [50, 51]. But those results were not linked to long-term cost-benefit. However, the application of wearable devices use in physical activity and rehabilitation of IRD patients should be a part of a multidisciplinary management for these patients, including sports medicine and physical medicine and rehabilitation specialists. This helps set up adequate protocols and choose the appropriate evaluation tools and questionnaires to improve the uniformity of outcome evaluation.

Limitations

There are several potential limitations related to our study that should be considered. First, the number of studies regarding this topic is limited. This can be explained by the novelty of this area of focus. However, we included only English and French papers; there are possibly interesting studies in other languages. Besides, most of randomized controlled trials included a little number of participants which may influence results. Furthermore, the follow-up duration was not long enough. There was only one study, which has been extended at 12 months. There was a lack of assessment on the prolonged effect of wearable devices in promoting physical function. Finally, even though our systematic review showed positive results, it is important to keep in mind that the selected studies included a heterogeneous population in terms of disease duration as exercise can be more difficult in patients with longstanding IRD.

CONCLUSION

Physical activity and rehabilitation via wearable devices are a promising method for patients with IRD to enhance their physical function at home. The main purpose of this review is to identify the efficacy of wearables that provide rehabilitation programs for this vulnerable population that still exposed to disability. The results of this study indicate that there is always a benefit of wearables tools. Their utilization is simple and safe. They could improve physical activity and different fields of rehabilitation, performance-based physical function, and mobility without harming patients' health. However, further studies with large population sizes and long-term follow-up are needed to make reliable conclusions.

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