ORIGINAL RESEARCH

Engagement and attrition with eHealth tools for remote monitoring in chronic arthritis: a systematic review and meta-analysis

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ABSTRACT

Objectives Although eHealth tools are potentially useful for remote disease monitoring, barriers include concerns of low engagement and high attrition. We aimed to summarise evidence on patients’ engagement and attrition with eHealth tools for remotely monitoring disease activity/impact in chronic arthritis.

Methods A systematic literature search was conducted for original articles and abstracts published before September 2022. Eligible studies reported quantitative measures of patients’ engagement with eHealth instruments used for remote monitoring in chronic arthritis. Engagement rates were pooled using random effects meta-analysis.

Results Of 8246 references, 45 studies were included: 23 using smartphone applications, 13 evaluating wearable activity trackers, 7 using personal digital assistants, 6 including web-based platforms and 2 using short message service. Wearable-based studies mostly reported engagement as the proportion of days the tracker was worn (70% pooled across 6 studies). For other eHealth tools, engagement was mostly reported as completion rates for remote patient-reported outcomes (PROs). The pooled completion rate was 80%, although between-study heterogeneity was high (I² 93%) with significant differences between eHealth tools and frequency of PRO-collection. Engagement significantly decreased with longer study duration, but attrition varied across studies (0%–89%). Several predictors of higher engagement were reported. Data on the influence of PRO-reporting frequency were conflicting.

Conclusion Generally high patient engagement was reported with eHealth tools for remote monitoring in chronic arthritis. However, we found considerable between-study heterogeneity and a relative lack of real-world data. Future studies should use standardised measures of engagement, preferably assessed in a daily practice setting.

Trial registration number The protocol was registered on PROSPERO (CRD42021267936).

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ eHealth tools, such as smartphone applications, wearable activity trackers and web-based platforms, are increasingly used in the management of chronic arthritis. Although these tools could provide unique opportunities to improve care, for instance through remote monitoring and by facilitating patient-initiated follow-up, concerns are often raised in relation to attrition and limited patient engagement with these tools.

WHAT THIS STUDY ADDS

⇒ We found generally high reported engagement rates with eHealth tools used to remotely monitor disease activity or impact in patients with chronic arthritis. However, engagement declined over time to a highly variable degree and data mostly came from strictly controlled research settings, possibly underestimating the problem of attrition.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Although remote monitoring of chronic arthritis using eHealth tools seems a feasible approach, future eHealth-related research should aim to optimally characterise feasibility in a real-world setting.

INTRODUCTION

Chronic arthritis is an umbrella term for several inflammatory and non-inflammatory musculoskeletal conditions that rank among the most prevalent chronic diseases worldwide and represent a considerable societal burden.1 People suffering from chronic arthritis are faced with pain, stiffness, fatigue and functional decline, negatively affecting their quality of life and social participation.3 These symptoms fluctuate over time and can even persist when the disease is clinically well-controlled, often giving rise to discordance.
between patients’ and physicians’ views on disease activity. Consequently, potentially relevant information about the disease’s impact between clinic visits is insufficiently captured in routine care. Moreover, following shifts to targeted treatment strategies, managing chronic inflammatory arthritis increasingly requires lifelong follow-up on a regular basis. However, the resulting increase in demand has not been met with a corresponding expansion of the rheumatology workforce, leading to increasing referral times and rising pressure on the conventional care model.

Possible solutions to some of these challenges could be found in the form of eHealth, defined as the use of information and communication technologies to support healthcare. Recent years have brought a revolution of technological innovations, including the widespread availability of internet connectivity, smartphones and wearable activity trackers, all of which could provide healthcare practitioners and researchers with opportunities to improve patient care. One potential strategy is to use eHealth tools like these to monitor patients with chronic arthritis remotely. Remote monitoring can be implemented in a synchronous setting, where patients and care providers remain in real-time contact through digital communication tools like telephone or video calls. Alternatively, this strategy can be approached asynchronously, which implies that the eHealth tool collects information, such as patient-reported outcomes (PROs), that is only later accessed by the care provider. Particularly in an asynchronous setting, eHealth tools could provide researchers or care providers with a unique window into the day-to-day variability of disease activity and its impact on patients. Such information has also shown potential to facilitate patient-initiated follow-up, as opposed to prescheduled clinic visits, ultimately contributing to reduced healthcare utilisation. Finally, there is an ongoing evolution in technology that allows patients to self-sample capillary blood for biochemical markers like urate or C-reactive protein, and recent studies have shown promising feasibility for such devices.

However, despite their potential benefits, the implementation of eHealth tools in routine rheumatology care is associated with several challenges, including concerns about vulnerable populations, legal and organisational barriers, and respondent fatigue. Among these, arguably the biggest challenge of eHealth studies is missing data due to attrition and limited patient engagement, potentially biasing study results and hampering larger-scale implementation. Consequently, it is crucial to comprehensively describe how engagement with eHealth tools is currently measured, how reliably patients use and continue to use these tools, and which population-based or study-specific factors are associated with eHealth engagement.

The objective of this systematic review was to summarise the available evidence on patients’ engagement and attrition with eHealth tools for remote monitoring of disease activity or impact in chronic arthritis. For these purposes, this review focused on asynchronous eHealth interventions, rather than on tools intended for remote consultations.

METHODS
This systematic review was conducted in accordance with the Cochrane Handbook and reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.

Eligibility criteria
Studies were eligible for inclusion if they were conducted in patients with chronic arthritis, defined as either rheumatoid arthritis (RA), spondyloarthritis (SpA), psoriatic arthritis, osteoarthritis (OA), gout or juvenile idiopathic arthritis (JIA). Records not reporting delineable outcome data for any of these populations were excluded. Participants of all ages were eligible. Moreover, studies were considered only if they included any eHealth instrument for asynchronous remote monitoring purposes, and additionally provided information on patients’ objectively measured engagement, adherence or compliance with the use of this eHealth instrument. Records were excluded if engagement was solely self-reported or if no information on data completeness was reported. As an eHealth tool, we considered any application of information and communication technology in the context of health or health-related fields.

Study design
We included randomised controlled trials (RCTs), observational studies and case–control studies published in English and in peer-reviewed journals. Given the rapid evolution of this research field, we additionally included conference abstracts adhering to the eligibility criteria and updated the search a second time. To allow for maximal comparability, we did not consider purely qualitative studies.

Outcomes
The primary outcome was any quantitative assessment of patients’ engagement or adherence with the reported eHealth instrument. As secondary outcomes, we aimed to summarise the evidence on attrition, defined as a loss of participant engagement over time, and to describe demographic, disease-related or study-related factors associated with engagement or attrition.

Search strategy and study selection
We systematically searched the following databases from inception to 29 May 2021 (updated to 31 August 2022): Embase, PubMed, Cochrane Central, CINAHL, Web of Science, ClinicalTrials.gov and the International Clinical Trials Registry Platform. The search string was developed in collaboration with biomedical reference librarians of KU Leuven Libraries and was based on keywords and free-text entries combining the concepts of “chronic arthritis” AND “eHealth” (online supplemental material 1). In
addition, we screened the reference lists of included reports as a backward citation search.

Duplicates were removed with Endnote V.20.1. First, all records were screened by title and abstract independently by two reviewers (CVL and MD), using Rayyan QRCI (https://www.rayyan.ai/). Finally, the full texts were screened for all remaining articles. A third reviewer (DDC) was consulted to resolve conflicts.

Data extraction
Two reviewers (CVL and MD) independently extracted data from included studies into a Microsoft Excel database. The following data were considered: general study characteristics (first author, publication year, study design and study duration); population characteristics (number of participants, age, sex and diagnosis); eHealth-related characteristics (type of eHealth tool, outcomes collected by the tool, requested frequency of outcome collection and incentives for use of the tool); and engagement or attrition-related characteristics (definition and quantitative outcome).

Data synthesis
Meta-analysis was performed for engagement outcomes available in ≥3 studies. As we expected high between-study heterogeneity, a random-effects model (restricted maximum likelihood method with Hartung-Knapp adjustment) was applied to estimate the pooled effect across studies with similar engagement outcomes. An inverse variance method was used for weighting each study in the meta-analysis. The proportion of variability in effect estimates due to between-study heterogeneity was summarised using $\tau^2$ and $I^2$. Logit-transformed proportions were used for variance stabilisation. If ≥10 studies were available and relevant subgroups were sufficiently large, heterogeneity among studies with similar engagement outcomes was further explored by subgroup analyses for the type of eHealth tool, the outcome collection frequency, diagnosis and study design (RCT or observational/case–control study). In addition, the impact of study duration was explored with univariable regression. Finally, sensitivity analyses were performed by excluding abstracts. Meta-analysis was conducted with R (V.2021.09.1), using the meta package.

Risk of bias assessment
Risk of bias was assessed for all included studies for which a full text was available, using the Newcastle-Ottawa scale for cohort studies and the PEDro scale for RCTs.

RESULTS
Search results
The systematic search resulted in 10,526 potentially relevant records (figure 1). After deduplication, 5,438 articles were screened by title and abstract, 186 of which were eligible for full-text screening. Among these, 45 articles were eventually included in the final review, with publication dates ranging from 2008 to 2022. No additional records meeting the inclusion criteria were identified through backward citation searching.

Study characteristics and risk of bias
A total of 14,341 patients were included across the 45 eligible studies (table 1). Of these 45 studies, 32 were observational studies, 8 were RCTs or post hoc analyses thereof, 2 were case–control studies and 3 were conference abstracts. Sixteen (36%) studies were conducted in an RA population, 13 (29%) in an OA population, 9 (20%) in JIA, 2 (4%) in a population with gout and 3 (7%) in patients with ankylosing spondylitis (AS) or axial SpA, while 4 (9%) studies included mixed populations. The reported mean age of included participants ranged from <18 years in the JIA studies to over 60 years in several OA-focused studies. Most studies included a predominantly female patient population. Only six articles included mostly men with either gout, JIA, SpA or OA.21 22 23 24 25 26

Study durations varied considerably across the included studies, ranging from 7 days to up to 1 year. Moreover, a large degree of heterogeneity was seen in the studies’ approach to patient recruitment. Although most studies recruited participants during a physical clinic visit, 13 studies (29%) approached eligible participants through fully digital channels such as email, social media, short message service (SMS) messages or online surveys.

Finally, risk of bias was assessed for all 42 studies with full-text availability (online supplemental material 2). Overall, included studies had a moderate risk of bias when considering the outcome of participant engagement. The main source of bias was selection bias, with most studies including only participants who had both access to smartphones or computers and sufficient experience using them. Furthermore, some studies recruited
### Table 1  Characteristics and engagement data for included eHealth studies

| First author (year) | Diagnosis | N     | Age, years (SD) | Female, % | Duration, days | Recruitment | eHealth tool | Monitoring frequency | Incentives | Engagement (definition) | Engagement (%) |
|---------------------|-----------|-------|-----------------|-----------|----------------|-------------|--------------|----------------------|------------|------------------------|----------------|---|
| Austin (2020)       | RA        | 20    | 32–84           | 75        | 85             | Physical/clinic | Smartphone app | Daily; weekly; monthly | Reminders  | Completion rate         | 86; 85; 58    |   |
| Bellamy (2010)      | OA        | 12    | 63 (9)          | 75        | 12             | Physical/clinic | Smartphone app | Once every 3 days   | Reminders  | Completion rate         | 100           |   |
| Beukenhorst (2020)  | OA        | 26    | 64              | 50        | 90             | Advertisements -> event | WAT (C) | Continuous+PROs daily; weekly; monthly | Reminders  | Proportion of days worn (WAT) + completion rate (PRO) | 73 + 66; 69; 89 |   |
| Bingham III (2019)  | RA        | 1305  | 53 (12)         | 77        | 84             | Physical/clinic | PDA e-diary | Daily              | Reminders  | Completion rate         | 94            |   |
| Connelly (2010)     | OA        | 100   | 57 (10)         | 60        | 28             | Online survey -> phone call | Web-based | Daily              | Financial; phone calls | Completion rate | 96; 100 |   |
| Connelly (2013)     | OA        | 98    | 57 (10)         | 60        | 28             | Online survey -> phone call | Web-based | Daily              | Financial; phone calls | Completion rate | 66     |   |
| Costantino (2022)   | RA        | 78    | 55 (11)         | 81        | 210            | Physical/clinic | Smartphone app | Daily | Reminders; financial; phone calls | Completion rate | 93     |   |
| Connelly (2012)     | JIA       | 43    | 13 (3)          | 80        | 28             | Physical/clinic | Smartphone app | Thrice daily | Reminders; financial; phone calls | Completion rate | 88     |   |
| Connelly (2017)     | JIA       | 66    | 13 (3)          | 73        | 30             | Physical/clinic | Smartphone app | Thrice daily | Reminders; financial | Completion rate | 69     |   |
| Colls (2021)        | OA        | 21    | 49 (15)         | 15        | 183            | Social media | Smartphone app | Weekly; monthly | Reminders | Proportion of active participants (per week) | 20-100°    |   |
| Druce (2017)        | RA (19%) | 6370  | 49 (13)         | 81        | 180            | Advertisements; directing to app | Smartphone app | Daily | Reminders | Categorical engagement: - High (15%) - Moderate (22%) - Low (38%) - Tourists (25%). For each group: proportion of days with complete data | High: 70 Moderate: 28 Low: 3 Tourists: 1 |
| Elmagboul (2020)    | Gout      | 33/44 | 49 (15)         | 15        | 183            | Physical/clinic | WAT (C) + smartphone app | Continuous + ePROs weekly | Reminders | Proportion of days worn + completion rate | 61; 81      |   |

Continued
| First author (year) | Diagnosis | N     | Age, years (SD) | Female, % | Duration, days | Recruitment | eHealth tool | Monitoring frequency | Incentives | Engagement (definition) | Engagement (%) |
|---------------------|-----------|-------|-----------------|-----------|----------------|-------------|-------------|----------------------|------------|-------------------------|----------------|
| Fu (2019)           | OA        | 252   | 62 (8)          | 79        | 90             | Online survey -> phone call | Web-based   | Once every 10 days + in case of flare | Reminders | Completion rate          | 81             |
| Gilbert (2021)      | OA        | 2127  | 65 (9)          | 56        | 7              | Physical/clinic | WAT (R)     | Continuous           | NR         | Proportion wearing WAT ≥7/ days | 91             |
| Harbottle (2018)    | JIA       | 12    | 14              | 50        | 90             | Physical/clinic | WAT (R)     | Continuous           | NR         | Proportion of days worn | 17             |
| Heale (2018)        | JIA       | 28    | 15              | 74        | 28             | Physical/clinic | WAT (C)     | Continuous           | Reminders  | Proportion of days worn | 72             |
| Heiberg (2007)      | RA        | 38    | 58 (13)         | 66        | 84             | Mail -> event | PDA e-diary | Daily; weekly        | Phone calls | Completion rate (overall daily/ weekly) | 85             |
| Jacquemin (2018)    | RA & axSpA| 177   | 46 (12)         | 64        | 90             | Physical/clinic | WAT (C)     | Continuous           | NR         | Proportion of days worn | 88             |
| Kempin (2022)       | axSpA     | 69    | 42 (11)         | 42        | 168            | Physical/clinic | Smartphone app | Once every 2 weeks | Reminders (1/2); phone calls | Proportion providing requested data ≥80% of moments by week 12 | 29 (but 81% exported at least once) |
| Laloo (2021)        | JIA       | 60    | 15 (2)          | 78        | 56             | Physical/clinic | Smartphone app | Daily                 | Financial; phone calls | Completion rate | 52             |
| Lazaridou (2019)    | OA        | 121   | 66 (9)          | 59        | 7              | Physical/clinic | PDA e-diary | Daily                | NR         | Completion rate          | 98             |
| Lee (2013)          | RA        | 85    | 18+ (categorical) | 77       | 60             | Physical/clinic | SMS         | Monthly              | Reminders; financial | Completion rate | 75             |
| Lee (2020)          | JIA       | 14    | 13 (2)          | 64        | 56             | Physical/clinic | Smartphone app | Twice daily; daily; weekly + in case of pain | Phone calls | Completion rate 51; 63; 38 |                |
| Martin (2021)       | RA        | 104   | Ongoing         |           |                | Ongoing SMS    | SMS         | Monthly              | Reminders   | Completion rate          | 69             |
| McBeth (2022)       | RA        | 254   | 57 (49-64)      | 81        | 30             | Email -> phone call | Smartphone app | Thrice daily; daily; once every 10 days | Reminders | Completion rate (overall thrice daily & daily) | 92             |
| Murray (2022)       | RA        | 26    | 18+ (categorical) | 77       | 56             | Mail† -> phone call | Smartphone app | Daily (alternating cycle) | Reminders | Completion rate          | 66             |
| Nowell (2020)       | RA        | 278   | 50 (11)         | 92        | 84             | Email to ArthritisPower members | WAT (C) + smartphone app | Continuous + PROs daily; weekly | Reminders; financial; phone calls/ emails | Proportion providing requested data >70% of days | 82 + 57; 87 |
| Nowell (2021)       | OA (65%); RA (49%); PaA (26%); AS (16%); FMS (16%); OP (16%); SLE (9%) | 253 | 56 (9)          | 89        | 90             | Email to ArthritisPower members | Smartphone app | Monthly             | Reminders   | Proportion completing all ePROs | 55             |
| Östlind (2021)      | OA        | 74    | 57 (5)          | 87        | 84             | Physical/clinic | WAT (C)     | Continuous           | Emails     | Proportion of days worn | 88             |
| First author (year) | Diagnosis  | N  | Age, years (SD) | Female, % | Duration, days | Recruitment      | eHealth tool          | Monitoring frequency | Incentives                  | Engagement (definition) | Engagement (%) |
|---------------------|------------|----|----------------|-----------|----------------|--------------------|----------------------|----------------------|--------------------------|--------------------------|------------------|
| Pers (2021)         | RA         | 45 | 18-75          | 73        | 183            | Physical/clinic    | Smartphone app       | Weekly               | Reminders Phone calls   | Completion rate (final 16 weeks) | 67               |
| Pouls (2021)        | Gout       | 29 | 57 (13)        | 3         | 90             | Physical/clinic    | Smartphone app       | Daily                | Reminders                | Completion rate          | 96               |
| Reade (2017)        | RA         | 20 | 60             |           |                | Physical/clinic    | Smartphone app       | Daily                | Reminders                | Completion rate          | 68               |
| Renskers (2020)     | RA & SpA   | 47 | 57 (11)        | 57        | 14-597 (mean 350) | Physical/clinic    | Web-based            | Free to choose (at baseline) | Reminders                | Completion rate          | 68               |
| Rouzaud-Laborde (2021) | OA      | 28 | 73 (6)         | 70        | 14             | Physical/clinic    | WAT-based ePRO-app (C) | Thrice daily; daily | Reminders                | Completion rate (adjusted for wear time - technical issues) | 81; 93             |
| Seppen (2020)       | RA         | 42 | 54 (13)        | 86        | 28             | Physical/clinic    | Smartphone app       | Weekly               | NR                       | Completion rate          | 82               |
| Seppen (2022)       | RA         | 27 | 52 (11)        | 78        | 28             | Physical/clinic    | Smartphone app       | Weekly               | NR                       | Completion rate          | 70               |
| Skrepnik (2017)     | OA         | 211 | 63 (9)        | 50        | 90 (+ 90 day follow-up) | Physical/clinic    | WAT (Q ± smartphone app (1:1) | Continuous | Reminders (app only) | Proportion providing data >80% of days (first 90 days) | 91               |
| Stinson (2008)      | JIA        | 13 | 13 (3)         | 85        | 14             | Physical/clinic    | PDA e-diary          | Thrice daily         | Reminders Financial Phone calls | Completion rate | 72               |
| Tyrrell (2016)      | AS         | 223 | 50 (14)       | 39        | 84             | Email/social media | Web-based            | Weekly               | Reminders                | Completion rate          | 67               |
| Wilson (2013)       | OA         | 144 | 66 (10)       | 57        | 22             | Physical/clinic    | PDA e-diary          | Daily                | NR                       | Completion rate          | 92               |
| Yu (2022)           | OA         | 65 | 61 (6)         | 46        | 2x7            | Physical/clinic    | WAT (C)              | Continuous           | NR                       | Proportion wearing WAT ≥6/7 days | 99               |
| Zaslavsky (2019)    | OA         | 24 | 71 (4)         | 70        | 133            | Physical/clinic    | WAT (C)              | Continuous           | Reminders Financial Phone calls | Proportion of hours worn per day | 88               |

*Proportion of active participants was reported separately for each week, ranging from 100% in week 1 to approximately 20% at week 12.
†ePROs were evaluated in 44 participants, WAT in a subgroup of 33 participants from the same study.
‡Recruitment letters were mailed to patients who participated in the preceding trial with the same smartphone app.
AS, ankylosing spondylitis; FMS, fibromyalgia syndrome; JIA, juvenile idiopathic arthritis; OA, osteoarthritis; OR, osteoporosis; PDA, personal digital assistant; PPROs, patient-reported outcomes; PsA, psoriatic arthritis; RA, rheumatoid arthritis; SLE, systemic lupus erythematosus; SMS, short message service; SpA, spondyloarthritis; WAT, wearable activity tracker (either consumer-grade C or research-grade R).
participants based on a self-reported physician’s diagnosis of arthritis, particularly when a fully digital recruitment approach was taken, and most studies lacked control groups.

Characteristics of reported eHealth tools
In all, 23 studies (51%) evaluated the use of a smartphone application, while 13 studies (29%) reported on the use of wearable activity trackers, 7 (16%) provided participants with a personal digital assistant (PDA) e-diary, 6 (13%) used a web-based platform and 2 (4%) were based on an SMS messaging system (table 1). Generally, in studies evaluating activity trackers, participant data such as step counts and physical activity were collected continuously while wearing the tracker. By contrast, other eHealth tools primarily collected PROs, usually in the form of questionnaires sent to participants via the system. However, these eHealth systems differed significantly in the specific type of outcome measures collected, in the frequency of requested PRO-reporting, and in the incentives provided to participants to adhere to this reporting frequency. For instance, 7 studies (16%) asked participants to complete PROs three times each day, whereas once-a-day reporting was requested in 19 studies (42%), weekly reporting in 14 (31%), and monthly reporting in 6 (13%). Some systems allowed data entry at any time, for instance in case of a flare, while one study asked participants to choose their preferred reporting frequency at baseline. Finally, incentives to participants for providing complete data ranged from financial compensation and regular compliance checks in some studies to no incentives whatsoever in others.

Participant engagement with eHealth tools
Engagement was defined in several ways across the included studies (table 1). Some studies defined engagement categorically or based on the proportion of patients providing data above a certain threshold of completeness.

However, where applicable, most articles reported a completion rate for the collected PRO data, defined as the proportion of all requested data entries in the study that were effectively completed by participants. Meta-analysis of the 34 studies that reported completion rates (figure 2) resulted in a pooled global completion rate of 80% (95% CI 73% to 85%) with high between-study heterogeneity (τ^2 0.78; I^2 93%).

Subgroup analysis (figure 3) showed significant differences between eHealth tools (p for interaction<0.01), with a pooled completion rate of 73% (95% CI 64% to 80%) in studies using smartphone applications, 91% (95% CI 81% to 96%) in studies using PDA e-diaries, 81% (95% CI 54% to 94%) in studies evaluating a

![Figure 2](image-url) Forest plot of pooled completion rates for patient-reported outcomes collected with eHealth tools.
web-based platform and 71% (95% CI 29% to 94%) in studies using an SMS messaging system. In addition, two studies involved PRO registration via a smartwatch app and reported a pooled completion rate of 79%.

PRO completion rates also differed according to the requested frequency of data collection (p for interaction=0.02), with a pooled completion rate of 86% (95% CI 77% to 92%) for daily, 70% (95% CI 57% to 81%) for weekly and 71% (95% CI 50% to 86%) for monthly intervals (figure 4). In studies collecting data more than once per day, a pooled completion rate of 69% (95% CI 56% to 80%) was reported. Additional subgroup meta-analyses (online supplemental material 3) showed no apparent differences in PRO completion rates according to diagnosis (including only studies in an RA population) and study design (comparing RCTs and observational studies).

Finally, studies using a wearable activity tracker mostly defined engagement as the proportion of days the tracker was actively worn. Across the six studies for which this was

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**Figure 3**  Forest plot of pooled completion rates according to eHealth tool. PDA, personal digital assistant; SMS, short message service; WAT, wearable activity tracker.
reported, the pooled proportion of days worn was 70% (95% CI 39% to 90%) with high between-study heterogeneity ($\tau^2$ 1.18; $I^2$ 86%) (figure 5).

In sensitivity analyses excluding abstracts, meta-analysis resulted in a pooled global PRO-completion rate of 80% (unchanged to when considering all records) and a pooled proportional tracker wear time of 77% (compared with 70% when considering all records) (online supplemental material 4).

### Attrition
In total, 20 studies reported on attrition, defined as a loss of participant engagement over time (table 2). Among these, 14 studies (70%) defined attrition as the difference between the start and end of the study in PRO-completion rate or in the amount of time the wearable tracker was worn. The remaining six articles reported on attrition either as the proportion of participants who were no longer active with the eHealth system by the end...
Factors facilitating or hindering engagement

Facilitators or barriers to eHealth engagement were reported in 17 (38%) of the included studies (table 3), but only 13 of these studies provided quantitative assessments.

First, evidence for the influence of demographic or disease-related aspects on engagement was largely inconsistent. Overall, higher levels of engagement were reported for older adults and for children rather than adolescents with JIA. However, while one study found women with chronic arthritis to be more engaged than men,31 no such difference was apparent in others.28 40 Similarly, higher completion rates were reported with lower disease activity in an established RA population,40 whereas the inverse was found in a recent study on SpA,25 and qualitative data suggested that a lack of symptoms might hinder engagement.41 In addition, one study found higher completion rates for patients treated with biological disease-modifying drugs,32 while this finding was contradicted in another report.25 Moreover, engagement was not affected by the diagnosis itself in any of the included studies with mixed populations. Conflicting results were also reported for the influence of employment status, with one study reporting more dropouts in non-employed participants,32 whereas another found lower completion rates in fully employed patients.42

In addition, several studies indicated that the approach to outcome collection might influence participants’ engagement. For instance, less time-intensive PRO-reporting schedules, such as weekly rather than daily reporting, were associated with higher completion rates in 5 out of 6 studies for which this information was available.29 32 43–45 Moreover, higher engagement was found when feedback was provided to patients about the data they reported, either by discussing them in clinic or through data visualisation in the eHealth tool itself. Specifically, the PARADE study reported a 4% difference in attrition in favour of participants who had daily access to their data compared with those who did not.27 Similarly, using a smartphone app to provide visual feedback on step counts resulted in increased engagement with a wearable activity tracker in another report.46 Interestingly, however, using reminders to prompt data entry did not appear to have a clear effect on participant engagement in both studies that investigated this.11 25

DISCUSSION

In this systematic review, we summarised the evidence on patients’ engagement with eHealth systems used to remotely monitor disease activity or impact in chronic arthritis. Relatively high levels of eHealth engagement were reported across 45 included studies, which primarily consisted of observational cohorts and RCTs. The pooled global completion rate for remotely monitored PROs was 80%, while wearable activity trackers were worn for a pooled global proportion of 70% of study days, rising to 77% in a sensitivity analysis excluding abstracts.

In general, these results are in line with engagement data from remote monitoring studies in other chronic diseases, including diabetes, obesity and mental health conditions.47 However, between-study heterogeneity for engagement outcomes was high in both previous research and in our review. This considerable heterogeneity encountered between studies represents a first major challenge in the current landscape of eHealth research. Among the included studies, much variability was apparent in study population and duration, ranging from only a few days to 1 year, as well as in the incentives to participants for providing complete data, and even in how engagement was defined and measured. Furthermore, comparisons between studies are inevitably limited because of these differences. Similar reports on the challenges of heterogeneity in eHealth studies also emerged as major conclusions in several recent systematic reviews,
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Table 2  Overview of included studies reporting loss of eHealth engagement over time (attrition)

| First author (year) | Duration (days) | eHealth tool | Monitoring frequency | Attrition (definition) | Attrition (%) |
|---------------------|----------------|--------------|----------------------|------------------------|--------------|
| Beukenhorst 2020    | 90             | WAT          | Continuous+ PROs daily; weekly; monthly | Active participants (WAT) + completion rate (overall PROs): baseline to end | 54 + 55 |
| Bingham III 2019    | 84             | PDA e-diary  | Daily                | Completion rate: week 1 to week 12 | 0            |
| Colls 2021          | 210            | Smartphone app | Daily              | Completion rate: first 3 months to final 3 months | 26           |
| Connelly 2012       | 28             | Smartphone app | Thrice daily        | Completion rate: first 2 weeks to second 2 weeks | 24           |
| Crouthamel 2018     | 84             | Smartphone app | Weekly; monthly     | Active participants: baseline to end | 89           |
| Elmagboul 2020      | 183            | WAT+smartphone app | Continuous+ePROs weekly | Proportion not meeting minimal WAT wear time | 18           |
| Jacquemin 2018      | 90             | WAT          | Continuous           | Active participants: baseline to end | 22           |
| Kempin 2022         | 168            | Smartphone app | Once every 2 weeks  | Proportion providing data ≥80% of moments: week 12 to week 24 | 10           |
| Lalloo 2021         | 56             | Smartphone app | Daily                | Completion rate: first day to final day | 48           |
| Lee 2013            | 60             | SMS          | Monthly              | Completion rate: first month to final month | 10           |
| Nowell 2021         | 90             | Smartphone app | Monthly              | Active participants: baseline to final month | 45           |
| Murray 2022         | 56             | Smartphone app | Daily (alternating cycle) | Completion rate: first week to final week | 16           |
| Östlind 2021        | 84             | WAT          | Continuous           | Proportion of days worn: first week to final week | 20           |
| Pouls 2021          | 90             | Smartphone app | Daily                | Active participants: baseline to end | 0            |
| Renskers 2020       | 14–597 (mean 350) | Web-based | Free to choose (at baseline) | Active participants: baseline to end | 49           |
| Seppen 2020         | 28             | Smartphone app | Weekly               | Completion rate: first week to final week | 39           |
|                     | 28             | Smartphone app | Weekly               | Completion rate: first week to final week | 63           |
| Seppen 2022         | 356            | Smartphone app | Weekly               | Completion rate: first 3 months to final 3 months | 4            |
| Skrepnik 2017       | 90 (+90 day follow-up) | WAT+smartphone app (1:1) | Continuous | Proportion providing data >80% of days: day 90 to day 180 (app-group) | 64           |
| Stinson 2008        | 14             | PDA e-diary  | Thrice daily         | Completion rate: week 1 to week 2 | 10           |
| Zaslavsky 2019      | 133            | WAT          | Continuous           | Proportion of hours worn per day: first week to final week−1 (increase) | |

PDA, personal digital assistant; PROs, patient-reported outcomes; SMS, short message service; WAT, wearable activity tracker.

focusing on synchronous telemedicine, mobile health interventions and wearable activity trackers in rheumatology. Moreover, this challenge is clearly not limited to the rheumatology field. Therefore, future research on the use of eHealth systems should not only assess engagement outcomes, but also report them in a standardised way. Based on our review results, the most suitable measures for this purpose seem to be completion rates and proportional wear time for PRO-based and wearable-based interventions, respectively.

A second challenge faced by the eHealth research field in rheumatology is the limited availability of data.
from daily clinical practice, as is clear from the studies included in our review. This seems particularly important when considering the issue of disengagement over time reported both in many eHealth studies and for mobile applications outside of the research setting. For instance, an estimated 71% of app users across all industries stop using the app within 3 months, and a study of adherence to activity trackers in students showed 75% disengagement within 4 weeks. In our review, only 20/45 included studies effectively reported data on attrition, and in most cases these data were collected within a strictly controlled research environment. This is particularly relevant since generally low levels of attrition were primarily reported in studies that were either of shorter duration or included strong incentives to support engagement, such as financial compensation. Similarly, completion rates for the PDA e-diaries did not show any decline over time in the phase III baricitinib trials RA-BEAM and RA-BUILD, again in a setting of close follow-up and targeted participant training. By contrast, much higher attrition rates were reported in several ‘fully digital’ studies, with 89% of participants disengaging within less than 3 months in the PARADE study, and 45% disengaging within 3 months in an ancillary study of the ArthritisPower registry and 41% not completing the 2-week lead-in period in another ArthritisPower study. These striking differences in attrition between closely or less closely controlled research settings have also been reported for other chronic diseases, with higher engagement rates in studies that compensated patients for their participation. Consequently, there is a clear need for more eHealth engagement data from routine care settings, where higher attrition rates are likely. Pending such data, the current evidence on eHealth in rheumatology might underestimate the problem of attrition.

However, we should note that some potentially relevant studies from daily practice settings were excluded from our review because they did not report engagement based on data completeness. For instance, in a 12-month, multicentric study from France, patients with RA were randomised to either usual care or additional access to the web-based Sanoia platform, developed to support self-monitoring. In this study, no direct incentives to access the platform were provided to optimally mirror daily care. Although satisfaction with the platform was high, 26% of patients never accessed Sanoia, and the number of accesses clearly declined over time.

The phenomenon of attrition has prompted researchers to explore the optimal target population and possible barriers and facilitators for engaging with eHealth systems. Our review identified several demographic and disease-related aspects that might be associated with eHealth engagement. Among these, the finding that older age seems associated with higher engagement is somewhat surprising, given the known barriers of ageing on technology use. However, since much of the available evidence stems from research populations, it is likely that the most vulnerable elderly patients were either excluded from these studies or did not express an interest to participate. Moreover, older age was associated with lower eHealth engagement in JIA studies, in line with the commonly reported lower treatment adherence in adolescents. Interestingly though, the diagnosis did not appear to affect eHealth engagement, either in individual studies or in subgroup meta-analysis, despite the important differences in how different types of chronic arthritis are managed.

Another intriguing finding of our review is that engagement rates do appear to be affected by the approach to outcome collection. For instance, one included

### Table 3 Factors quantitatively associated with eHealth engagement in included studies

| Facilitates engagement | Hinders engagement | No apparent influence | Reference |
|------------------------|--------------------|-----------------------|-----------|
| Age: older adults ♦     |                    |                       | 25 31 32 40 |
| Age: children versus adolescents ♦ | | | 35 |
| Sex: female ♦ | | | 31 |
| Disease activity: higher ♦ | ♦ | | Facilitates25 Hinders40 |
| Treatment: bDMARDs ♦ | ♦ | | Facilitates32 Hinders25 |
| Employment: full time ♦ | | | 42 |
| Employment: non-employed ♦ | | | 32 |
| Outcomes: less frequent reporting ♦ | | | 30 32 43 44 |
| Outcomes: morning reporting ♦ | | | 58 |
| Feedback ♦ | | | 27 46 |
| Reminders ♦ | | | 11 25 |
| Habitual use of eHealth tools ♦ | | | 45 |

bDMARDs, biological disease-modifying antirheumatic drugs.
Some limitations of this systematic review should be acknowledged. We focused specifically on remote monitoring in an asynchronous setting, which implies that eHealth tools were not considered if they were intended to facilitate real-time contact between patients and care providers. Consequently, studies based on telehealth interventions like telephone or video consultations were not included. The results of this systematic review can therefore not be extended to any type of eHealth intervention. In addition, we did not consider purely qualitative studies. Finally, both the conclusions and the generalisability of our review are inherently limited by selection bias in the included studies, the majority of which considered participants only if they had access to digital tools and sufficient experience using them.

However, our review was conducted and reported according to commonly recommended guidelines. The protocol was registered in PROSPERO, the search string was developed in collaboration with biomedical reference librarians, study selection and data extraction were conducted independently by two reviewers in both published and ‘grey’ literature, and a third reviewer was consulted to resolve conflicts. Moreover, the search was updated at a later time, and a meta-analysis was performed with subgroup and sensitivity analyses to explore between-study heterogeneity.

CONCLUSION
Relatively high levels of participant engagement were reported in studies involving eHealth systems for asynchronous remote monitoring in chronic arthritis. However, comparisons were hindered by considerable heterogeneity and a relative lack of data from routine care settings. This is of particular importance given the observed differences in attrition in closely controlled versus less incentivised research settings, as well as the finding that engagement tends to decline with longer study duration. To provide a clear picture of the feasibility of remote monitoring eHealth strategies, future studies should therefore use standardised measures of engagement, such as PRO-completion rates or proportional tracker wear time, and assess them with study designs that optimally reflect daily clinical practice.

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