



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 (I^2 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.² 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.³ Consequently, potentially relevant information about the disease's impact between clinic visits is insufficiently captured in routine care.⁴ Moreover, following shifts to targeted treatment strategies, managing chronic inflammatory arthritis increasingly requires lifelong follow-up on a regular basis.⁵ 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.⁶

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.⁷ 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.⁸ 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.⁹ 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.¹⁰ Such information has also shown potential to facilitate patient-initiated follow-up, as opposed to prescheduled clinic visits,¹¹ ultimately contributing to reduced healthcare utilisation.¹² 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.^{13–15}

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.¹⁶ 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.¹⁷ 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.¹⁸

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.⁷

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

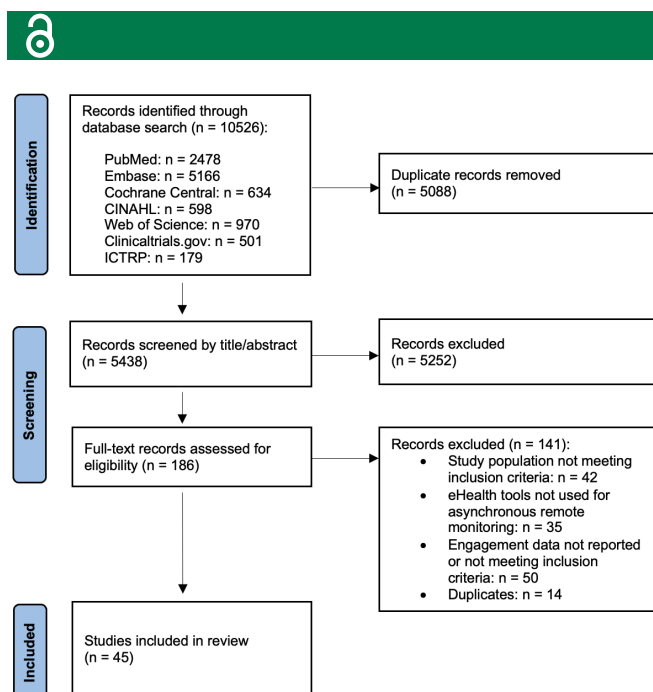


Figure 1 PRISMA flow chart of systematic review. ICTRP, International Clinical Trials Registry Platform.

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 τ^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 meta-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.^{19 20}

RESULTS

Search results

The systematic search resulted in 10526 potentially relevant records (figure 1). After deduplication, 5438 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 14341 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,^{21 22} JIA,²³ SpA^{24 25} or OA.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) ⁶¹	RA	20	32–84	75	85	Physical/clinic	Smartphone app	Daily; weekly; monthly	Reminders	Completion rate	86; 85; 58
Bellamy (2010) ⁶²	OA	12	63 (9)	75	12	Physical/clinic	Smartphone app	Once every 3 days	Reminders	Completion rate	100
Beukenhorst (2020) ³⁰	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) ³⁹	RA	1305	53 (12)	77	84	Physical/clinic	PDA e-diary	Daily	Reminders	Completion rate	94
	RA	684	52 (12)	82	84	Physical/clinic	PDA e-diary	Daily	Reminders	Completion rate	93
Broderick (2013) ⁴⁴	OA	98	57 (10)	60	28	Online survey -> phone call	Web-based	Daily; weekly	Financial; phone calls	Completion rate	96; 100
Bromberg (2014) ²³	JIA	59	13 (3)	45	28	Physical/clinic	Smartphone app	Thrice daily	Reminders; financial; phone calls	Completion rate	66
Christodoulou (2014) ²⁹	OA	100	57 (10)	60	28	Online survey -> phone call	Web-based	Daily	Reminders; financial; phone calls	Completion rate	93
Collis (2021) ⁴⁰	RA	78	55 (11)	81	210	Physical/clinic	Smartphone app	Daily	Reminders	Completion rate	79
Connelly (2010) ⁶³	JIA	9	12 (3)	89	14	Physical/clinic	PDA e-diary	Thrice daily	Reminders	Completion rate	88
Connelly (2012) ⁶⁴	JIA	43	13 (3)	86	28	Physical/clinic	Smartphone app	Thrice daily	Reminders; phone calls	Completion rate	69
Connelly (2017) ⁶⁵	JIA	66	13 (3)	73	30	Physical/clinic	Smartphone app	Thrice daily	Reminders; financial	Completion rate	81
Costantino (2022) ⁶⁶	AxSpA	99	NR	64	356	Online (SPONDY+ platform)	Web-based	Weekly	NR	Completion rate	54
Crouthamel (2018) ²⁷	RA	388	48 (12)	81	84	Social media	Smartphone app	Weekly; monthly	Reminders	Proportion of active participants (per week)	20–100*
Druce (2017) ³¹	RA (19%) SpA (9%) Arthritis (40%) Gout (3%) FMS (24%) Headache (7%) Neuropathic (13%) Other(23%)	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) ²¹	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

Table 1 Continued

First author (year)	Diagnosis	N	Age, years (SD)	Female, %	Duration, days	Recruitment	eHealth tool	Monitoring frequency	Incentives	Engagement (definition)	Engagement (%)
F-u (2019) ⁶⁷	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) ⁶⁸	OA	2127	65 (9)	56	7	Physical/clinic	WAT (R)	Continuous	NR	Proportion wearing WAT $\geq 4/7$ days	91
Harbottle (2018) ³⁵	JIA	12	14	50	90	Physical/clinic	WAT (R)	Continuous	NR	Proportion of days worn	17
Heale (2018) ³⁶	JIA	28	15	74	28	Physical/clinic	WAT (C)	Continuous	Reminders	Proportion of days worn	72
Heiberg (2007) ⁶⁹	RA	38	58 (13)	66	84	Mail -> event	PDA e-diary	Daily; weekly	Phone calls	Completion rate (overall daily/weekly)	85
Jacquemin (2018) ³⁷	RA & axSpA	177	46 (12)	64	90	Physical/clinic	WAT (C)	Continuous	NR	Proportion of days worn	88
Kempin (2022) ²⁵	AxSpA	69	42 (11)	42	168	Physical/clinic	Smartphone app	Once every 2 weeks	Reminders (1/2); phone calls	Proportion providing requested data $\geq 80\%$ of moments by week 12	29 (but 81% exported at least once)
Lalloo (2021) ⁷⁰	JIA	60	15 (2)	78	56	Physical/clinic	Smartphone app	Daily	Financial; phone calls	Completion rate	52
Lazaridou (2019) ⁷¹	OA	121	66 (9)	59	7	Physical/clinic	PDA e-diary	Daily	NR	Completion rate	98
Lee (2013) ⁴²	RA	85	18+ (categorical)	77	60	Physical/clinic	SMS	Monthly	Reminders; financial	Completion rate	75
Lee (2020) ⁴³	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) ⁷²	RA	104			Ongoing	SMS	SMS	Monthly	Reminders	Completion rate	69
McBeth (2022) ³³	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) ⁷³	RA	26	18+ (categorical)	77	56	Mail† -> phone call	Smartphone app	Daily (alternating cycle)	Reminders	Completion rate	66
Nowell (2020) ³²	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) ²⁸	OA (65%); RA (49%); PsA (26%); AS (16%); FMS (40%); OP (16%); SLE (9%)	253	56 (9)	89	90	Email to ArthritisPower members	Smartphone app	Monthly	Reminders	Proportion completing all ePROs	55
Östind (2021) ³⁸	OA	74	57 (5)	87	84	Physical/clinic	WAT (C)	Continuous	Emails	Proportion of days worn	88

Continued

Table 1 Continued

First author (year)	Diagnosis	N	Age, years (SD)	Female, %	Duration, days	Recruitment	eHealth tool	Monitoring frequency	Incentives	Engagement (definition)	Engagement (%)
Pers (2021) ⁷⁴	RA	45	18-75	73	183	Physical/clinic	Smartphone app	Weekly	Reminders Phone calls	Completion rate (final 16 weeks)	67
Pouls (2021) ²²	Gout	29	57 (13)	3	90	Physical/clinic	Smartphone app	Daily	Reminders	Completion rate	96
Reade (2017) ⁵⁷	RA	20			60	Physical/clinic	Smartphone app	Daily	Reminders	Completion rate	68
Renskers (2020) ³⁴	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) ⁴⁵	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) ⁴¹	RA	42	54 (13)	86	28	Physical/clinic	Smartphone app	Weekly	NR	Completion rate	82
	RA	27	52 (11)	78	28	Physical/clinic	Smartphone app	Weekly	NR	Completion rate	70
Seppen (2022) ¹¹	RA	50	58 (13)	56	356	Physical/clinic	Smartphone app	Weekly	Reminders (only 1 month)	Completion rate	59
Skrepnik (2017) ⁴⁶	OA	211	63 (9)	50	90 (+ 90 day follow-up)	Physical/clinic	WAT (C) ± smartphone app (1:1)	Continuous	Reminders (app only)	Proportion providing data >80% of days (first 90 days)	91
Stinson (2008) ⁵⁸	JIA	13	13 (3)	85	14	Physical/clinic	PDA e-diary	Thrice daily	Reminders Financial Phone calls	Completion rate	72
Tyrrell (2016) ²⁴	AS	223	50 (14)	39	84	Email/social media	Web-based	Weekly	Reminders	Completion rate	67
Wilson (2013) ⁷⁵	OA	144	66 (10)	57	22	Physical/clinic	PDA e-diary	Daily	NR	Completion rate	92
Yu (2022) ²⁶	OA	65	61 (6)	46	2x7	Physical/clinic	WAT (C)	Continuous	NR	Proportion wearing WAT ≥6/7 days	99
Zaslavsky (2019) ⁷⁶	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. tePROs 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.⁴⁰

AS, ankylosing spondylitis; FMS, fibromyalgia syndrome; JIA, juvenile idiopathic arthritis; OA, osteoarthritis; OP, osteoporosis; PDA, personal digital assistant; PROs, 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,^{27–33} 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.³⁴ 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

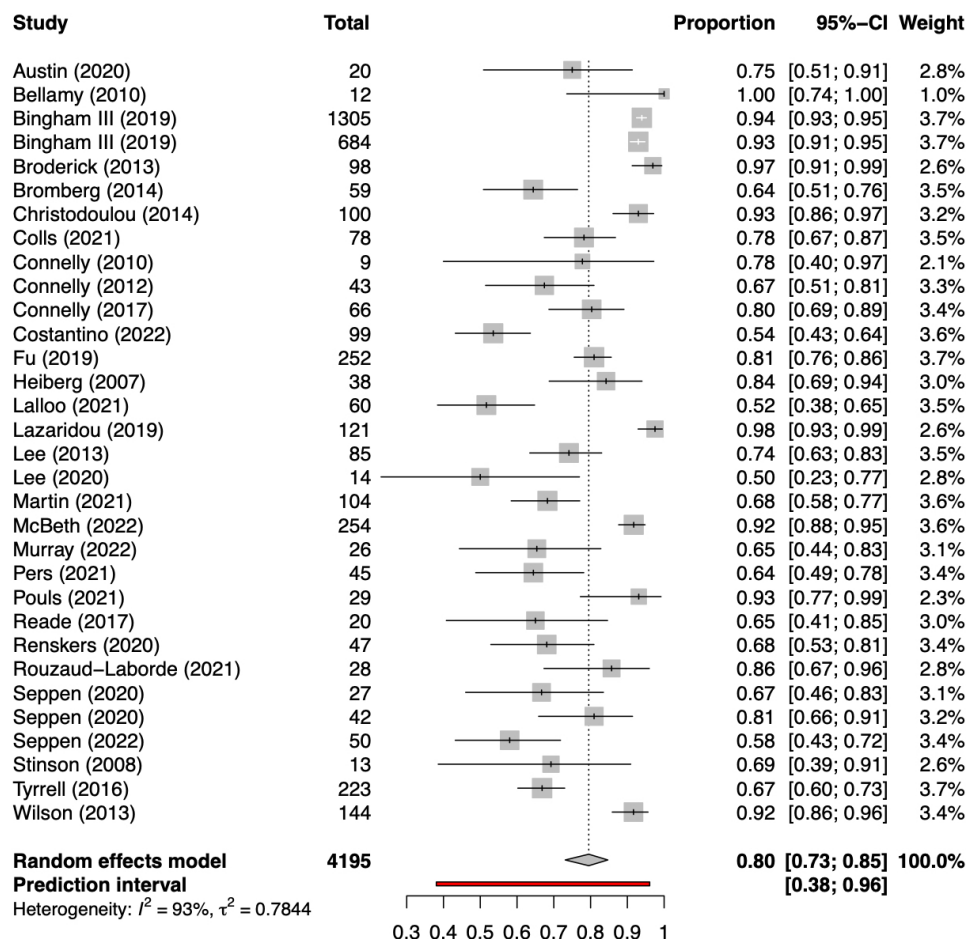


Figure 2 Forest plot of pooled completion rates for patient-reported outcomes collected with eHealth tools.

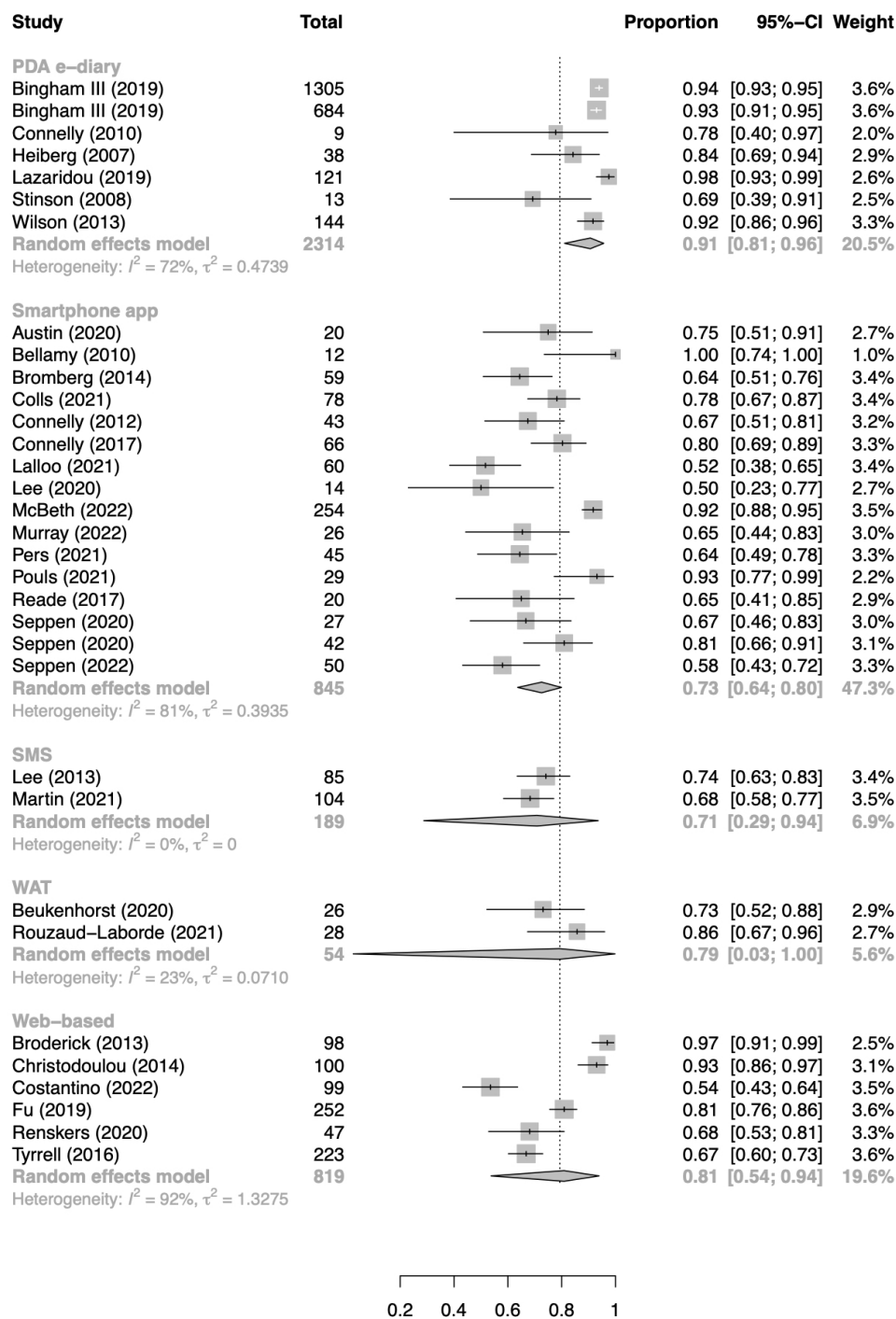


Figure 3 Forest plot of pooled completion rates according to eHealth tool. PDA, personal digital assistant; SMS, short message service; WAT, wearable activity tracker.

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

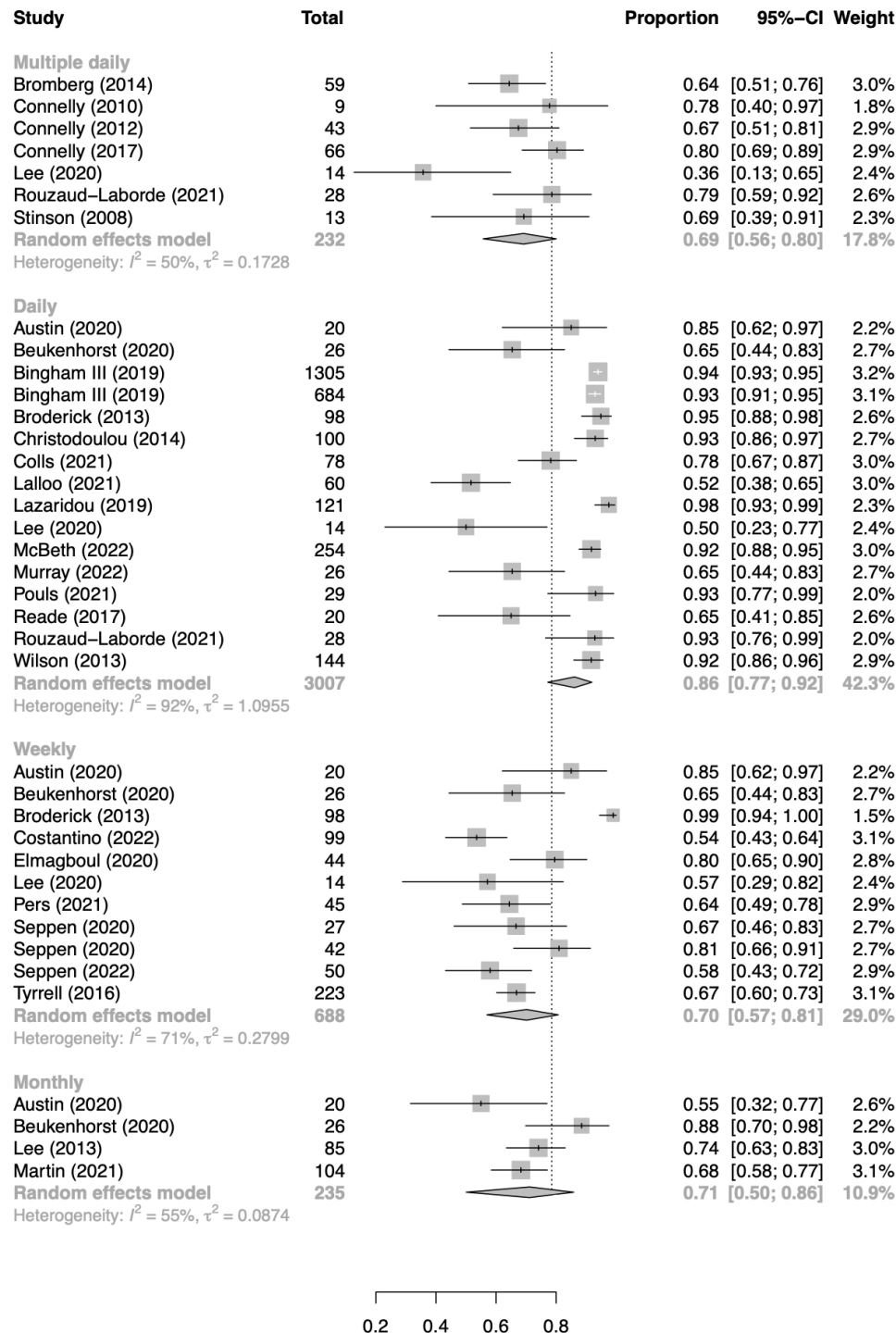


Figure 4 Forest plot of pooled completion rates according to patient-reported outcome collection frequency.

reported,^{21 30 35–38} the pooled proportion of days worn was 70% (95% CI 39% to 90%) with high between-study heterogeneity (τ^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

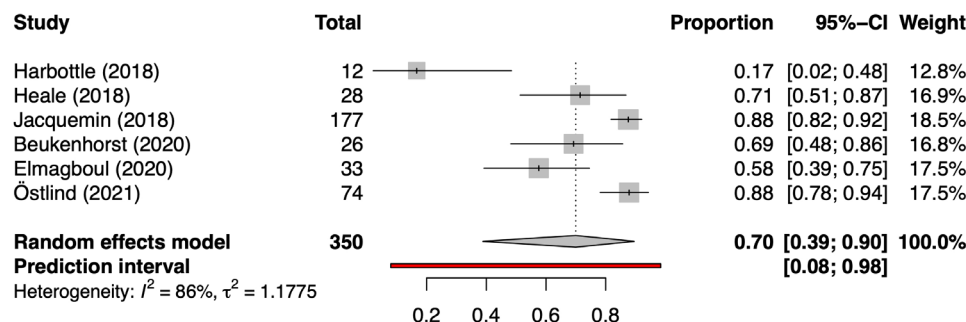


Figure 5 Forest plot of pooled proportion of study days a wearable activity tracker was actively worn.

of the study, or as the proportion who did not meet a minimal threshold of data completeness.

Generally, attrition rates were highly variable, ranging from no change in completion rate over time in a PDA e-diary study nested within a large phase III drug trial³⁹ to as much as 89% drop-out in a smartphone feasibility study that recruited participants exclusively through social media.²⁷ Overall, longer study durations were associated with lower completion rates ($p=0.029$ in univariable meta-regression) (online supplemental material 5).

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.^{30 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, some studies used an entirely digital recruitment approach without physical contact between patients and investigators, for instance by including participants via social media. All these study-related aspects might affect both engagement with an eHealth monitoring approach and the generalisability of the results. 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,

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 ³⁰	90	WAT	Continuous+ PROs daily; weekly; monthly	Active participants (WAT) + completion rate (overall PROs): baseline to end	54 + 55
Bingham III 2019 ³⁹	84	PDA e-diary	Daily	Completion rate: week 1 to week 12	0
Colls 2021 ⁴⁰	210	Smartphone app	Daily	Completion rate: first 3 months to final 3 months	26
Connelly 2012 ⁶⁴	28	Smartphone app	Thrice daily	Completion rate: first 2 weeks to second 2 weeks	24
Crouthamel 2018 ²⁷	84	Smartphone app	Weekly; monthly	Active participants: baseline to end	89
Elmagboul 2020 ²¹	183	WAT+smartphone app	Continuous+ePROs weekly	Proportion not meeting minimal WAT wear time	18
Jacquemin 2018 ³⁷	90	WAT	Continuous	Active participants: baseline to end	22
Kempin 2022 ²⁵	168	Smartphone app	Once every 2 weeks	Proportion providing data $\geq 80\%$ of moments: week 12 to week 24	10
Lalloo 2021 ⁷⁰	56	Smartphone app	Daily	Completion rate: first day to final day	48
Lee 2013 ⁴²	60	SMS	Monthly	Completion rate: first month to final month	10
Nowell 2021 ²⁸	90	Smartphone app	Monthly	Active participants: baseline to final month	45
Murray 2022 ⁷³	56	Smartphone app	Daily (alternating cycle)	Completion rate: first week to final week	16
Östlind 2021 ³⁸	84	WAT	Continuous	Proportion of days worn: first week to final week	20
Pouls 2021 ²²	90	Smartphone app	Daily	Active participants: baseline to end	0
Renskers 2020 ³⁴	14–597 (mean 350)	Web-based	Free to choose (at baseline)	Active participants: baseline to end	49
Seppen 2020 ⁴¹	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 ¹¹	356	Smartphone app	Weekly	Completion rate: first 3 months to final 3 months	4
Skrepnik 2017 ⁴⁶	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 ⁵⁸	14	PDA e-diary	Thrice daily	Completion rate: week 1 to week 2	10
Zaslavsky 2019 ⁷⁶	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.^{9 48 49} Moreover, this challenge is clearly not limited to the rheumatology field.⁵⁰ 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

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	♦	♦		Facilitates ²⁵ Hinders ⁴⁰
Treatment: bDMARDs	♦	♦		Facilitates ³² Hinders ²⁵
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.				

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,¹⁷ and a study of adherence to activity trackers in students showed 75% disengagement within 4 weeks.⁵¹ 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.³⁹ 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,²⁷ 45% disengaging within 3 months in an ancillary study of the ArthritisPower registry²⁸ and 41% not completing the 2-week lead-in period in another ArthritisPower study.³² 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.⁵² 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.⁵³ 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.⁵⁴ 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.⁵⁵ 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

study investigated the effect of different pain reporting frequencies on completion rates in JIA patients, using a randomised N-of-1 cross-over design.⁴³ In this study, engagement was higher in less time-intensive schedules, such as weekly rather than daily reporting, even though participants tended to prefer the once-a-day schedule. Similar differences were apparent in an additional four studies,^{30 32 44 45} while another intervention allowed participants to choose their preferred reporting frequency up-front and found that monthly reporting was chosen most often.³⁴ In contrast, our meta-analysis showed that completion rates were highest in studies requesting daily PRO reporting. This discrepancy might be explained by differences in study or population characteristics. Nevertheless, these findings are particularly interesting in relation to concerns, raised in qualitative research, that more frequent reporting could cause more internal resistance or illness behaviour in patients.^{16 41} Evidence to support this concern is still limited, however, with one trial indeed showing a negative effect of a gout self-management app on illness perceptions,⁵⁶ while Lee *et al* found no differences in pain interference between reporting schedules in their N-of-1 trial.⁴³ Interestingly, the choice of outcome measure to be collected by the eHealth system might be equally important, with some studies allowing participants to freely select their preferred outcome measure.^{28 34}

Regardless of the way eHealth tools are implemented, benefiting from their promising potential requires efforts to maximise and maintain participant engagement. To achieve this, previous research has highlighted the importance of co-designing eHealth systems with patients, optimising system usability, minimising workload and time commitment for users, including community-building efforts or personal contact with care providers, and sending automated reminders for data entry.¹⁷ Interestingly though, reminders did not appear to have a clear effect on data completeness in both included studies that quantitatively assessed this. Additionally, qualitative results from the studies included in our review suggested that eHealth engagement might be hindered in case of well-controlled symptoms or by system-related technical issues, lack of digital literacy, interference of other daily activities and internal resistances like respondent fatigue.^{24 30 34 41 57 58}

Furthermore, our review showed positive effects on engagement when feedback was provided to participants, either by the physician or by the eHealth system itself,^{27 46} a finding that is extensively supported by qualitative evidence.^{16 24 30 34 41} Finally, motivational techniques such as gamification could help users to remain engaged and are generally underused in the existing array of eHealth systems.^{59 60} Our systematic review adds to this growing body of evidence and could support researchers and system developers in designing and implementing eHealth tools that optimally meet the challenges of attrition and low engagement.

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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