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Abstract: (242 words)

Objective: Wearable activity trackers (WATs) could be a promising strategy to improve physical activity (PA) in patients with rheumatic and musculoskeletal diseases (RMDs). The aim was to assess the adherence and effectiveness of WATs to increase PA levels in RMDs.

Methods: A systematic review was performed to identify all cohorts and controlled trials evaluating WATs in RMDs, published between 2000 and 2018, by searching MEDLINE, EMBASE, PsycINFO and Cochrane. Data collected pertained to (a) adherence, (b) effectiveness on PA or (c) effectiveness on symptoms (pain, function, quality of life or fatigue). Meta-analyses were performed with a random effect model.

Results: Of 2378 references, 17 studies were included with a total of 1588 patients; 8 studies (47%) in osteoarthritis, 5 (29%) in low back pain and 3 (18%) in inflammatory arthritis. Adherence assessed in 4 studies was high (weighted mean time worn: 92.7% (standard deviation 4.6%). A significant increase in PA was noted (mean difference 1520 steps, 95% confidence interval [580 - 2460], I^2=77% or 16 minutes [2 – 29] of moderate to vigorous PA, I^2=0%). A significant increase in pain was found for long interventions (>8 weeks) (standardized mean difference 0.25 [0.07, 0.43], I^2= 0%).

Conclusion: WATs in RMDs had a high short-term adherence with a significant increase in number of steps and time spent in moderate to vigorous PA though pain should be monitored. WATs may be an effective option to increase PA in this at risk population. Registered in PROSPERO: CRD42018083532.

Significance and Innovations:

- Short-term adherence to wearable activity trackers was high in people with rheumatic and musculoskeletal diseases.
- Interventions using wearable activity trackers were effective to increase physical activity levels in rheumatic and musculoskeletal diseases, with a mean difference of 1520 steps per day and 16 daily minutes spent in moderate to vigorous physical activity.
- Symptoms did not worsen with short term use of wearable activity trackers though pain increased in long-term interventions.

Physical inactivity has been identified as the fourth leading risk factor for global mortality around the world (1). The positive effects of physical activity on health, wellness and reduced mortality are widely established and documented for all ages (2–5).

Patients with rheumatic and musculoskeletal diseases (RMDs), such as low back pain, lower limb osteoarthritis and rheumatic inflammatory diseases are more prone to physical inactivity (6). However, patients with RMDs derive specific benefits from regular physical activity. Physical activity and exercises are a key component of clinical practice guidelines for the management of several rheumatic conditions (7–9).

Self-monitoring of physical activity, e.g. with wearable activity trackers (WATs) is one of the most used strategies to increase physical activity for adults with disability (10). Via sensors, these devices help users track their daily movement and provide feedback on activity, e.g. with monitor displays or companion smartphone tools (11). This technology aims to educate and motivate users toward better physical activity habits and better health behavior (12). An issue with WATs is medium term adherence. A survey on 6223 consumers revealed that more than half of individuals who purchased an activity tracker stopped using it; and, of these, one third did within 6 months (13). It is possible that adherence to WATs may be different in patients with RMDs, potentially given physical limitations (14).

WATs have shown their effectiveness to increase physical activity in a variety of contexts. Systematic reviews of the literature showed that activity trackers led to an increase of physical activity in the general population (15,16), in young populations (17), in adults with overweight or obesity (18). WATs could be a promising strategy

to improve physical activity levels in patients with RMDs (20). However, WATs may pose specific challenges for this population due to pain in particular. Furthermore, for this population, being physically active could modify pain, fatigue, function and quality of life (7–9).

The aim of this systematic review with meta-analysis was to summarize the available evidence regarding adherence to WATs and effectiveness in increasing physical activity levels and improving symptoms for rheumatic patients and to identify factors that may have an impact on this effectiveness.

MATERIALS AND METHODS

This review was conducted in accordance with the Cochrane Handbook and the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement (see online supplement 1 for PRISMA checklist) (21). The protocol was registered on PROSPERO CRD42018083532. More detailed information is available in online supplement 2.

Eligibility criteria

Participants

Patients of all ages with RMD were included, i.e. lower limb osteoarthritis, low back pain or chronic inflammatory rheumatic diseases (i.e. spondyloarthritis, rheumatoid arthritis, psoriatic arthritis or juvenile arthritis).

Type of intervention

We considered as a WAT, any device designed to be worn on the user's body;

using accelerometers, with or without altimeters or other sensors to track the wearer's movements and/or biometric data; with or without the possibility to upload activity data to an online application that shows trends over time (22). The announced objective of the WAT had to be an increase in physical activity (rather than gait or posture). Simple pedometers (e.g. Yamax) were distinguished from more 'advanced' WATs (e.g, Fitbit), which allow automatic transmission of information and could be linked with an App.

Study design and type of comparison

For adherence, all studies whatever the design were included. For effectiveness, randomised controlled trials were considered with the following comparison: WAT versus no intervention or waiting list; and for exploratory purposes WAT plus other adjunctive intervention (WAT+), e.g. educational programme, versus WAT only or with less important adjunctive intervention. When studies reported more than one intervention arm, the intervention with the less components associated with the WAT was chosen. Given our objective to analyze WAT versus no WAT, WAT+ was only analyzed when there was no "WAT alone" group.

Outcomes

The primary outcome was the amount of physical activity with (I) steps per day and / or (II) time spent in moderate-to-vigorous physical activity at the end of the intervention. Secondary outcomes were adherence to the device (e.g. duration of

use, percentage of patients still in the study at completion (study completion rate); symptoms: pain, functional tests, disability scores, quality of life and fatigue (online supplement 2). Quality of life was reported using either Knee Injury and Osteoarthritis Outcome Score, or the Knee related Quality of Life subscale on health-related quality of life (EuroQol EQ-5D-3L Weighted Health Index). Measures were collected at intermediate time points (i.e. time points measured before end of intervention), end of the intervention and follow-up after end of intervention (if available).

Search strategy

A comprehensive search of articles available in English, with a publication date between 2000 and 2018 (May) were performed, in the following databases: MEDLINE via Ovid, EMBASE via EMBASE, PsycINFO via EBSCOhost and the Cochrane Central Register for Controlled Trials. A search equation involving both key-words and free-text words was initially developed for the MEDLINE search (online supplementary 2) and adapted for the other databases. We also conducted a search of ClinicalTrials.gov (www.ClinicalTrials.gov) for ongoing studies.

Other databases were searched (online supplementary 2). The reference lists of included reports (backward citation searching) and references that refer to the included studies using Google Scholar and Web of Science (forward citation searching) were screened. Studies presented at the American College of Rheumatology et European League Against Rheumatism conferences of the two previous years were consulted to identify full-text published articles.

Study selection

The online data manager Covidence (http://www.covidence.org) was used for the selection process. The study selection was performed by one reviewer (TD) firstly on title and abstract and secondly on full-length articles and verified by double reading (i.e., verified included studies) (AP). Authors were contacted when full-text articles were not available or complementary information was needed.

Data items and data extraction

Two review authors (TD and AP) independently extracted data from included studies and recorded information on a standardized extraction form accompanied by a codebook. Information were extracted regarding (I) general characteristics (i.e. study design, sample size, authors, year of publication, journal, title, country, objectives of the studies (as reported verbatim by the authors), and setting (e.g. healthcare center)), (II) characteristics of populations (i.e. number of patients included in each study, diseases and means duration of the diseases, physical activity levels at baseline, age, gender, medications), (III) interventions (i.e. intervention related to the activity tracker: availability of feedback, wearing position, duration, interface used for the feedback, nature of the feedback, characteristics of the device (brand, type of device, type of activity measured) and co-intervention: type, behavior targeted, duration) and (IV) outcomes of interest, tools to measure steps per day, and time point assessment. The main data collected in extraction forms were summarized in evidence tables. The results concerned adherence or effectiveness of intervention.

For adherence, the percentage of days worn and retention rate over intervention duration was reported.

Risk of bias assessment

Risk of bias was evaluated using the Risk of Bias tool developed by the Cochrane Collaboration (23) by two independent reviewers (TD and AP). Any discrepancies were resolved by discussion to reach a consensus.

Synthesis of results and heterogeneity

Adherence was pooled using weighted mean time worn and weighted mean study retention rate. The effects of the intervention were pooled using a meta-analysis if possible (i.e, standardized mean difference (SMD) using random effects models for physical activity and symptoms) in RevMan (version 5.3) (24). For the meta-analysis, we adapted data (i.e. absolute values were used) in order to have a higher result meaning better outcome, thus by convention the right side of forest plots was always favoring WATs. To interpret the SMD, the following method was used: no effect (<0.2), small effect (0.2-0.5), moderate effect (0.5-0.8) or large effect (>0.8) (25). To illustrate the SMD for steps and time spent in moderate to vigorous physical activity, two methods were used. Firstly, the difference between groups in terms of step count increase was meta-analysed using mean difference in RevMan. Secondly, the step count in the intervention group (both at end of intervention and as a change from baseline) was calculated by weighted mean, to give indication of clinical relevance of results.

Heterogeneity was evaluated using forest plots to compare results across trials and the I^2 statistic measuring the proportion of variation (i.e., inconsistency) between studies that is due to heterogeneity rather than chance (26). An I^2 value of >40% indicates substantial heterogeneity, and an I^2 value >80% considerable heterogeneity, lower I^2 is considered better (23).

To identify factors that may have an impact on effectiveness, subgroup analyses were conducted for the primary outcome according to the type of WAT (pedometer versus more advanced WAT) and intervention duration and follow-up duration (short duration = 0-8 weeks; long duration >8 weeks). An analysis was performed on studies with lower limb osteoarthritis. For other outcomes, subgroup analyses regarding intervention duration and follow-up duration were performed.

RESULTS

Articles identified

The electronic search yielded 2,380 potentially relevant hits *(Figure 1)*. In total, 17 studies were included in the review, of which 10 were pooled for meta-analysis (14,27–42). One study was potentially relevant but full-text was not available (43). Studies were published between 2003 and 2018, with 9 studies (53%) published in 2017-2018. On top of the included publications, 10 ongoing studies were identified (online supplement 3).

General characteristics of included studies and population

The review included a total of 1,588 participants (Table 1 and online supplement 4). The median sample size per study was 34 participants (range 17-246). The mean age of the population was 55 years (range 16-72 years) (Table 1). One study included a young population (<19 years with juvenile arthritis) (27) and 5 studies included elderly patients with osteoarthritis (the remaining 4 studies on osteoarthritis were not related specifically to elderly patients) (35,38,40,41,42). Of the 17 studies, 15 were randomized controlled trials and 2 were cohort studies (used to assess adherence). Among the 17 studies, 9 (53%) were related to osteoarthritis, 5 (29%) to low back pain and only 3 (18%) to chronic inflammatory rheumatic diseases. When reported, mean disease duration was 8 to 14 years (14,31,32,36,41). Overall, 41.3% of the population was male.

All included studies were conducted in high-income countries: 10 (59%) in North America, 5 (29%) in Europe, 1 (4%) in Australia and 1 (4%) in Asia.

Risk of bias was low for 5 studies (30–33,39), unclear for 5 studies (27,29,36,38,40) and high for 5 studies (34,35,37,41,42) (online supplement 5).

Characteristics of interventions and comparators

In all, 8 studies (47%) reported on advanced WATs and 9 (53%) on simple pedometers (Table 1). All studies but one used co-interventions in addition to the use of WATs. Among them, 12 (71%) studies used goal setting, 9 (53%) educational walking booklets, and 8 (47%) used counselling (*Table 1*). Weighted mean duration of intervention was 21.8 weeks (range: 2.0-52.0). *Activity trackers were worn on wrist (6 studies (35%)) and waist (11 studies (65%)).* Out of 13 studies measuring steps

per day, the measurement was performed by the WAT itself in 9 studies (69%), a research device (e.g. Actigraph) in 3 studies (23%) and both in 1 study (8%).

In all, 10 studies (59%) used education, usual care or inactive comparator group, 5 studies (29%) used a WAT only or with less important adjunctive intervention in the comparator group and 2 studies (12%) (corresponding to cohorts used for adherence) had no comparator group.

Adherence to WATs

Adherence was reported in 4 studies (24%) including 2 RCTs and 2 cohort studies, in a total of 416 patients (14,28,38,39). The weighted mean time worn reported in 3 studies wearing WAT at the wrist was 92.7% (standard deviation (SD) 4.6%) for a weighted mean duration of 10.0 weeks (range 2.0-14.0). A fourth study wearing WAT at the hip reported that 63% of the participants wore the WAT more than 80% of study duration. Study retention rates were reported in all studies with a weighted mean retention rate of 90% (SD 11%) over a weighted mean duration of 24.3 weeks.

Effectiveness of WATs on physical activity

The effect of WATs of physical activity for rheumatic condition was investigated in 9 randomised controlled trials. Two trials were not included in the meta-analysis as one did not report results in the comparator group (36) and another did not report steps as outcome (35). Meta-analysis based on 7 studies (i.e. 463 patients) showed a large effect on mean daily steps at end of intervention (mean study duration 13.9 weeks (SD 6.9)): the SMD was large: 0.83 [95% confidence interval (95%CI) 0.29 to 1.38],

corresponding to a mean difference over the comparator group of 1,520 steps per day [95% CI 580 to 2460]) (Figure 2). The overall heterogeneity of study effects was large (I^2=77%). A visual inspection of the forest plot according to risk of bias did not give indications of distortion of the results, which is concordant with the result of I^2. For indicative purposes, the calculation of weighted mean steps per day in the WAT groups at baseline and at end of intervention was 4,741 (SD 1,629) steps and 6,019 (SD 1297) steps respectively, corresponding to a weighted mean increase from baseline of 1,448 steps (SD 1098).

Meta-analysis based on 3 studies (i.e. 117 patients) showed a small effect for time spent in moderate to vigorous physical activity at end of intervention (mean study duration 12.0 weeks (SD 10.6)): the SMD was small: 0.41 [95%CI 0;04 to 0.77], (I^2=0%) (*Figure 3*). This result corresponds to a mean difference over the comparator group of 16 minutes per day [95% CI 2 to 29].

No significant results were found for sedentary time (assessed in 2 studies). In studies with a prolonged follow-up after the end of the intervention period, no significant results were found for mean daily steps, time spent in moderate to vigorous physical activity and sedentary time (assessed in 2, 1 and 1 study respectively, data not shown).

Subgroup analysis suggested larger effects for advanced WATs than for simple pedometers (not significant, p= 0.42). Subgroups for study duration did not indicate a difference in effectiveness (Table 2). Regarding studies with lower limb osteoarthritis, meta-analysis based on 6 studies of patients with lower limb osteoarthritis (i.e. 406 patients) showed a large effect on mean daily steps at end of intervention: the SMD

was large: 0.92 [95% confidence interval (95%CI) 0.33 to 1.52] with large heterogeneity (I^2=84%).

Effectiveness of WATs on symptoms

Meta-analyses for pain, functional test, disability, quality of life and fatigue did not show any effect at end of intervention and end of follow-up (Figure 4). However, the analysis according to study duration indicated a small effect on pain in long interventions (>8 weeks); in the 5 randomised controlled trials (485 patients), the SMD was small: -0.25 [95%CI -0.43, -0.07], I^2= 0%, indicating an increase in pain when using WATs for long term (Table 2).

Effectiveness of WATs assessed against a comparator comprising another WAT

5 studies assessed WATs plus other adjunctive interventions versus WAT only or with less important adjunctive intervention, involving 531 participants for a weighted mean duration of 45.8 weeks (SD 22.8) (Table 1) (27,29,33,37,41). No meta-analysis was performed because of lack of data reported and heterogeneity regarding components of interventions. Krein et al. reported a significant improvement in disability assessed with the Roland Morris Questionnaire at end of intervention and at end of follow-up compared with the control group (mean difference of 2.0 [95%CI 0.42, 3.55] and 1.70 [95%CI 0.10, 3.30] respectively) (33). In the other studies, no significant difference between groups was reported (data not shown).

DISCUSSION

This study has brought to light interesting results regarding the use of WATs for RMDs. Short term adherence to WATs was high. Interventions using wearable activity trackers were effective to increase physical activity levels in rheumatic and musculoskeletal diseases, with a mean difference of 1520 steps per day and 16 daily minutes spent in moderate to vigorous physical activity. Finally, the use of WATs did not change symptoms at short term though an increase in pain was noted for long study durations (>8 weeks).

This study has strengths and weaknesses. A relatively small number of studies were included in this review. However, a systematic search was completed in most major databases with complementary hand search of references to ensure that no relevant studies were missed. It is noteworthy that the majority of the references (10/17 studies) were only identified through the extensive hand search though they did not appear in the results of the electronic search, despite a sensitive search equation. This means that when checking back those references in the initial searches, they were not present (i.e. they were not missed in the selection phase). This could indicate a lack of clear identification of interventions using WATs in search engines, given the fact that Internet of Things is a relatively new topic. This is also indicated by the fact that half of studies included in this review were published in 2017-2018.

Only one reviewer performed the study selection process because this is a time consuming step which is not key for the quality of systematic review. Indeed alternatives to the conventional “double screening” approach exists and appear to be

potentially more efficient approaches to identifying eligible studies for systematic reviews (44). The key step is data extraction in double author rather than data selection as shown in Buscemi 2006 (45).

However, a second reviewer did verify the selection by screening included studies for inclusion criteria. This review was based on a protocol registered in PROSPERO. Both SMD and mean difference were calculated for steps counts which is unusual but allows comparisons with other meta-analyses, whatever the technique used to report results.

Not all studies contributed to all outcomes (e.g. adherence = 4 studies, mean daily steps = 7 studies etc). This could come from a lack of standardisation in choice of outcomes during the conception of trials, to different objectives across trials or missing data in publications (35,36). However, authors were contacted when outcomes of interest were missing.

Results showed a large heterogeneity. This heterogeneity is probably explained by differences in components of interventions and duration of intervention, type of comparator and type of RMD. Nevertheless, appropriate statistics such as SMD and random effects were used (23). Moreover, subgroup analyses based on rheumatic condition indicated residual high heterogeneity in lower limb osteoarthritis.

Although using endpoint data can lead to misinterpretation in case of imbalance in baseline, change of measure or confidence interval of change were not available for 5 of the included studies (30, 34, 35, 38, 40).

In the present review, short term adherence to WATs was excellent. Among included studies, the percentage of wearing time was >90% over a mean duration of 10 weeks. Although scarce data were available for medium to long term use, this result is encouraging. A study assessing adherence to WATs in undergraduate students (range 20-24 years old) showed that more than half of the participants stopped using the FitBit activity tracker after two weeks (75% after four weeks) (46). This difference of results could come from extra efforts to maintain adherence in randomised clinical trials (e.g. weekly phone calls). Strategies to drive adoption and adherence have been identified, such as issues with remembering, issues with physical design and aesthetics, issues with data management, and should be further implemented in clinical research and clinical practice (13,46).

The number of daily steps was significantly higher across studies at the end of intervention for interventions using WATs compared to interventions not using them, with a large SMD of 0.83 and mean difference of 1520 steps. Intervention groups using WAT moved from an average of 4741 steps to an average of 6019 steps, corresponding to a mean increase from baseline of 1448 steps. This physical activity represents at the group level a change of activity state from sedentary to low activity (45). As regards time in moderate to vigorous physical activity, results were quite difficult to interpret since, firstly the number was low, and secondly there was a discrepancy between the moderate SMD and the rather high mean difference (16 minutes per day). 16 minutes may be considered clinically relevant when time in moderate to vigorous physical activity is around 10 minutes per day in lower limb osteoarthritis (47).

This activity is encouraging though smaller than the recommendation of 30 minutes of moderate intensity exercise (48). The question of the effectiveness of WATs over the long term remains unsolved. Indeed in the present review, the two studies with follow-up after end of intervention did not evidence any increase in steps after stopping wearing the WATs.

Our result is consistent with other systematic reviews in the general population (15,49). Mansi et al reported in a systematic review for musculoskeletal conditions a significant effect in 2 studies out of 7 though no meta-analysis was performed (20). The present result demonstrates that interventions using WATs are an effective strategy to improve physical activity levels for rheumatic conditions. As shown in Table 1, there was a diversity of interventions and use of adjunctive components in the trials making it difficult to attribute the causality of the positive effects to the WAT itself rather than to the global intervention. However, analyses comparing WATs plus other adjunctive interventions versus WATs only or with less important adjunctive intervention did not show any effectiveness at increasing physical activity level, which could indicate that WATs may be a major component of effectiveness.

No effect was found (either increase or decrease) by use of WATs for pain, disability, functional tests, quality of life and fatigue. An improvement of symptoms may be expected since physical activity is encouraged by most of the clinical guidelines for RMDs (7–9). It is possible that the moderate increase in physical activity was not sufficient to lead to clinical benefits. Surprisingly, a significant increase in pain was observed compared with the control groups in subgroup analysis for interventions

longer than 8 weeks. Mansi et al reported a significant improvement of pain and function in 4/7 studies (20), but these results were found in intervention groups not considering the difference between groups. In the present review, in 5 trials (485 patients), the SMD was small (-0.25 [95%CI -0.43, -0.07]) which can be illustrated by a mean difference of 0.63 point in a 0-10 numeric pain rating scale (23). This slight though significant increase in pain should be further confirmed and should not discourage activity given the potential benefice of physical activity. To deal with potential increase of pain, activity should be tailored to the individual characteristics such as type of disability and evolution of disability (14,50).

In conclusion, WATs appear to be a promising strategy to improve physical activity for patients with RMDs. However, research may be needed to determine whether changes are maintained over time, ways to improve long-term use, and the most effective adjuncts.

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Online supplement 1: PRISMA statement

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	8
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	8 and online supplement 2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Online supplement 2
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Online supplement 2
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	9 and online supplement
Summary	13	State the principal summary measures (e.g., risk ratio, difference	9

measures		in means).	
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	9 and online supplement 2
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	NA due to small number of studies included
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	9
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	10, figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Online supplement 3
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	27
Synthesis of results	21	Present the main results of the review. If meta-analyses are done, include for each, confidence intervals and measures of consistency	11
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	NA
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	11
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	12, 13
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	1

Online supplement 2: methods used for the systematic review on WATs

Search strategy on MEDLINE	1. arthritis rheumatoid.sh. 2. Spondylarthropathies.sh. 3. Arthritis, Psoriatic.sh. 4. osteoarthritis.sh. 5. Osteoarthritis, Knee.sh. 6. Osteoarthritis, Hip.sh. 7. back Pain.sh. 8. sciatic neuropathy.sh. 9. spondylosis.tw. 10. lumbago.tw. 11. back disorder$.tw. 12 OR/ 1-11 13. feedback.sh. 14. accelerometry.sh. 15. actigraphy.sh. 16. ((physical or physiolog$ or perform$ or fit$ or train$ or activ$ or endur$ or exercise) adj3 (track$ or monitor$ or measur$ or device$ or app$)).tw. 17. ((step$ or walk$) adj3 (count$ or meter$ or daily)).tw. 18. (pedometer$ or actigraph$ or accelerometer$).tw. 19 OR/13-18 26. OR/ 20-24 27. AND 12,19,25 Searches were not limited to type of publication. For additional references, the database for studies using Fitbit devices: https://www.fitabase.com/research-library/ and a key journal in the field: Journal of Medical Internet Research were screened.
Type of intervention	Studies not using WATs as defined previously and interventions that aimed to improve gait or movement rather than increasing the level of physical activity were excluded. Studies that used mobile phones rather than a wearable activity tracker were also excluded.
Outcomes	Pain (i.e. numeric rating scale and numeric rating scale during the 6 minutes walking test, the 6-item PROMIS pain interference questionnaire, Knee Injury and Osteoarthritis Outcome Score pain subscale, Present Pain Intensity Scale from the McGill Pain Questionnaire); functional test (6 minutes walking test, the time “up & go” test, Timed Stair Climb); score of disability (i.e. The Oswestry low back pain disability questionnaire (, The Western Ontario and McMaster Universities (WOMAC) Osteoarthritis Index numeric rating scale (NRS), Health Assessment Questionnaire (HAQ), the back painspecific Roland Morris Disability Questionnaire (RDQ), Childhood Health Assessment Questionnaire (CHAQ), Knee Injury and Osteoarthritis Outcome Score Sports and Recreation Function subscale); quality of life (i.e. Knee Injury and Osteoarthritis Outcome Score Knee related Quality of Life subscale, health-related quality of life (EuroQol EQ-5D-3L Weighted Health Index)) and fatigue (i.e. PROMIS Fatigue Short Form 7a questionnaire). sedentary time, walking

	duration, time spent in light physical activity and mood were reported in the protocol but none of these outcomes were founded in articles
Type of studies	Experimental designs were considered for effectiveness (i.e. randomised, quasi randomised controlled trials, cluster and cross-over design) and non-controlled design for adherence. Studies with the following characteristics were excluded: results of eligible trials available only in abstract form with insufficient methodological details to allow critical appraisal or replication, qualitative studies (e.g., interviews, focus groups and case reports), accuracy studies, diagnostic studies or prognostic studies, review article, editorials, opinions and letters.
Data collection process	Two review authors (TD and AP) independently extracted data from included studies and record this information on a data on a standardized piloted extraction form accompanied by a codebook. The extraction form was first tested on 3 reports and then adjusted to ensure clarity and comprehensiveness of data collection. Extracted results were compared and any disagreements were resolved by consensus.
Risk of bias assessment	The risk of bias tool reviews the random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases. Since the blinding of participants is practically infeasible in a self-monitoring intervention, this was not assessed and blinding of personnel was scored separately. We separately assessed the blinding of self-reported subjective outcomes (e.g., fatigue, quality of live) and the blinding of independent outcome assessors to objective outcomes (such as steps per day). Studies were classified as having: a low risk of bias if all key domains were assessed to be at low risk of bias and had no serious flaws; a high risk of bias if one or more categories was assessed at high risk of bias; and an unclear risk of bias if one or more key domains was assessed as having an unclear risk of bias.
Synthesis of result	For the meta-analysis, we adapted data in order to have a higher result meaning better outcome. By convention, the right side of forest plots was always favouring WATs. When an author used more than one scale for a same outcome, we selected a single one.
Subgroups analysis	Subgroup analysis based on the device localization was mentioned in the protocol but not completed because of enough lack of studies with location other than wrist.

Online supplement 3: Studies identified through ClinicalTrials.gov and addressing effectiveness of WATs to increase physical activity of patients with rheumatic conditions.

Ongoing Studies	**Estimated Study Completion Date**
Clinical Outcomes in Chronic Low Pain Back Utilizing Activity Trackers - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT03385083	May 11, 2018
OPAM-IA: Using Digital Activity Trackers to Improve Physical Activity in Inflammatory Arthritis - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT02554474	August 2019
SuPRA: Using Wearable Activity Trackers With a New Application to Improve Physical Activity in Knee Osteoarthritis - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT02585323	April 2019
an On-demand Program to EmpoweR Active Self-management (OPERAS) - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT03404245	February 13, 2021
Active@Work - Optimizing Physical Activity at Work. - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT03354091	December 2018
Stepping Up For Inflammatory Arthritis - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT02912221	October 2019
Studies with estimated completion date before January 2018	
Pedometer Based Intervention After Total Hip Replacement-A Pilot Study - Full Text View - ClinicalTrials.gov [Internet]. [cited	March 2015

2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT01972594	
Walk for Rheumatoid Arthritis (WARA Study) - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT02467205	April 2016
Impact of Physical Activity and Vitamin D on Osteoarthritic Knee Pain - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT02293889	July 2016
MobilWise: Mobile Phone Remote Coaching After Worksite Joint ADventure Exposure - Full Text View - ClinicalTrials.gov [Internet]. [cited 2018 Apr 25]. Available from: https://clinicaltrials.gov/ct2/show/NCT02950090	May 2017

Online supplement 4: detailed characteristics of the studies

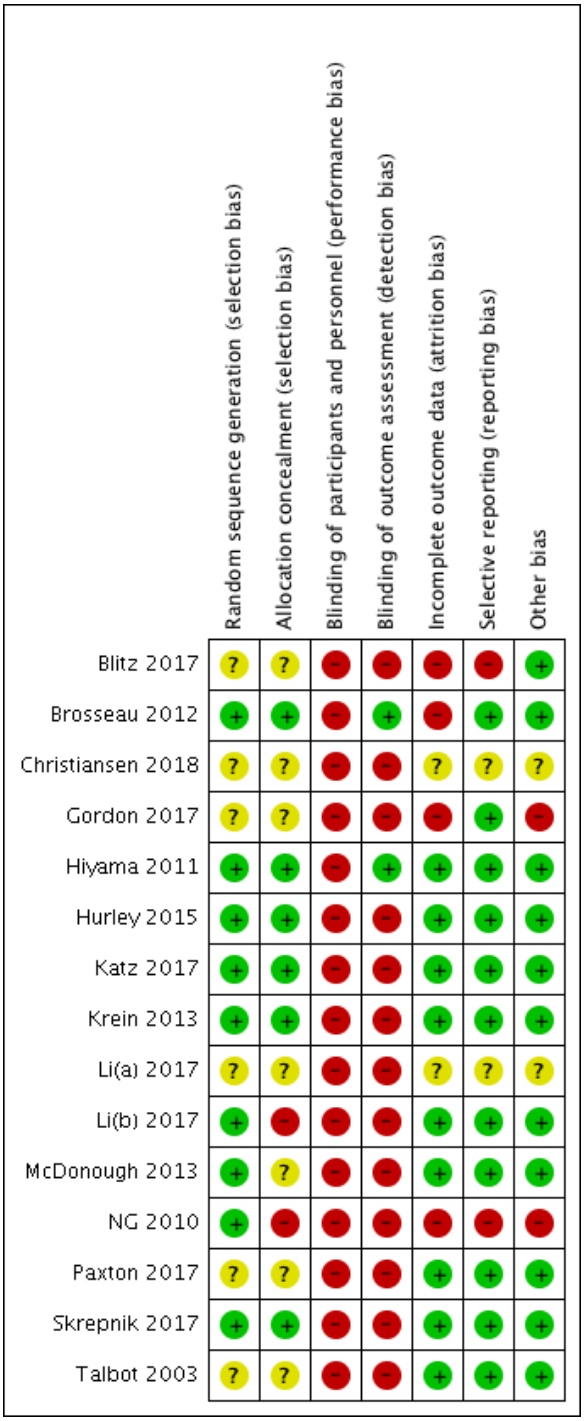
Author, publication year (ref)	N participants baseline	Study duration (weeks)	Brand and model of WAT	Mean age (SD)	Gender (% men)	Wearing position of WAT	Steps measurement tool	baseline steps/ day
WAT versus no WAT								
Paxton 2017 (38)	45	12	Fitbit Zip	64 (6)	47	wrist	RT	5382
Skrepnik 2017 (39)	221	14	Jawbone UP 24	62 (9)	50	wrist	WAT	4275
Katz 2018 (49)	96	21	Fitbit Zip	55 (13)	12	waist	WAT	4938
Li(a) 2017 (34)	61	8	Fitbit	62 (9)	18	wrist	RT	7312
Hiyama 2011 (30)	40	4	KenzLifecoder EX, Suzuken Co	73 (5)	0	waist	WAT	4439
Talbot 2003 (40)	40	12	Yamax Digiwalker Pedometer Model SW-200	70 (6)	24	waist	Both	4085
Li(b) 2017 (35)	34	4	Fitbit Flex	55 (9)	18	wrist	-	7312
Christiansen 2018 (42)	22	24	Fitbit	67 (7)	50	waist	RT	1849
McDonough 2013 (36)	57	8	Yamax Digiwalker CW-701, Yamax, Japan	49 (6)	45	waist	WAT	7752
Hurley 2015 (31)	246	8	Yamax Digiwalker Pedometer Model SW-200	45 (11)	32	waist	-	-
WAT versus other WAT								
Gordon 2017 (29)	17	6	Fitbit Charge HR	52 (16)	NR	wrist	WAT	7238
Krein 2013 (33)	229	52	Omron HJ720ITC	51(13)	87	waist	WAT	4407
NG 2010 (37)	36	12	NR	40 to 75	39	waist	WAT	3920
Blitz 2017 (27)	27	14	Omron HJ-720ITC electronic pedometer	15 (2)	8	waist	WAT	2728
Brosseau 2012 (41)	222	52	pedometer	63 (9)	31	waist	-	-
No comparator group*								
Jacquemin 2018 (14)	178	2	fitbit	46 (12)	36	wrist	WAT	7300
Dekker 2015 (28)	17	12	Mt-x movement sensor and a PDA	54 (11)	41	waist	-	-

PDA: Personal Digital Assistant
NR: not reported
RT: research tracker
WAT: wearable activity tracker
*this thype of study was included for results on adherence.
OA: Osteoarthritis;

CIRD: chronic inflammatory rheumatic disease;
I/C: intervention / Comparator;
WAT: wearable activity tracker;
PA: physical activity

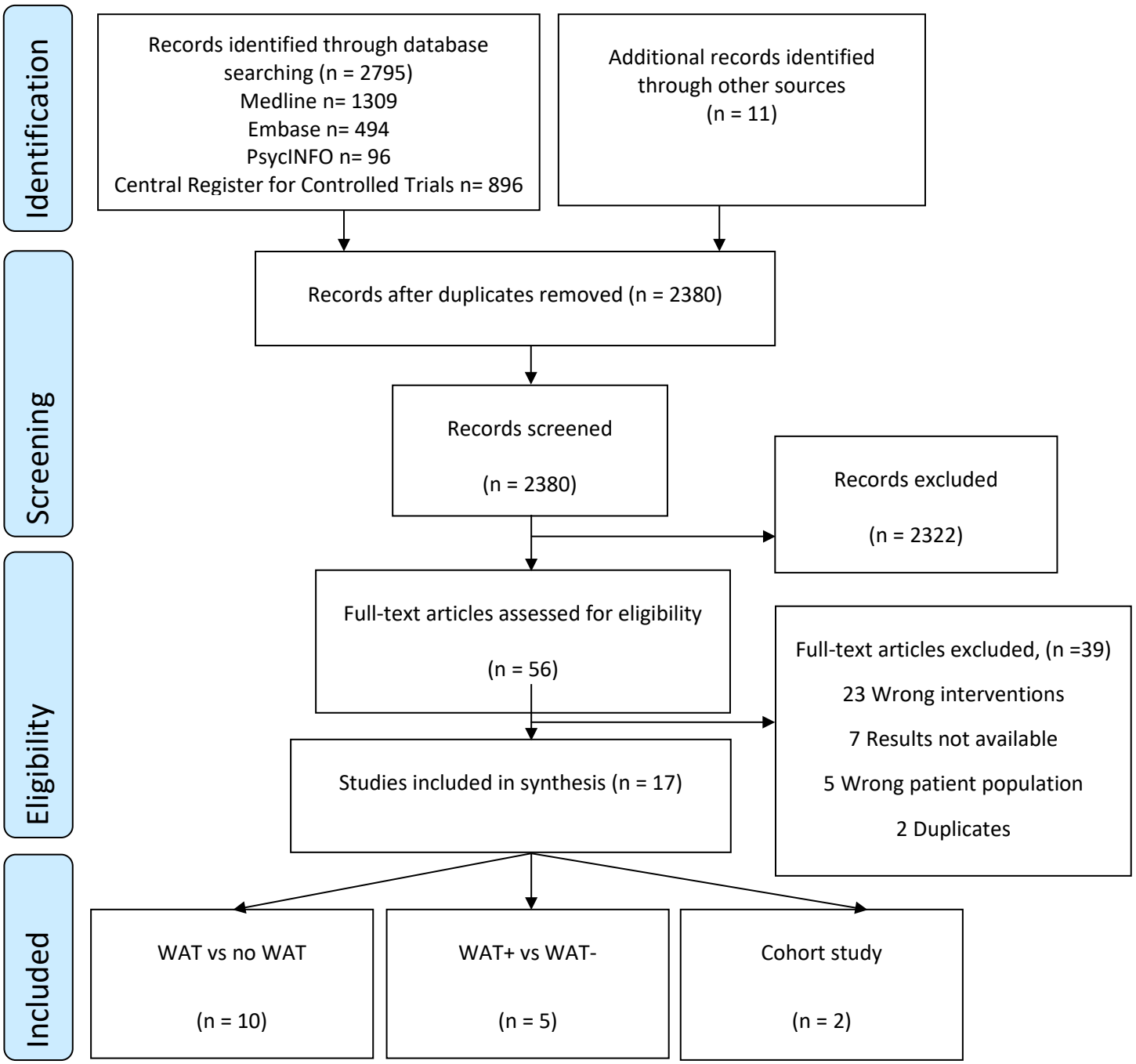
SD: standard deviation

Online supplement 5 : Risk of bias assessed on 14 studies using wearable activity trackers in rheumatic musculoskeletal conditions



+= low risk of bias, ?= unclear, -= high risk of bias

Figure 1: PRISMA flowchart: selection process of articles reporting WATs in rheumatic musculoskeletal diseases



WAT= wearable activity tracker
WAT+ vs WAT- = WAT plus other adjunctive intervention (WAT+) versus WAT only or with less important adjunctive intervention (WAT-).

Figure 2: Forest plot of standardized mean differences between WAT and control in mean number of daily steps.

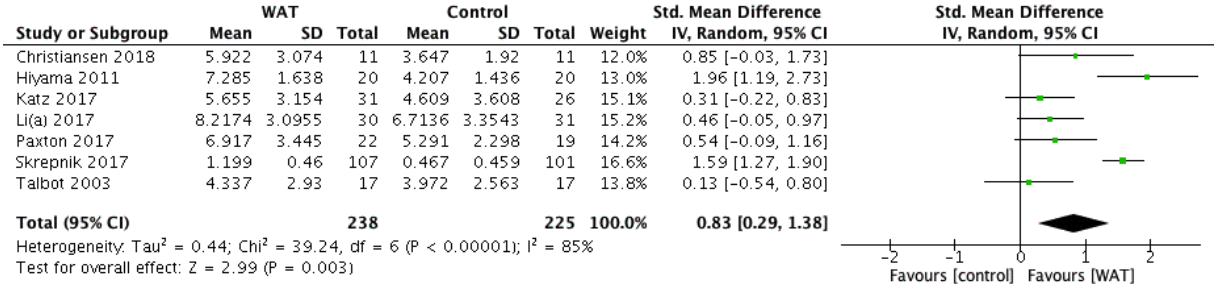


Figure 3: Forest plot of standardized mean differences between WAT and control in moderate to vigorous physical activity (MVPA).

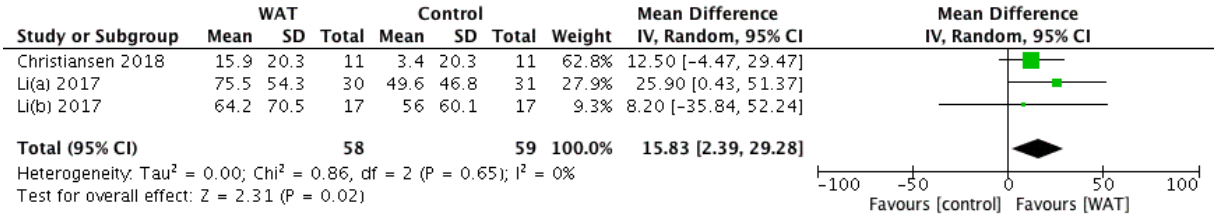


Figure 4: Forest plot of standardized mean differences between WAT and control in pain, disability, functional tests, quality of life and fatigue.

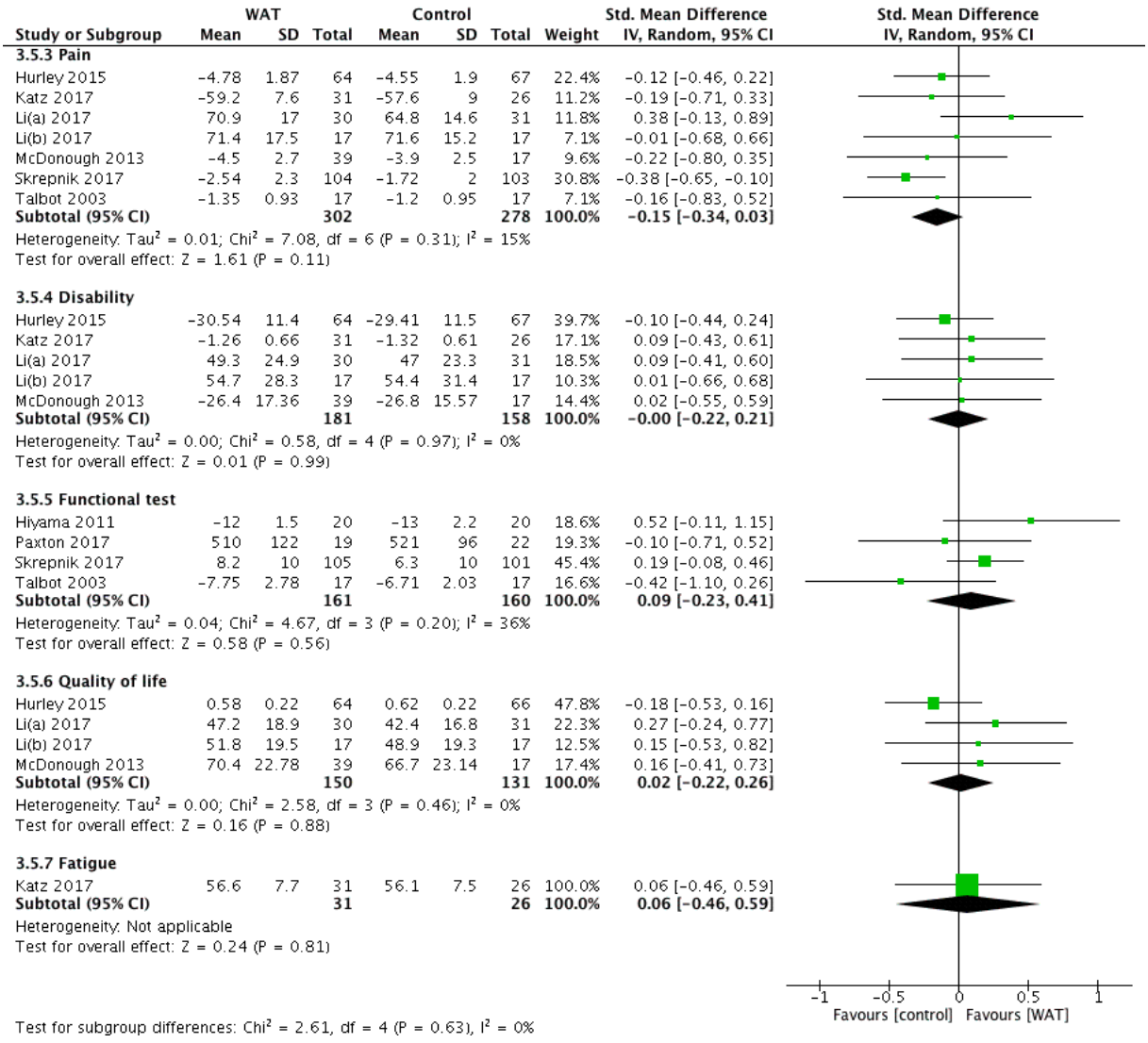


Table 1: Characteristics of interventions using WATs to increase physical activity levels for rheumatic musculoskeletal diseases.

Author, publication year (ref)	N participants baseline	Study duration (weeks)	Rheumatic condition			Intervention / comparator										Outcome		
						WAT		Components associated										
			OA of lower limbs	Low back pain	CIRD	Advanced WAT	Pedometer	Mobile App or website	Activity goal setting	Written activity log	Counselling - education	PA Guideline or booklet	Exercise class	Usual care	Self-management	Adherence	Physical activity	symptoms
WAT versus no WAT																		
Paxton 2017 (38)	45	12	✓			I			I		I	I		C		✓	✓	✓
Skrepnik 2017 (39)	221	14	✓			I		I				I/C				✓	✓	✓
Katz 2018 (49)	96	21			✓		I			I		I/C					✓	✓
Li(a) 2017 (34)	61	8	✓			I			I		I						✓	✓
Hiyama 2011 (30)	40	4	✓				I		I					I/C			✓	✓
Talbot 2003 (40)	40	12	✓				I		I	I		I			I/C		✓	✓
Li(b) 2017 (35)	34	4	✓			I					I						✓	✓
Christiansen 2018 (42)	22	24	✓			I			I					I/C			✓	
McDonough 2013 (36)	57	8		✓			I		I	I	I	I/C						✓
Hurley 2015 (31)	246	8		✓			I		I	I		I/C	I	C				✓
WAT versus other WAT																		
Gordon 2017 (29)	17	6		✓		I	C							I/C			✓	✓
Krein 2013 (33)	229	52		✓			I/C	I	I	I	I	I					✓	✓
NG 2010 (37)	36	12	✓				I/C		I/C	I/C	I/C	I/C					✓	✓
Blitz 2017 (27)	27	14			✓		I/C		I		I							✓
Brosseau 2012 (41)	222	52	✓				I/C		I	I/C	I	I/C	I					✓
No comparator group*																		
Jacquemin 2018 (14)	178	2			✓	I										✓		
Dekker 2015 (28)	17	12		✓			I		I							✓		

*this thype of study was included for results on adherence. OA= Osteoarthritis; CIRD= chronic inflammatory rheumatic disease; I/C= intervention / Comparator; WAT= wearable activity tracker; PA= physical activity

Table 2: Effectiveness of WATs on different outcomes and in subgroups analyses

Outcome or Subgroup (end of intervention)	No Participants (studies)	Effect Estimate of WAT (95% CI)*
Daily steps count	441 (7)	1,520 [580, 2460]
• Short intervention (0-8 weeks) $	343 (4)	1,460 [100, 2,830]
• Long intervention (>8 weeks) $	120 (2)	1,580 [490, 2,660]
• Pedometer$	74 (2)	1,840 [-810, 4,490]
• Advanced WAT$	389 (5)	750 [620, 870]
Time spent in moderate to vigorous physical activity	117 (3)	SMD 0.41 [0.04, 0.77]
Sedentary time	95 (2)	SMD -0.17 [-0.77, 0.42]
Pain	580 (7)	SMD -0.15 [-0.34, 0.03]
• Short intervention$	95 (2)	SMD 0.24 [-0.17, 0.64]
• Long intervention$	485 (5)	SMD -0.25 [-0.43, -0.07]

**Results are reported in mean difference (MD) unless otherwise reported*

$Subgroup analysis

SMD: standardized mean difference.