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Systematic review and meta analysis

Physical activity assessment with wearable devices in rheumatic diseases: a systematic review and meta-analysis

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Abstract

Objectives. In the management of rheumatic musculoskeletal disorders (RMDs), regular physical activity (PA) is an important recognized non-pharmacological intervention. This systematic review and meta-analysis aims to evaluate how the use of wearable devices (WDs) impacts physical activity in patients with noninflammatory and inflammatory rheumatic diseases.

Methods. A comprehensive search of articles was performed in PubMed, Embase, CINAHL and Scopus. A random-effect meta-analysis was carried out on the number of steps and moderate-vigorous physical activity (MVPA). Univariable meta-regression models were computed to assess the possibility that the study characteristics may act as modifiers on the final meta-analysis estimate.

Results. In the analysis, 51 articles were included, with a total of 7488 participants. Twenty-two studies considered MVPA outcome alone, 16 studies considered the number of steps alone, and 13 studies reported information on both outcomes. The recommended PA threshold was reached for MVPA (36.35, 95% CI 29.39, 43.31) but not for daily steps (–1092.60, –1640.42 to –544.77). Studies on patients with fibromyalgia report a higher number (6290, 5198.65–7381.62) of daily steps compared with other RMDs. Patients affected by chronic inflammatory arthropathies seemed to fare better in terms of daily steps than the other categories. Patients of younger age reported a higher overall level of PA than elderly individuals for both the number of steps and MVPA.

Conclusion. Physical activity can be lower than the recommended threshold in patients with RMDs when objectively measured using WD. WDs could be a useful and affordable instrument for daily monitoring physical activity in RMDs and may support an increase in activity levels.

PROSPERO trial registration. CRD42021227681, https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=227681.

Key words: wearable device, rheumatic, inflammatory, arthritis, fibromyalgia

Rheumatology key messages

- Levels of physical activity are compared to recommended threshold in patients with RMDs.
- RMDs suffer from a low level of physical activity.
- WDs can be used in daily monitoring of physical activity in RMDs.

Introduction

Millions of people suffer from rheumatic musculoskeletal disorders (RMDs), from noninflammatory to acute or chronic inflammatory musculoskeletal diseases [1]. RMDs are known to have a direct impact on physical activity (PA) [2, 3] both in terms of physical impairment, due to acute inflammation or residual damage with a disability, and psychological burden [4], frequently associated with depressive

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CLINICAL SCIENCE

symptoms, which further impair motivation to engage in PA.

Physical activity is defined by the World Health Organization (WHO) as any bodily movement produced by the skeletal muscles that requires energy expenditure [5]. It has been proven to reduce the overall mortality [6] and the incidence of various diseases, such as type II diabetes, cancer, obesity [7], cognitive decline [8–10], and hypertension; it also improves psychological [11, 12] and sleep health. The intensity of PA can be classified as light, moderate and vigorous according to different subjective and objective criteria: currently, it is most commonly classified according to oxygen consumption using the Metabolic Equivalent of Task (MET) scale, where 1 MET is equal to 3.5 ml of O2/kg/min and is roughly equivalent to the oxygen consumption of an average human being during rest [13]. A recent analysis has shown that the increase of moderate-vigorous physical activity (MVPA) by 10 min per day was associated with a 6.9% decrease in deaths per year [14].

WHO guidelines recommend at least 150 weekly min of moderate PA (3–6 METs), at least 75 weekly min of vigorous PA (>6 METs) or an adequate combination of both [5]. Walking is the most common and accessible form of PA: the optimal target according to WHO guidelines is currently set at 10 000 daily steps for healthy people [15, 16], with evidence of a similar benefit for a lower daily steps target in subjects affected by chronic conditions [17].

PA can significantly improve pain and functionality [18]. It also improves cardiovascular health, for which most RMDs are known to be independent risk factors [19] and reduces depressive symptoms.

In recent years, digital health technologies have been discovered as a possible solution for some evaluations of RMDs [20], especially in events such as the pandemic that has forced physicians worldwide to shift to remote assessment [21, 22]. Wearable technology can objectively assess PA and has seen an important rise in popularity in the last decade. Data derived from wearable devices have been proven to be a valuable asset in monitoring patients' physical behavior in addition to subjective scales [23]. Wearable devices (WDs) are currently affordable and globally available, with some basic functions being integrated into smartphones as well [24].

Recently, Davergne *et al.* [25] published a systematic review evaluating the use of wearable activity trackers to improve physical behavior in patients with RMDs. From this work emerges that RMDs patients had a high short-term adherence with increased levels of number of steps and MVPA.

Objective

The purpose of this study is 2-fold. The study aims to make a systematic review of the literature and meta-analysis concerning the use of WDs to objectively assess PA in RMDs in order: (i) to evaluate the level of physical activity assessed through the use of wearable devices in patients with non-inflammatory and inflammatory RMDs; and (ii) to compare daily steps and MVPA with recommended reference values [5, 26].

Materials and methods

The review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [27]. Supplementary Table S1 (available at *Rheumatology* online) shows the PRISMA checklist. This systematic review protocol was registered in the PROSPERO database (CRD42021227681). The objective was structured according to the PICO [28] framework (Supplementary Table S2, available at *Rheumatology* online). Search strategy, eligibility criteria, study selection, and study design and participants are reported in detail in the supplementary materials (Supplementary Data S1, available at *Rheumatology* online).

Outcomes

The primary outcome is the level of physical activity evaluated with a wearable device as number of daily steps and moderate to vigorous physical activity (MVPA). The secondary outcome is the comparison of both the number of steps and MVPA to the reference value for healthy people.

Data items and data extraction

Two expert reviewers (R.A. and M.B.) independently extracted data from the included studies. A predesigned data collection form was created on the data manager Covidence. The following information was extracted: (i) study characteristics (authors, year of publication, country, study design, setting); (ii) participant characteristics (number, gender); (iii) type and characteristics of the activity tracker and its use (duration, frequency of use); (iv) comparison group (when available); and (v) outcomes, the number of steps per day and daily MVPA.

Risk of bias assessment

The methodological quality of each study was assessed independently by two authors (H.O. and F.T.). A third reviewer was consulted when agreement was not achieved (D.A.). Study designs considered eligible for the study varied, so different checklists of the Joanna Briggs Institute Critical Appraisal [29] tools were used according to the study design. The revised Cochrane risk-of-bias (rob2) tool was used for randomized trials [30]. The risk of bias cut-off considered was as follows: rob2, high quality when all answers were no, low-moderate quality when at least one answer was yes. Cross-sectional studies were of high quality with >7 yes answers; this cut-off was derived in a previous meta-analysis [31], cohort and case-control study where high quality involved >8 and 9 yes answers, respectively.

The publication bias was visually inspected via funnel plot representations.

Synthesis methods

The variables used in the metanalysis were grouped into categories. The diagnosis was categorized as follows: fibromyalgia; osteoarthritis; rheumatoid arthritis and other inflammatory rheumatic disorders (including seronegative spondylarthritis, polymyalgia rheumatica, gout), and autoimmune diseases (including myositis, Sjögren's syndrome, and systemic lupus erythematosus). Due to the great heterogeneity in the age distribution between studies, the age was classified according to the distribution of data by diagnosis. Age was divided into elderly and nonelderly based on two cut offs: 50 years for all the diagnoses (fibromyalgia; rheumatoid and other arthritides, and autoimmune diseases) and 65 years for patients with osteoarthritis. Gender was used to distinguish among studies that had a prevalence of female or male participants, and studies were divided into female or male prevalent studies. The model device was classified as follows: ActiGraph, Fitbit, Omron, and other models.

The number of steps per day and the time spent in MVPA, including the mean or median, were collected. Missing information was calculated from available data when possible as reported in the Cochrane handbook [28].

The reference value for steps was 7000 steps per day; this value was derived by a literature review commissioned by the Public Health Agency of Canada on the number of steps/day suitable for adults [15]. The MVPA reference value was 150 min/week and was derived by WHO guidelines [5] and applied in the Canadian guidelines on physical activity [32] and recently used in the study of Knox *et al.* [33].

Agreement

The interrater agreement between the two reviewers was evaluated with Cohen's kappa. The percentage of agreement in the title/abstract selection was 85% and 0.94% in the full-text screening. In the risk of bias evaluation, the agreement was 63%.

Meta-analysis synthesis

A random-effect meta-analysis was carried out on the number of steps and MVPA. The study estimates with the 95% CIs were reported in forest plot representations for each study along with the pooled meta-analytical estimate. Metanalysis estimates were illustrated using a forest plot. The standard errors of the study estimates were adjusted by including a measure of the amount of variation, or heterogeneity, among the study treatment effects. The heterogeneity was estimated via the Der Simonian and Laird Estimator using the I^2 measure. The measure expresses the percentage of errors between-study variability that is related to heterogeneity rather than chance [28]. The statistic is defined as: $I^2 = 100 \times (Q-df)/Q$. In the formula the Cochran's Q is a weighted sum of squared differences between study effect and the meta-analytic estimate across studies; df are the degrees of freedom representing the number of studies minus one. Cochran's Q-test was calculated to identify a significant source of heterogeneity between studies [28]. I^2 is in several cases higher than 75% [28], indicating that observational studies with different characteristics were included in the same pool of results. Meta regressions were also used to handle this component by capturing possible effect modifiers.

Subgroup analyses were performed to show differences across different variables, such as diagnosis, age, gender prevalence, type of wearable device, and level of risk of bias and reference value. Comparison with the reference value is measured as the difference between this value and the value of our results. A lower difference from the reference value means that the absolute value is closer to the reference value.

Univariable meta-regression models were computed to assess the possibility that the study characteristics may act as effect modifiers on the final meta-analysis estimate. The moderators considered were (i) model of the wearable device; (ii) age; (iii) sex; (iv) diagnosis; and (v) time of use of the WD.

The analyses were conducted using R 3.6.2 [34] and rms [35] and metaphor [36] packages.

Results

Study selection

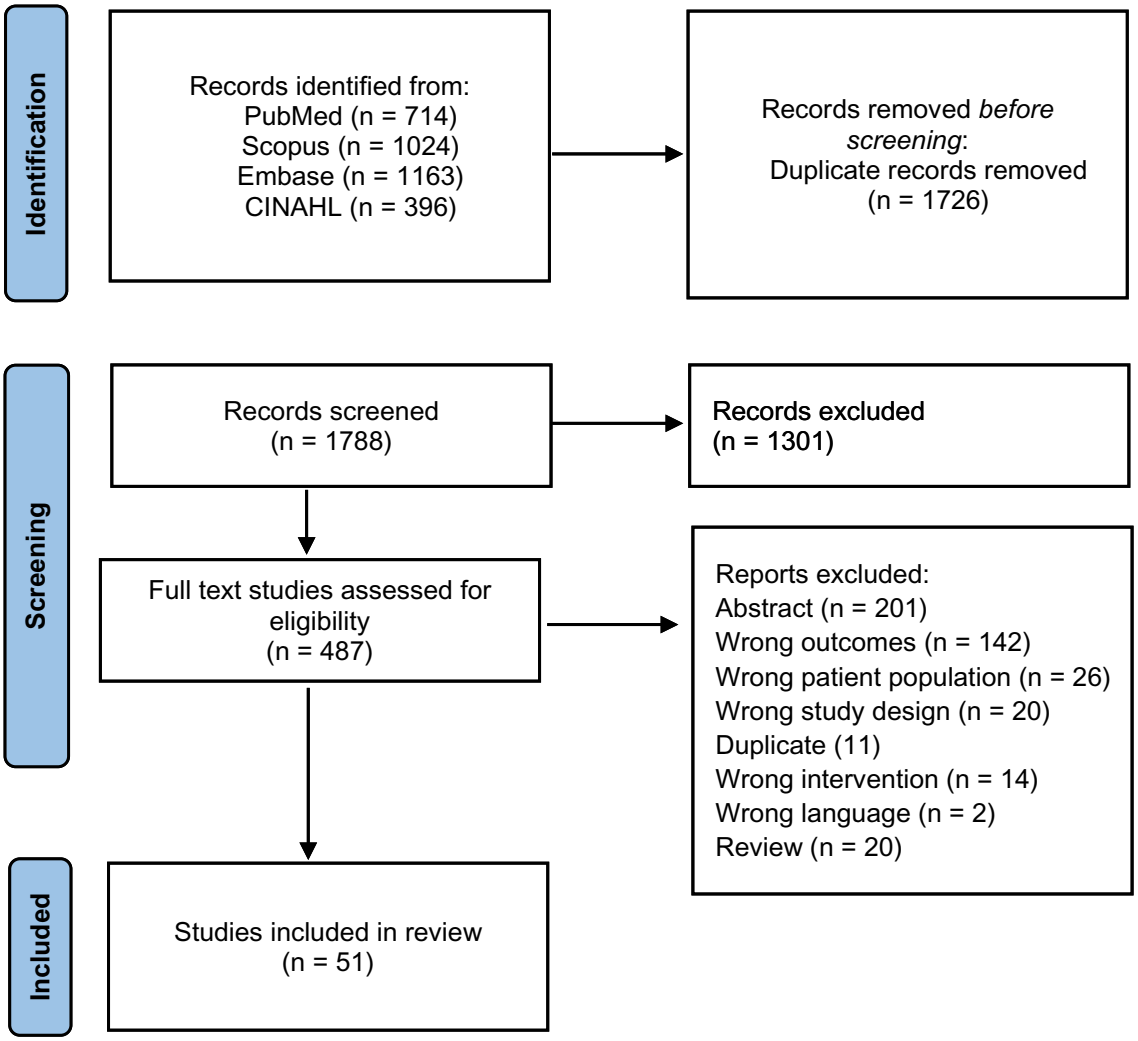
Overall, 1788 studies were considered in the title/abstract screening. In the analysis, 51 articles were included (Fig. 1), which correspond to 85 subpopulations and 7488 participants overall. Twenty-two studies (33 subpopulations) considered MVPA outcome alone, 16 studies (23 subpopulations) considered the number of steps alone, and 13 studies (28 subpopulations) reported information on both outcomes.

According to the study design, most of the studies were cross-sectional (54, 64.3%), and there were 23 (27.4%) randomized controlled trials, five case–control studies (6%), and two (2.4%) cohort studies.

Descriptive characteristics of the study

Table 1 reports the descriptive characteristics of the studies included in the meta-analysis; each row refers to the single subpopulation considered. Osteoarthritis was the most represented diagnosis (36, 42.4%) [37–56], followed by rheumatoid arthritis and other arthritis (26, 30.6%) [57–72], fibromyalgia (14, 16.5%) [73–81] and autoimmune diseases (9, 10.6%) [65, 66, 82–87]. Females were mostly represented in all the studies except for Coulter, Fenton, Hernandez and VanGenderen, which were the only studies with a male prevalent component. ActiGraph was the most represented model device (39, 45.9%), followed by Fitbit (14, 16.5%) and Omron (10, 11.8%), and the rest were in the other category (22, 25.9%). The device was mainly worn on the waist (37, 44%), wrist and hip (16, 19%), three

Fig. 1 PRISMA flow diagram of the article selection process



(3.6%) on the arm, three (3.6%) on the leg, and six (7.1%) on the thigh.

Risk of bias of the included studies

Supplementary Table S3 (available at *Rheumatology* online) shows the details of the RoB assessment for each study. Questions related to other cohorts were not applicable in the cohort study design. High and low-moderate quality included 25 and 26 studies, respectively.

Supplementary Fig. S1 (available at *Rheumatology* online) presents the funnel plots for the number of steps and MVPA. The plots reveal publication bias for both outcomes among the studies considered. In both cases, approximately half of the studies are outside the triangles.

Meta-analysis results

The results of this meta-analysis show that there is a high level of I^2 heterogeneity, 99%, according to diagnosis.

Number of steps

Patients with rheumatoid and other arthritis diseases reported a higher number of steps, with 6361 (95% CI 5382.51, 7340.35) and 6290.14 (95% CI 5198.65, 7381.62) steps, respectively (Fig. 2).

The overall effect shows that patients with rheumatologic conditions included in this metanalysis reported −1092.60 steps (95% CI −1617.49, 340.35) compared with the reference value (Supplementary Fig. S2, available at *Rheumatology* online). A higher difference from the reference value was reported for autoimmune diseases −1865.91 (95% CI −3006.05, −725.76) and osteoarthritis −1385.63 (95% CI −2243.91, −527.39).

The supplementary material contains the forest plot for the rest of the subgroup analysis for the number of steps (Supplementary Figs S3–S6, available at *Rheumatology* online) and difference from the reference value (Supplementary Figs S7–S10, available at *Rheumatology* online) according,

Table 1 Characteristics of the included studies

Author, Year	Subpopulation	Diagnosis	Subpopulations characteristics	*n* participants	*n* female (%)	BMI	Age (mean)	Country	Device brand	Position	WDs use (days)
Bernard 2018 [73]	0	FM		128	100	27.9	53.7	Canada	Other	Hip	7
Brisson 2020 [37]	0	OA	Knee	59	81	28.1	61.1	Canada	Actigraph	Waist	7
Camiletti-Moirón 2015 [74]	1	FM	Sensewear Pro3 Armband	39	100		49.4	Spain	Other	Arm	7
Camiletti-Moirón 2015 [74]	2	FM	Actigraph GT1M	39	100		49.4	Spain	Actigraph	Waist	7
Coulter 2020 [57]	0	SpA		45	49		49	UK	Other	Thigh	7
Dassouki 2017 [82]	1	SS		29	100	26	53.5	Brazil	Actigraph	Waist	7
Daugaard 2018 [38]	1	OA	Without arthroplasty	54	54	27.4	62	Germany, Netherlands, Denmark	Other	Thigh	5.5
Daugaard 2018 [38]	2	OA	With arthroplasty	52	50	29.5	66	Germany, Netherlands, Denmark	Other	Thigh	5.5
Elmagboul 2020 [58]	1	Gout	Flare	27				UK; USA	Fitbit	Wrist	180
Elmagboul 2020 [58]	2	Gout	No flare	30				UK; USA	Fitbit	Wrist	180
Falck 2018 [39]	1	OA	Immediate intervention	30	73	29.16	61.73	Canada	Fitbit	Arm	21
Falck 2018 [39]	2	OA	Delayed intervention	31	90	29.24	62.61	Canada	Fitbit	Arm	21
Farr 2008 [40]	1	OA	Female knee	196	100	27.6	54.5		Actigraph	Waist	7
Farr 2008 [40]	2	OA	Male knee	59	100	28.5	55.3		Actigraph	Waist	7
Fawole 2020 [41]	0	OA		23	61		64.87	UK	Other	Thigh	9
Fenton 2017 [59]	1	RA	Female	41	100		53	UK	Actigraph	Hip	7
Fenton 2017 [59]	2	RA	Male	20	0		58.85	UK	Actigraph	Hip	7
Foucher 2021 [42]	0	OA		36	100	29.9	60.3	USA	Actigraph	Wrist	7
Fukutani 2016 [43]	1	OA	Early knee (grade 1-2)	207	80	23.6	51	Japan	Other	Leg	14
Fukutani 2016 [43]	2	OA	Severe knee (grade 3-4)	63	75	25.4	45	Japan	Other	Leg	14
Garver 2014 [44]	1	OA	Normal weight	8		28.4		USA	Other	Hip	7
Garver 2014 [44]	2	OA	Overweight	22				USA	Other	Hip	7
Garver 2014 [44]	3	OA	Class I obese	19				USA	Other	Hip	7
Garver 2014 [44]	4	OA	Class II obese	17				USA	Other	Hip	7
Garver 2014 [44]	5	OA	Class III obese	13				USA	Other	Hip	7
Gavilán-Carrera 2019 [75]	0	FM		407	100	28.4	51.4	Spain	Actigraph	Hip	9
Gilbert 2021 [45]	1	OA	No weekly restless sleep	751	54	28.2	65.4	USA	Actigraph	Waist	7
Gilbert 2021 [45]	2	OA	1–2 days of restless sleep	841	55	28.4	65.5	USA	Actigraph	Waist	7
Gilbert 2021 [45]	3	OA	3–4 days of restless sleep	168	61	28.5	63.7	USA	Actigraph	Waist	7
Gilbert 2021 [45]	4	OA	5–7 days of restless sleep	132	61	29.7	63	USA	Actigraph	Waist	7
Haider 2020 [60]	0	RA		70	73		57.9	Austria	Actigraph	Hip	7
Hernández-Hernández 2014 [61]	1	RA		50		29.2	54.5		Other	Hip	5
Hernández-Hernández 2020 [83]	1	PsA	6 months follow up	52	48	28	53	Spain	Actigraph	Hip	
Herrador-Colmenero 2021 [76]	1	FM	<51 active commuters	128	100		44.9	Spain	Actigraph	Waist	7
Herrador-Colmenero 2021 [76]	2	FM	<51 passive commuters	57	100		44.1	Spain	Actigraph	Waist	7

(continued)

Table 1 Continued

Author, Year	Subpopulation	Diagnosis	Subpopulations characteristics	*n* participants	*n* female (%)	BMI	Age (mean)	Country	Device brand	Position	WDs use (days)
Herrador-Colmenero 2021 [76]	3	FM	>51 active commuters	165	100		58.2	Spain	Actigraph	Waist	7
Herrador-Colmenero 2021 [76]	4	FM	>51 passive commuters	70	100		57.1	Spain	Actigraph	Waist	7
Hirata 2006 [46]	0	OA		65	100	21.4	50	Japan	Other	Waist	7
Hörnberg 2020 [62]	1	RA	Early	84	70	27.2	56.1	Sweden	Omron	Chest	7
Hörnberg 2020 [62]	2	RA	Long-standing	37	84	26	58.5	Sweden	Omron	Chest	7
Kaleth 2010 [77]	0	FM		30	90	32.5	49.1	USA	Actigraph	Waist	7
Kaleth 2014 [78]	0	FM		199	95	31.55	46.14	USA	Actigraph	Waist	14
Katz 2018 [63]	1	RA	Education only	28	86	29.2	59.1	USA	Other	Wrist	147
Katz 2018 [63]	2	RA	Fitbit only	34	88	32.1	55.9	USA	Fitbit	Wrist	147
Katz 2018 [63]	3	RA	Fitbit + education	34	88	33.9	50.2	USA	Fitbit	Wrist	147
Kimura 2021 [47]	0	OA	Ankle	50	68	26	70	Japan	Omron	Waist	7
Lee 2012 [64]	0	RA		176	57		55	USA	Actigraph	Hip	7
Legge 2017 [65]	1	RA		19	58	27.3	51.5	Canada	Actigraph	Waist	7
Legge 2017 [65]	2	SLE		20	90	28.1	43.9	Canada	Actigraph	Waist	7
Legge 2020 [84]	0	SLE		100	92	26.9	52.4	Canada	Actigraph	Waist	7
Li 2020a [66]	1	RA	Immediate intervention	43	88	26.6	54.8	Canada	Fitbit	Wrist	84
Li 2020a [66]	2	RA	Delayed intervention	43	93	29.3	55.3	Canada	Fitbit	Wrist	84
Li 2020a [66]	3	SLE	Immediate intervention	16	81	28.1	49.9	Canada	Fitbit	Wrist	84
Li 2020a [66]	4	SLE	Delayed intervention	16	88	27	47.1	Canada	Fitbit	Wrist	84
Li 2020b [48]	1	OA	Immediate intervention	26	88	29.8	64.9	Canada	Fitbit	Wrist	84
Li 2020b [48]	2	OA	Delayed intervention	25	76	28.9	64.8	Canada	Fitbit	Wrist	84
Liu 2016 [49]	0	OA	Self-reported knee	533	69		65.1	USA	Actigraph	Hip	7
Mahieu 2016 [85]	0	SLE		123	94	27.9	45.3	USA	Actigraph	Hip	7
Merriwether 2018 [79]	0	FM		171	100	34.4	49.3	USA	Actigraph	Wrist	
Moellenbeck 2021 [50]	0	OA		28	61	23.03	71.11	Germany	Actigraph	Waist	7
Morcos 2020 [51]	0	OA		122	58	30.1	65	Canada	Fitbit	Wrist	7
Morillas-de-Laguno 2018 [86]	0	SLE		47	100	26.1	41.2	Spain	Actigraph	Hip	7
Oka 2021 [52]	1	OA	Unilateral pain	37	78	25.8	69.1	Japan	Omron	Waist	7
Oka 2021 [52]	2	OA	Unilateral pain + low-back pain	23	78	25.2	69.1	Japan	Omron	Waist	7
Oka 2021 [52]	3	OA	Bilateral pain	30	77	27.7	74.3	Japan	Omron	Waist	7
Oka 2021 [52]	4	OA	Bilateral pain + low-back pain	36	78	24.7	72.5	Japan	Omron	Waist	7
O'Leary 2021 [67]	0	RA		72	65	28.9	61.5	Ireland	Other	Thigh	7
Östlind 2021 [53]	0	OA		75	69		56.9	Sweden	Fitbit	Wrist	84
Rockette-Wagner 2021 [87]	0	Myositis		44	68		51.6	USA	Actigraph	Waist	42
Ruiz 2013 [80]	1	FM	Week	94	100		41	Spain	Actigraph	Waist	5
Ruiz 2013 [80]	2	FM	Weekend	94	100		41	Spain	Actigraph	Waist	2
Salvat 2017 [81]	0	FM		155	100	26.3	50	Spain	Other	Leg	84
Shahine 2020 [54]	1	OA	Intervention	33	64		65.55	Egypt	Other		84

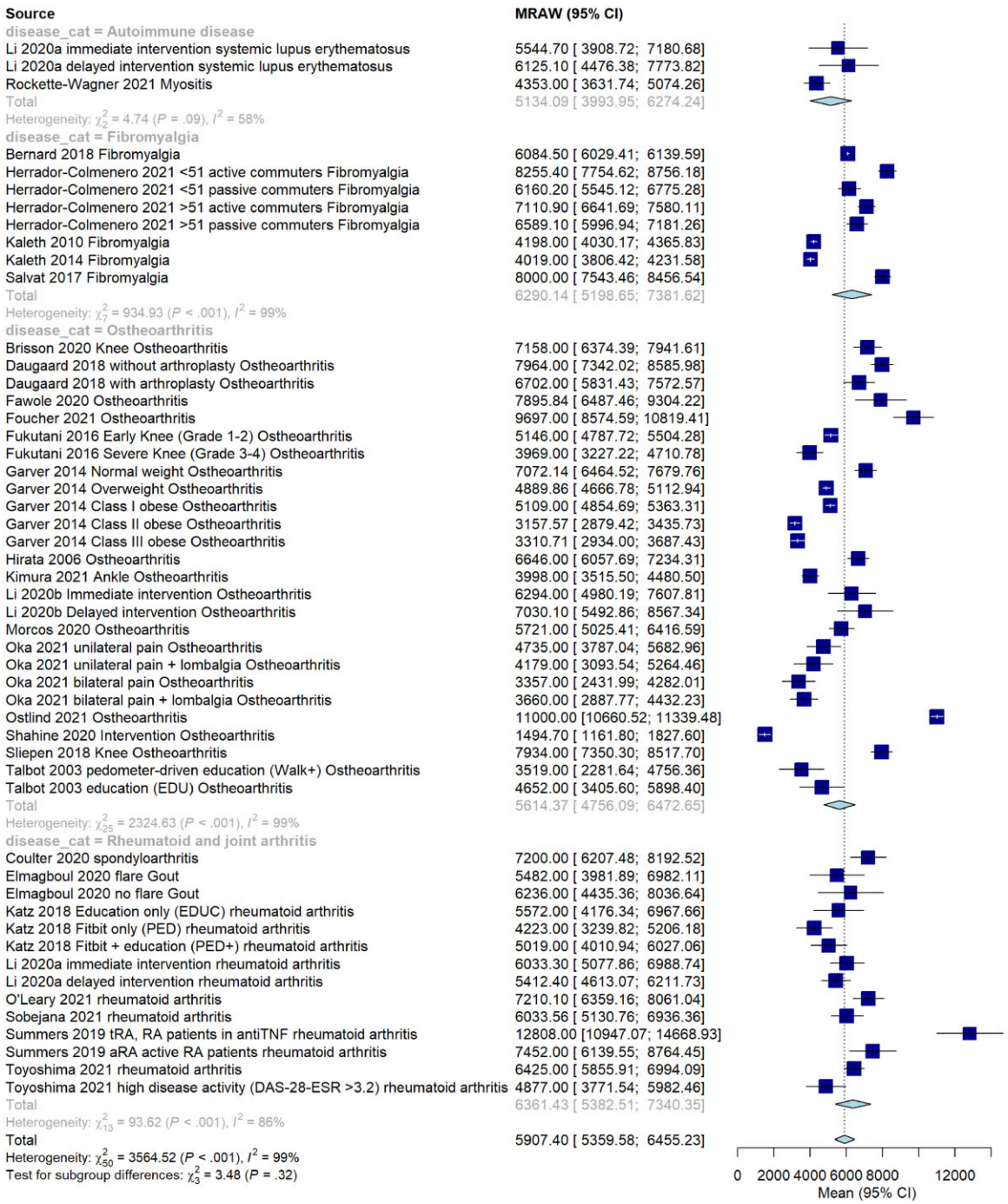
(continued)

Table 1 Continued

Author, Year	Subpopulation	Diagnosis	Subpopulations characteristics	*n* participants	*n* female (%)	BMI	Age (mean)	Country	Device brand	Position	WDs use (days)
Sliepen 2018 [55]	0	OA	Knee	61	56	27.3	60.7	Germany	Other	Thigh	7
Sobejana 2021 [68]	0	RA		24	79	27.2	65.33	Netherlands	Actigraph	Wrist	7
Summers 2019 [69]	1	RA	Anti-TNF	40	100	25.7	59	UK	Actigraph	Waist	7
Summers 2019 [69]	2	RA	Active	32	100	27.7	60.4	UK	Actigraph	Waist	7
Talbot 2003 [56]	1	OA	Pedometer-driven education (Walk+)	17	76	31.01	69.59	USA	Other	Waist	3
Talbot 2003 [56]	2	OA	Education	17	76	32.63	70.76	USA	Other	Waist	3
Toyoshima 2021 [70]	1	RA		20	95	21.4	54.6	Japan	Omron	Waist	7
Toyoshima 2021 [70]	2	RA	High disease activity (DAS28-ESR >3.2)	14	71	19.5	51.6	Japan	Omron	Waist	7
Van Genderen 2015 [71]	1	SpA	Axial	135	40	26	51	Multicentric	Actigraph	Waist	7
Yuksel Karsli 2021 [72]	1	SpA	Radiographic	34	59	26.1	41	Turkey	Actigraph	Waist	7
Yuksel Karsli 2021 [72]	2	SpA	Non-radiographic	33	61	26.3	37	Turkey	Actigraph	Waist	7

Each row refers to a specific subpopulation, and 0 is the overall population. SpA: spondyloarthritis; WD: wearable device.

Fig. 2 Forest plot for the number of steps according to disease classification



respectively, to age category (elderly *vs* nonelderly), gender ratio (female *vs* male prevalent study), model device classification (ActiGraph, Fitbit, Omron, Other) and risk of bias (high or low quality).

Nonelderly people showed a higher overall level of physical activity than elderly people, 6796.11 (95% CI 5974.10, 7618.13) *vs* 5431.85 (95% CI 4633.76, 6229.95) (Supplementary Fig. S3, available at *Rheumatology* online).

The model device Omron showed a lower level of heterogeneity (I^2=90%) compared with the other models (Supplementary Fig. S5, available at *Rheumatology* online). High-quality studies showed a lower level of heterogeneity (I^2=95%) than low- to moderate-quality studies

(I^2=99%) (Supplementary Fig. S6, available at *Rheumatology* online).

Number of steps and reference value

Nonelderly people had a lower level of difference from the reference value compared with elderly people, −203.89 (95% CI −1025.90, 618.13) *vs* −1568.14 (95% CI −2366, −770.05) (Supplementary Fig. S7, available at *Rheumatology* online). The number of steps evaluated with the ActiGraph model showed a lower difference from the reference value of −92.01 (95% CI −1437.56, 1253.53) (Supplementary Fig. S9, available at *Rheumatology* online). The same was true for studies with a high risk of bias of −975.54 (95% CI −1673.40, −277.68) (Supplementary Fig. S10, available at *Rheumatology* online).

MVPA results

Figures 3 and Supplementary Figure S11 (available at *Rheumatology* online) report MVPA forest plots according to disease and compared with the reference value.

The supplementary material contains the forest plot for the rest of subgroup analysis for MVPA (Supplementary Figures S12, S13, S14, S15, available at *Rheumatology* online) and MVPA difference from the reference value (Supplementary Figs S16–S19, available at *Rheumatology* online) according, respectively, to age category (elderly *vs* nonelderly), gender ratio (female *vs* male prevalent study), model device classification (ActiGraph, Fitbit, Omron, Other) and risk of bias (high or low quality). Elderly individuals had a higher level of MVPA than nonelderly individuals (Supplementary Fig. S12, available at *Rheumatology* online), 60.39 (95% CI 39.78, 81.01) *vs* 33.19 (95% CI 24.75, 41.64).

Fitbit and Omron had the lowest level of heterogeneity compared with ActiGraph and another device, with I^2 values of 80% and 95%, respectively (Supplementary Fig. S8, available at *Rheumatology* online). Pooled MVPA was lower for Omron and another model device, being 29.61 (95% CI 20.13, 39.08) and 22.69 (95% CI 3.05, 42.33) (Supplementary Fig. S14, available at *Rheumatology* online), respectively, and the same was true of the reference value (Supplementary Fig. S16, available at *Rheumatology* online).

The risk of bias level for MVPA showed high levels of heterogeneity with a similar level of pooled MVPA in both forest plots (Supplementary Figs S15 and S19, available at *Rheumatology* online).

MVPA compared with the reference value

The non-elderly group showed a higher level of MVPA than the reference value of 38.96 (95% CI 18.35, 59.68) *vs* 11.77 (95% CI 3.32, 20.21) (Supplementary Fig. S16, available at *Rheumatology* online).

Metaregression

Table 2 reports the results of the meta-regression for the number of steps and MVPA. For each variable considered, the estimate, *P*-value and 95% CI are reported. The interpretation is as follows: patients using Fitbit report an increase of 6053 number of steps compared with ActiGraph (reference category). In the metaregression for the number of steps, none of the confounders considered showed a significant influence (Table 2). In the MVPA metaregression, patients with fibromyalgia had 28.74 more min of MVPA than patients with autoimmune diseases (*P*-value 0.006, 95% CI 8.25, 49.33). The level of MVPA also increases by 53.23 min/day in females compared with males (*P*-value 0.006, 95% CI 8.14, −49.33) (Table 2).

Discussion

To our knowledge, this study is the first systematic review on the use of WDs in the rheumatology field to compare noninflammatory and inflammatory arthropathies and systemic diseases. While the recommended threshold for daily steps was not reached it was reached for MVPA by patients with RMDs. Patients with fibromyalgia reported a higher number of daily steps compared with other RMDs, probably due to the extra-articular involvement of the disease. Patients suffering from inflammatory arthropathies seemed to fare better in terms of daily steps than the other categories. As expected, age had a significant impact on both outcomes, with younger patients reporting a higher overall level of PA.

The first result of this work is that neither the currently recommended target according to WHO PA guidelines of 10 000 daily steps for healthy people nor the proposed threshold of 7500 daily steps for subjects affected by chronic health conditions were reached by people affected by RMDs. We estimated an average of ∼5130 daily steps for systemic autoimmune diseases, 6045 for fibromyalgia, 5460 for osteoarthritis and 6360 for inflammatory arthropathies. This may imply that, in general, RMDs decrease PA. Maintaining an adequate level of PA should be suggested in these patients, since RMD, especially inflammatory RMD, represent an independent cardiovascular risk factor even in young people [19]. PA can improve quality of life and self-reported function in chronic inflammatory arthropathies, especially rheumatoid arthritis, as recently documented in the Enhance study [88]. More studies with larger cohorts are needed in spondyloarthritis and psoriatic arthritis, where great uncertainty is still great uncertainty. In this review three studies on spondyloarthritis [57, 71, 72] and one on psoriatic arthritis were included [83], therefore we are not able to evaluate the effect on these specific populations, but they were included in the main group of other arthritis.

Patients affected by fibromyalgia showed a significantly higher number of daily steps in comparison to those affected by osteoarthritis or systemic autoimmune diseases in the meta-regression analysis. This result could be linked to the absence of objective damage to the musculoskeletal system in fibromyalgia and reflects the extra-articular nature of the disease. In the other disease categories considered, however, a low number of studies

Fig. 3 Forest plot for MVPA according to disease classification

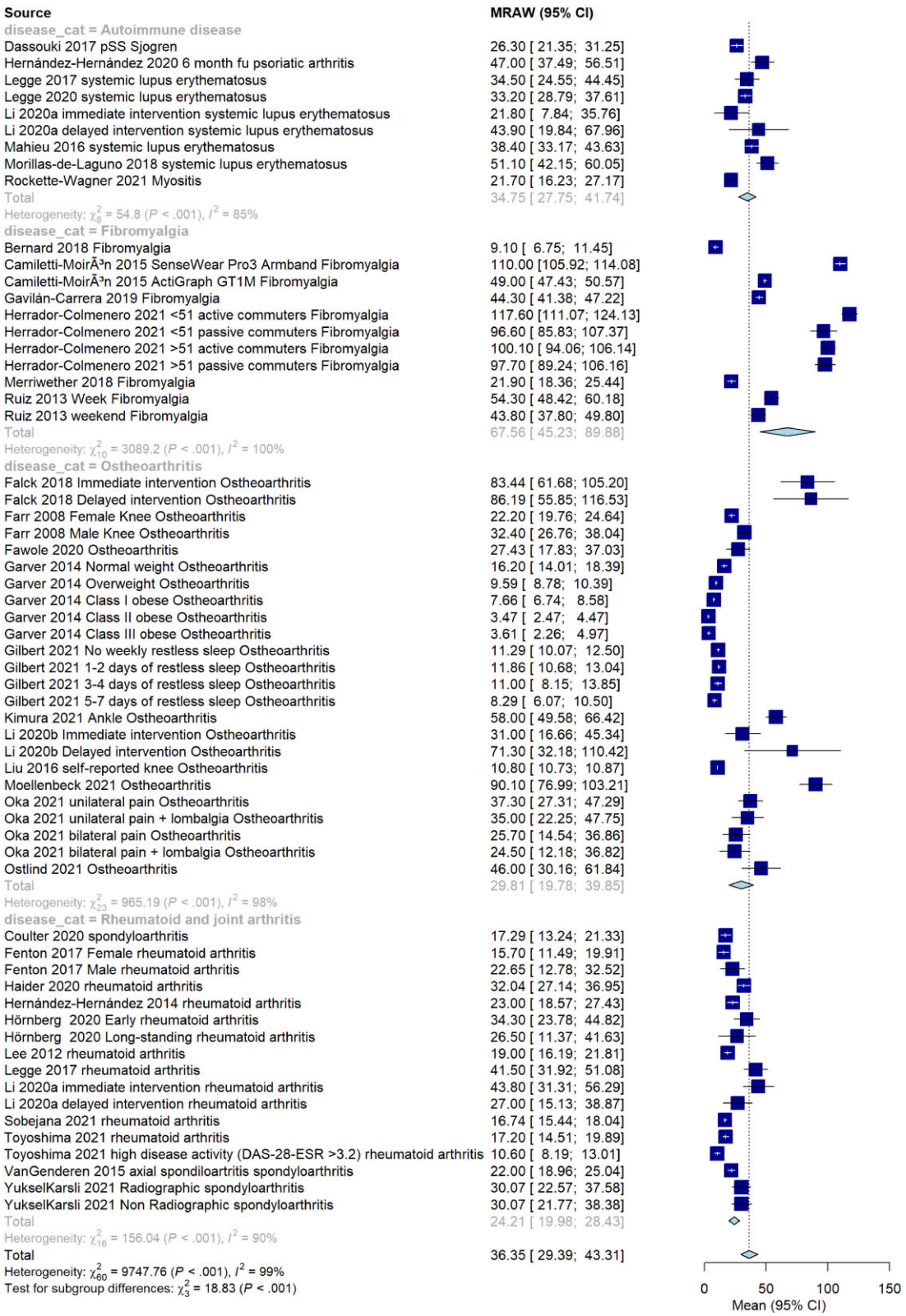


Table 2 Metaregression estimates for the number of steps and moderate to vigorous physical activity (MVPA)

Variable	Level	Number of steps					MVPA				
		Estimate	Standard error	*P*-value	95% CI lower	95% CI upper	Estimate	Standard error	*P*-value	95% CI lower	95% CI upper
Model device	Fitbit	6053	28 676	0.83	−50 151	62 258	−0.11	23.62	1.1	−46.42	46.19
	Omron	411.7	44 556	0.99	−86 916	87 739	−8.16	12.69	0.52	−33.03	16.71
	Other	1823	6168	0.77	−10 265	13 912	−13.58	9.55	0.15	−32.31	5.14
Age (mean)		180.3	924.1	0.84	−1631	1992	−0.90	0.48	0.06	−1.84	0.05
Age (categorical)	Not elderly	−1503	5920	0.80	−13 105	10 100	12.32	8.25	0.13	−3.85	28.48
Gender ratio	Male prevalent	833.2	156 371	0.99	−305 648	307 314	−11.31	15.50	0.46	−41.68	19.06
Gender	Female	11.1	63.26	0.86	−112.9	135.1	53.23	18.22	**0.003**	17.53	88.94
Disease	Fibromyalgia	1599	130 649	0.99	−254 469	257 667	28.74	10.51	**0.006**	8.14	49.33
	Osteoarthritis	392.8	130 873	0.99	−256 113	256 899	−16.69	9.80	0.08	−35.88	2.50
	Rheumatoid and other arthritis	1709	142 297	1.00	−277 187	280 606	−11.35	10.09	0.26	−31.12	8.42
Duration of wearable device use (days)		−3.785	240.2	0.99	−474.6	467	−0.03	0.30	0.92	−0.60	0.54
Risk of bias	Low moderate quality	39.85	19 410	1.00	−38 003	38 083	−7.02	7.77	0.37	−22.97	−7.17
Year of publication		271.8	807.7	0.34	−1311	1855	1.04	1.12	0.35	−1.158	3.23

For each variable considered are reported the estimate, *P*-value and 95% CI. The interpretation is as follow: patients using Fitbit reports an increase of 6053 number of steps compared with ActiGraph (reference category). The reference categories are the following: model device, Actigraph; age, elderly; gender ratio, female prevalent; gender, male; disease, autoimmune disease; risk of bias, high risk. Bold are reported *P*-value inferior to 0.05.

were available. Moreover, the studies on fibromyalgia included a younger population, with a median of 50 years of age, while it was 54 years for rheumatoid arthritis and 63 years for osteoarthritis. Yet, it should be considered that most studies on osteoarthritis recruited patients with involvement of the lower extremities, with a direct impact on PA.

Patients affected by inflammatory arthropathies seem to fare better in terms of daily steps than the other categories, with particularly relevant data of >10 000 daily steps reported in the study by Summers and colleagues [69] conducted on a selected population of patients affected by rheumatoid arthritis who were both in long-term remission and with a low disability index. This observation further supports the usefulness of an early diagnosis of rheumatoid arthritis, followed by an appropriate treatment strategy, according to the principles of the treat-to-target strategy [89], to allow patients to resume a normal life routine in rheumatoid arthritis due to the prevention of irreversible disability.

Overall, the data gathered on the daily average of steps in the various categories underscores the notion that the main drivers of a reduced level of PA in rheumatic patients seem to be the burden of organic disease (thus excluding fibromyalgia) and the disability index.

For MVPA, all categories exceeded the minimum target of MVPA recommended by the WHO, which is ∼22 daily min [5]. An average daily amount of ∼34.75 min for systemic autoimmune diseases, 29.8 min for osteoarthritis, and 45.7 min for inflammatory arthropathies were estimated in this review. People with fibromyalgia showed a significantly better result of ∼67.5 daily min of MVPA, with the highest level in the study conducted on commuters [76].

Importantly, the assessment of daily steps and MVPA showed high variability among the included studies, due to the inconsistency among the MET scales proposed [88, 90]. The studies included in our meta-analysis used different accelerometric criteria to estimate both MVPA and daily steps. This variability also affects the daily step count, albeit to a smaller extent.

However, the type of WD is relevant, as each brand and each model have their sensitivity and calibration. Omron devices seemed to provide less variable output, possibly due to a lesser amount and a higher standardization of offered models than Fitbit or other brands.

All these considerations highlight the complexity that arises from the need to translate three-dimensional complex movements into intelligible data, as well as into a measure of oxygen consumption, which is a critical variable in the evaluation of PA intensity that cannot be directly provided by WDs.

Limitations

This study has some limitations. As stated above, the low number of studies included in some categories, especially autoimmune systemic diseases, may limit the generalizability of the results. The studies included in our meta-analysis used different accelerometric criteria to estimate MVPA and daily steps. Moreover, the studies show a great variability on the assessment of daily steps and MVPA, this could be related to the use of different WDs, different in terms of brand and accelerometric structure. Lastly, studies are mainly observational ones and, for this reason, they are prone to have a higher level of risk of bias. For this reason, the risk of bias was added in the meta-regression to evaluate whether act an effect on the final meta-analysis estimate.

Conclusion

Patients suffering from RMDs generally seem to have lower levels of activities compared with the reference value of healthy people, while physical endurance may not be affected. This supports the ongoing pursuit of treatments that could also improve fatigue as well [91], especially in inflammatory chronic conditions [24]. Larger studies of specific populations are warranted.

The WD is, indeed, an economically affordable, relatively comfortable to wear, and simple to use instrument that could be a promising method to monitor patients through a constant flow of data unaltered by the patient's or the physician's perception (the so-called 'involuntary data') [92]. Monitoring PA is a crucial step that can lower cardiovascular risk and improve the quality of life and even the long-term survival of patients suffering from some RMDs.

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Data availability statement

The data underlying this article will be shared on reasonable request to the corresponding author.

Supplementary data

Supplementary data are available at *Rheumatology* online.

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