Tight control of disease activity fails to improve body composition or physical function in rheumatoid arthritis patients

Lemmey, A.B.; Wilkinson, Thomas; Clayton, Rebecca; Sheikh, F.; Whale, J.; Jones, H.; Ahmad, Y.A.; Chitale, S.; Jones, Jeremy; Maddison, P.; OBrien, Thomas

Rheumatology

DOI:
10.1093/rheumatology/kew243

Published: 10/06/2016

Peer reviewed version

OXFORD UNIVERSITY PRESS | Rheumatology

Tight control of disease activity fails to improve body composition or physical function in rheumatoid arthritis patients

Journal:	*Rheumatology*
Manuscript ID	RHE-15-1488.R1
Manuscript Type:	Original Article (includes systematic reviews)
Date Submitted by the Author:	n/a
Complete List of Authors:	Lemmey, Andrew; Bangor University, School of Sport, Health and Exercise Sciences Wilkinson, Thomas; Bangor University, SSHES Clayton, Rebecca; Bangor University, SSHES Sheikh, Fazal; Llandudno Hospital, BCUHB, Peter Maddison Rheumatology Centre Whale, John; Bangor University, SSHES Jones, Hope; Bangor University, SSHES Ahmad, Yasmeen; Llandudno Hospital, BCUHB, Peter Maddison Rheumatology Centre Chitale, Sarang; Llandudno Hospital, BCUHB, Peter Maddison Rheumatology Centre Jones, Jeremy G.; Bangor University, SSHES Maddison, Peter; Llandudno Hospital, BCUHB, Peter Maddison Rheumatology Centre O'Brien, Thomas; Liverpool John Moores University, Research Institute for Sport & Exercise Sciences
Keywords Please select a minimum FIVE keywords from the list provided. These keywords will be used to select reviewers for this manuscript. The keywords in the main text of your paper do not need to match these words.:	Rheumatoid arthritis < RHEUMATIC DISEASES, Muscle < TISSUES, Adipose tissue < TISSUES, Inflammation < BASIC & CLINICAL SCIENCES, Rehabilitation < THERAPIES

Tight control of disease activity fails to improve body composition or physical function in rheumatoid arthritis patients

Andrew B Lemmey[1], Thomas J Wilkinson[1], Rebecca J Clayton[1,2], Fazal Sheikh[1,2], John Whale[1], Hope S J Jones[1], Yasmeen A Ahmad[1,2], Sarang Chitale[1,2], Jeremy G Jones[1,2], Peter J Maddison[1,2], Thomas D O'Brien[1,3]

[1]Rehabilitation of Musculoskeletal Disorders with Exercise Sciences (ReMeDES) group, School of Sport, Health and Exercise Sciences (SSHES), Bangor University, Bangor, LL57 2PZ, United Kingdom;

[2]Peter Maddison Rheumatology Centre, Llandudno Hospital, Betsi Cadwaladr University Health Board, LL30 1LB, United Kingdom;

[3]Research Institute for Sport & Exercise Sciences, Liverpool John Moores University, Liverpool, L3 3AF, United Kingdom.

Correspondence: Andrew B. Lemmey, a.b.lemmey@bangor.ac.uk, 01248 383 932, ReMeDES group, SSHES, Bangor University, Bangor, LL57 2PZ, United Kingdom

Short title: Effects of T2T on body composition and function in RA

Abstract

Objective. RA typically features "rheumatoid cachexia" (loss of muscle mass (MM) and excessive fat mass (FM), especially trunk FM), which contributes to physical disability. Since rheumatoid cachexia is driven by inflammation, it would be anticipated that the success of tight control of

disease activity, such as "treat-to-target" (T2T), in attenuating inflammation would benefit body composition and physical function. This cross-sectional study assessed the impact of T2T on body composition and objectively-assessed function in RA patients.

Methods. Eighty-two RA patients exclusively treated by T2T, were compared to 85 matched sedentary healthy controls (HC). Body composition was estimated by DXA, with appendicular lean mass (ALM) the surrogate measure of total MM. Physical function was assessed by knee extensor strength, handgrip strength, 30s sit-to-stands, 8' up & go, and 50' walk (tests which reflect the ability to perform ADLs).

Results. Although generally well treated (mean DAS28=2.8, with 49 % in 'remission'), RA patients had ~10% proportionally less ALM and were considerably fatter (by ~27%), particularly in the trunk (~32%), than HC's. All measures of function were 24-34% poorer in the RA patients relative to HC.

Conclusion. Despite marked improvements in disease control (most patients achieving or approaching 'remission'), the relative loss of MM and increased adiposity in RA patients compared to matched-HC is similar to that observed pre-T2T. Additionally, performance of objective function tests is unchanged from that reported by our group for pre-T2T RA patients. Thus T2T, even in responsive RA patients, has not attenuated rheumatoid cachexia or improved objectively-assessed function.

Key words: rheumatoid arthritis, treat-to-target, rheumatoid cachexia, body composition, physical function

Key messages

- T2T RA patients still show significant muscle loss, exacerbated adiposity and substantially impaired physical function.

- Patients responding to T2T typically have the physical function of healthy individuals 25 years older.
- By concentrating on DAS28, T2T protocols may distract rheumatologists' attention from physical function.

INTRODUCTION

Rheumatoid arthritis (RA) is characterised by adverse changes in body composition (i.e. reduced muscle mass and increased adiposity) termed 'rheumatoid cachexia' [1]. Although prevalence of this condition varies according to measurement method and definition employed, muscle loss of 7.4-14.0% relative to matched healthy controls [2-5] are observed in up to 67% of stable RA patients [3, 6-15] whilst obesity, determined by body composition, is present in up to 80% of stable patients [3, 9-12, 16], with trunk adiposity especially prevalent [3, 8, 9-12, 17-18]. These changes in body composition, as well as exacerbating mortality and co-morbidity risk [15-19], also contribute significantly to disability [7, 20-22].

In recent years, individually tailored treatment strategies featuring early and aggressive DMARD use and frequent monitoring of treatment response to achieve low disease activity (LDA), preferably 'clinical remission', have been the cornerstone of pharmacologic treatment of RA. This approach, best exemplified by 'treat-to-target' (T2T) [23-24], has been shown to be substantially more effective in controlling inflammation and arresting progression of joint damage than previous treatment regimens [23-26]. Given that rheumatoid cachexia is thought to be driven by DA, and inflammation in particular [3, 14-15, 27], it would be anticipated that the tighter control of DA/inflammation achieved by T2T would attenuate rheumatoid cachexia and, as a consequence, reduce functional limitations in RA patients. Pertinently, restoration of functional ability is an explicit aim of both EULAR and ACR recommendations for T2T [23-24, 28]. Although studies assessing body composition in RA patients have been performed since the widespread use of T2T (~2008), these

studies [4, 6, 8, 10, 18, 20, 29-31] have either exclusively or primarily used patients who commenced treatment years prior to the adoption of T2T, and therefore do not inform on the effects on body composition of T2T *per se*. Additionally, investigations into the impact of T2T on physical function have, to date, only used subjective instruments such as the Health Assessment Questionnaire (HAQ) [26, 32-33]. However, these measures are strongly influenced by pain [34-35], which diminishes with T2T, and are often insensitive to changes in function in patients with controlled disease [9, 36]. Thus, we aimed to determine whether the adverse effects of RA on body composition and physical function still exist in this era of tight control of DA. To this end, we compared body composition and objectively-assessed physical function of RA patients exclusively treated by T2T era with that of age- and sex-matched healthy sedentary controls (HC). Additionally, we compared our current findings with those previously reported by our group for stable RA patients (i.e. studies performed either before local adoption of T2T strategies, or, if more recent, on patients who commenced treatment pre-T2T [3-4, 9-12, 30]). Lastly, this investigation sought to further examine the time-courses of rheumatoid cachexia and RA disability.

METHODS

This cross-sectional study was conducted between February 2013 and March 2015, in compliance with the Helsinki Declaration, and with approval from the North Wales Research Ethics Committee – West (12/WA/0323).

Study population

RA patients with stable disease were recruited from outpatient clinics of the Peter Maddison Rheumatology Centre (PMRC), North Wales. For inclusion, participants had to: (a) fulfil the ACR 2010 revised criteria for RA [37]; (b) be aged ≥ 18 years; (c) not be cognitively impaired; (d) be free of other cachectic diseases or conditions preventing safe participation; (e) not be taking anabolic

drugs or nutritional supplements; and (f) not be pregnant. Only patients who commenced DMARD treatment following the PMRC's adoption of treatment strategies in-line with the T2T recommendations of Smolen et al [23] (i.e. post 1/1/2008) were included. Once recruited, participants were categorised into either 'recent-onset' (≤ 12 months since diagnosis) or 'established' (> 12 months since diagnosis) disease cohorts.

For comparison, sedentary age- and sex-matched HC were recruited from the local community. To be eligible for the study, HC must have satisfied all of the inclusion criteria for RA patients, except for the diagnosis of RA.

Assessments and outcome measures

Participants presented for assessments in an overnight fasted state.

Anthropometric and body composition measures

Routine anthropometric measures (body mass (BM), height, and waist and hip circumferences) were performed using standard procedures.

Total and regional lean, fat, and bone masses were estimated using a whole body fan-beam DXA scanner (Hologic, QDR Discovery 45615, software V12.4), with appendicular lean mass (ALM) used as a surrogate measure of total body muscle mass [3]. The in-house co-efficient of variation (CV) of 1.4% of our scanner complies with manufacturer's guidelines.

Objective physical function

Maximal isometric knee extensor strength (IKES) was measured using an isokinetic dynamometer (Humac Cybex Norm 2004, Computer Sports Medicine Inc., Massachusetts, USA) and maximal

handgrip strength (HGS) by a Grip-A dynamometer (Takei Kiki Kogyo, Japan) using previously described protocols [3]. Three objective function tests, specifically developed to evaluate the capacity of older adults to perform activities of daily living (ADL [38]): 'sit-to-stands in 30 seconds' (STS-30), '8-foot up and go' (8'UG) and '50-foot walk' (50'W) tests), were also performed. Before each of the strength and function tests, which are routinely used by our group [3-4, 9-12, 30-31, 39], participants had a submaximal practice.

Clinical measures. Disease activity was assessed by the Disease Activity Score in 28 joints (DAS28) using C-reactive protein (CRP), with 'remission' defined as DAS28 < 2.6. Physical disability was subjectively evaluated by the Multidimensional Health Assessment Questionnaire (MDHAQ [40]).

Statistical analysis

The primary outcome of the study was ALM normalised for BM (ALM %), as this is the LM measure most relevant to performing ADL (i.e. comparing absolute ALM ignores disparities in BM and the effect fat mass (FM) has on performing ADL). The secondary outcomes included other aspects of body composition (total LM, total FM, trunk FM, and % body fat (BF%)) and the objective physical function measures.

The primary statistical analyses involved comparison of the RA group versus the HC group, followed by sub-analyses of: 'recent-onset' versus 'established' RA patients; RA patients who, at the time of testing, had achieved clinical remission versus patients who had not; 'remission' patients versus HC; and finally, informal comparison of current results with our 'historic', pre-T2T data [3-4, 9-12, 30-31; patients for these studies generally commenced treatment 1992-2004]. Statistical analysis involved multiple (MANOVA) or univariate analysis of variance (ANOVA) according to appropriateness, and Chi-squared tests were used for comparison of dichotomous variables.

Significance was set at $P < 0.05$ and a trend recognised as $P = 0.05$ - 0.10. Data is presented as mean (±SD).

RESULTS

One hundred and ninety-seven (n = 197) patients with RA were deemed eligible for the study and approached. Of these, 115 (58%) declined participation (primarily due to: 'not interested' or time and/or travel constraints) leaving 82 patients who were recruited. At the time of assessment, 33 of these 82 patients had been diagnosed ≤ 12 months previously ('recent-onset' group; mean disease duration ~7 months), whilst the remaining 49 had a disease duration of 1-7 years ('established' group; mean duration ~2 years 11 months). Eighty-five age- and sex-matched sedentary HC participants were also recruited.

Demographic and clinical characteristics

Table 1 displays the demographic and clinical characteristics of the 82 RA patients and 85 HC participants. These groups were precisely matched for mean age ($P = 0.962$) and gender distribution ($P = 0.992$). RA patients were more frequently current ($P < 0.001$) or former ($P < 0.001$) smokers, and generally were more sedentary ($P < 0.001$) than the HC. With regard to DA, the mean DAS28 score was 2.8, indicating generally 'low DA', and 49% of patients had achieved a current state of 'clinical remission'. DMARD treatment is summarised in Table 1.

No differences in demographic or clinical characteristics were identified between the 'recent-onset' or 'established' RA patients (data not shown), with the exception of disease duration and the proportion on combination therapy (7.1 ± 3.0 vs 34.7 ± 17.0 months, $P < 0.001$; and 16/33 (48%) vs 14/49 (29%), $P = 0.066$, respectively).

Anthropometry and body composition

Anthropometric and DXA-assessed body composition data appear in Table 2. Despite being shorter (mean ~3cm, P = 0.019), RA patients were heavier (mean BM: +4.8 kg, P = 0.093), and consequently their mean BMI higher (P = 0.002), than the HC. RA patients also had a greater mean waist circumference (+7.7 cm, P = 0.001) and waist:hip ratio (P < 0.001) than HC.

When adjusted for BM (i.e. % of), RA patients had ~10% less muscle than HC (ALM %, P < 0.001). This relative deficit corresponds with the proportional loss of ALM we observed in stable RA patients, of similar age and gender distribution, who had commenced treatment ~1992-2004 (i.e. ~9%, RA n = 23, matched HC, n = 23 [4]; ~11%, RA n = 20, matched HC, n = 20 [3]). When expressed absolutely (kg), RA patients in the current study exhibited less ALM (-1.1 kg) and TLM (-0.8 kg) than the HC, although these differences were not statistically significant.

DXA-assessed body composition confirmed that RA patients were considerably fatter than HC, with the group differences in BM more than accounted for by higher total FM in patients (+5.4 kg, 26.5% greater, P < 0.001). Consequently, BF% was also higher in patients (P < 0.001). As anticipated, the majority of this increased adiposity was situated on the trunk (+3.2 kg, 32.3% higher than HC, P = 0.001). In pre-T2T patients we had noted mean increases in total FM of ~17% [4] and ~13% [3] relative to HC.

No differences in anthropometric or DXA measures were evident between the 'recent-onset' and 'established' RA patients (data not shown; P's = 0.654 - 0.998).

Objective physical function

Compared with HC, RA patients performed poorly in each of the objective function measures (Table 3): IKES was 24.3% less ($P < 0.001$); HGS, 25.3% less ($P < 0.001$); STS-30, 34.2% less ($P < 0.001$); 8'UG, 31.1% slower ($P < 0.001$); and 50'W, 28.0% slower ($P < 0.001$). The absolute levels of performance for those tests not subject to equipment changes (i.e. STS-30, 8'UG, 50' W), achieved by RA patients in the current study are similar to those we observed in stable pre-T2T RA patients (STS-30: mean range 10.9 – 14.7 repetitions, overall mean = 12.4 (vs 12.0 repetitions in the current study) [3-4, 9-12, 30-31]; 8'UG: mean range 6.0 – 6.4 secs, overall mean = 6.2 (vs 7.4 secs) [4, 30-31]; 50'W mean range 9.1 – 10.0 secs, overall mean = 9.5 (vs 10.7 secs) [4, 9-10, 30-31].

As with the anthropometric and body composition measures, there were no differences in performance for any of the objective function tests between the 'recent-onset' and 'established' RA patients (data not shown; *P*'s = 0.435 - 0.778).

Subjective measures of disability and health

As expected, RA patients had higher MDHAQ scores than the HC group ($P = 0.001$; Table 1). Despite the marked impairments in objectively-assessed physical function relative to HC, the RA patients subjectively regarded themselves as only 'mildly disabled' (Table 1). There was no difference in MDHAQ scores between 'recent-onset' and 'established' RA patients (data not shown, $P = 0.880$).

'Remission' versus 'non-remission' RA patients

Of the 82 RA patients, 40 had achieved clinical remission at the time of assessment (DAS28: 2.0 ± 0.4). There were no differences in age, seropositivity, disease duration or medication between 'remission' and 'non-remission' patients, however, proportionally fewer females achieved 'remission' (58% vs 71%, $P = 0.187$) (Table 4).

In comparison to those not in remission (DAS28: 3.6 ± 0.8), the 'remission' patients generally had slightly better body composition, albeit not significantly (Table 5), and performed the function tests better (Table 6). However, even in this subgroup of highly responsive patients, body composition (i.e. waist circumference, $P = 0.039$; waist:hip ratio, $P < 0.001$; ALM, $P = 0.003$; ALM%, $P < 0.001$; total FM, $P = 0.014$; BF%, $P = 0.001$; trunk FM, $P = 0.017$) and objectively-assessed function (relative deficits of 13 – 31%; IKES, $P = 0.002$; HGS, $P < 0.001$; STS-30, $P < 0.001$; 8'UG, $P = 0.008$; 50'W, $P = 0.014$) were still much worse than for HC.

DISCUSSION

This is the first investigation of the effects on body composition and objectively-assessed physical function of current treatment regimens which aim to tightly control DA in RA patients. Overall the findings show that our T2T RA patients, including those who have achieved clinical remission, continue to have substantially reduced muscle mass, much greater levels of adiposity (especially in the trunk), and considerably worse function than sedentary age- and sex-matched healthy individuals. These adverse effects are despite a mean DAS28 of 2.8 (an 'acceptable alternative therapeutic goal' [23-24]) and achievement of 'clinical remission' in approximately half our patients, both of which indicate that our cohort is well-treated and generally benefiting from the T2T approach.

Whilst the precise mechanisms underlying rheumatoid cachexia remain unclear, disease activity (i.e. inflammation) is widely accepted to be the primary driver [1, 13, 27, 29, 41]. Hence, it would be anticipated that the success of T2T in suppressing inflammation would be reflected in improved body composition in RA patients treated exclusively by this strategy relative to patients who received earlier, less clinically effective treatments. However, the proportional loss of muscle mass of ~10 % observed in our current patients relative to matched, sedentary healthy controls is similar to what we

had noted in stable, pre-T2T RA patients (~9%, for patients with a mean RA Disease Activity Index (RADAI) = 3.1 ± 0.3 [4]; and ~11%, for patients with RADAI = 2.65 ± 1.4 [3]). This current deficit is also in line with the DXA-assessed ALM/BM% differences between controlled pre-T2T patients and healthy individuals described by others; i.e. 12% [5], 8% [42], 9% [43] (data collection 2004-2006), 11% in women and 10% in men [2] (RA patients diagnosed 1995-2001) and in the follow-up to the last study, 11% in women and 7% in men [44]. Additionally, Elkan et al [7] (data collection 2004-2005) found an 11% reduction in DXA-assessed fat free mass index (FFM/height $(m)^2$) of RA patients with active disease (mean DAS28 = 5.5) versus a matched European reference population.

The elevated adiposity we observed in our T2T RA patients relative to sedentary controls (FM (kg) increased by 26.5%, BF% increased 15.5%, trunk FM increased 32.3%) is also consistent with the observations made in our pre-T2T RA patients (total FM increases of ~17% [4] and ~13% [3] versus HC), and generally with the DXA-assessed disparities in adiposity reported by others in stable, pre-T2T RA patients relative to matched HC (FM (kg) increased by 12% [5]; FM and trunk FM increased 13% and 25%, respectively [43]; FM and trunk FM increased 12.5% and 13.5%, respectively, in females, and 5.4% and 7.1% in males [42]; FM and trunk FM increased 13.5% and 21.6%, respectively, in females, with no additional adiposity in males [2]; and FM and trunk FM increased 15.3% and 19.4%, respectively, in females, with no additional adiposity in males [44]). Whilst the RA patients in the current study were more sedentary than the HC, the between-group difference only amounted to approximately 30 minutes walking/week, and both groups, by a distance, failed to achieve the minimum recommendation for long-term loss of FM of 250 min/week of moderate intensity physical activity (PA) [45]. This 30 minute disparity in low-moderate intensity PA would also not account for the difference in MM, as higher-intensity exercise is required to elicit hypertrophy [45]. Thus, our findings clearly indicate that rheumatoid cachexia has not been resolved, or even attenuated, by tight control of DA, despite the other clinical benefits this approach confers.

We also demonstrated in this study that objectively-assessed physical function has not improved with T2T therapy. This finding is not surprising in view of the lack of improvement in either muscle mass or fat mass, and the strong association between these and physical function in RA patients [16, 20-22]. In our T2T patients, strength relative to health controls was reduced by ~25% and the performance level of tests designed to reflect the ability to perform ADL and live independently [38], reduced by about a third. More tellingly with regard to the effect of T2T on function, the test scores obtained by patients in the current study were not better, and in some cases were worse (8'UG, 50'W), than those of patients in our earlier studies [3-4, 9-12, 30-31] who were of similar age and gender distribution. To provide a context of how poor the physical function of our T2T RA patients is, Rikli and Jones [38] recently published minimal fitness standards compatible with living independently until late in life using objective tests (including STS-30 and 8'UG). In the present study, the RA women (mean age 58.6 years) achieved a STS-30 score appropriate for healthy 'moderate functioning' women aged 80-84 years, and the RA men (mean age of 65.0 years) a score in line with healthy 'moderate functioning' men of 85-89 years. For the 8'UG test, the respective equivalents were 85-89 years for the women, and the men failed to achieve the standard of 90-94 year old healthy men (the highest age category). Hence, on average, both the female and male patients had the function of healthy individuals approximately 25 years older.

Despite the substantial deficits in objectively-measured physical function (28-34% worse than sedentary HC), it is revealing that the patients generally rated their disability as only being 'mild' (mean MDHAQ = 0.57). Also of interest, is that our earlier (pre-T2T) patients, although generally performing the objective tests as well, if not better than, the recent T2T patients, subjectively rated their disability as being higher (e.g. data collected 2005-2007, baseline means; DAS28 = 3.3, STS30 = 12.5 reps, 50'W = 9.3 secs, IKES = 323 N, MDHAQ = 0.91 [9]). This improvement in

subjectively-assessed function (e.g. HAQ, MDHAQ) with T2T has been widely reported [26, 32-33] and may be due to reductions in pain [25], as pain is known to strongly influence HAQ scores [34-35, 46]. This discord between objectively- and subjectively-assessed function in stable RA patients, together with the underestimation RA patients have of their disability, highlights the value of objective function tests and provides further evidence of their greater sensitivity for detecting functional change in patients with well-controlled disease [9, 36].

A key aim of T2T is the "normalisation of function" (e.g. "Overarching principal" B; EULAR/International Task Force Recommendations [23-24]; ACR [28]). Our findings indicate that T2T has made inadequate progress in achieving this, even for patients achieving 'remission' (DAS28 = 2.0 ± 0.4; whose performance of function tests was approximately $1/5^{th}$ – $1/3^{rd}$ poorer than sedentary HC). Additionally, we may have underestimated the extent of functional loss (and the perturbations in body composition) existing in broader RA populations as low DA and a high remission rate were achieved for our patients primarily with DMARD monotherapy, and no recourse to biologics, indicating that our cohort generally only has mild-moderate, and responsive, disease.

Another point to raise is the failure of widely-used measures of treatment efficacy for T2T (e.g. DAS28) to assess function, either objectively or subjectively, which is counter to both the prominence that restoration of physical function has amongst the goals of this treatment, and the strong associations function has with morbidity, mortality, treatment costs and patient quality of life in RA [47].

An obvious question arising from our results is why has T2T failed to improve body composition and, consequently, physical function, given its beneficial effects on inflammation and disease activity, the purported drivers of rheumatoid cachexia? A likely explanation is that the perturbations

in body composition predominantly occur very early in the disease (i.e. during the 'pre-clinical' stage), and thus prior to the initiation of treatment. This proposal is consistent with: i) the absence of differences in anthropometric, body composition, or physical function measures between our 'recent' and 'established' RA patients; ii) reports of a similar incidence and magnitude of rheumatoid cachexia in recently diagnosed RA patients as for established patients [2, 12]; iii) indications that the rate of muscle loss in established, controlled patients is similar to that of healthy individuals [10, 44]; and iv) the consistent findings that disease processes, including inflammation and co-morbidity risk are already elevated in the pre-clinical period [48].

To summarise, our study shows that T2T, despite its enhanced efficacy in reducing DA, inflammation and joint damage, has not improved patients' body composition or physical function relative to previous treatment regimes. As a consequence, RA patients remain significantly muscle wasted and fatter, and this, at least in part, accounts for why they have substantially impaired function relative to healthy individuals. Unfortunately, these important adverse consequences of RA are usually neglected as the T2T regimen posits that the DAS28 score should be the clinician's primary concern. Consequently, in this pharmacological model of treatment, focus on the need for rehabilitation has diminished. The inclusion of an objective function test(s) during clinical reviews of disease activity would highlight to both the rheumatologist and the patient the need for adjunct treatments, such as high intensity exercise (especially resistance training [3, 9] and nutritional supplementation [11, 49-50], that specifically aim to restore body composition and physical function in RA patients.

Words: 3498

Funding: This work was supported by a clinical career development funding from the Wales Arthritis Research Network (WARN) which provided a 20% release from clinical duties for one year

for FS, enabling him to contribute to this study. No other specific funding was received from any funding bodies in the public, commercial or not-for-profit sectors to carry out the work described in this article.

Disclosure statement: The authors have declared no conflicts of interest.

REFERENCES

1 Roubenoff R, Roubenoff R, Ward L *et al*. Rheumatoid cachexia: depletion of lean body mass in rheumatoid arthritis. Possible association with tumor necrosis factor. J Rheumatol 1992;19:1505-10.

2 Book C, Karlsson MK, Åkesson K, Jacobsson LT. Early rheumatoid arthritis and body composition. Rheumatology 2009;48:1128-32.

3 Marcora SM, Lemmey AB, Maddison PJ. Can progressive resistance training reverse cachexia in patients with rheumatoid arthritis? Results of a pilot study. J Rheumatol 2005;32:1031-39.

4 Matschke V, Murphy P, Lemmey AB *et al*. Skeletal muscle properties in rheumatoid arthritis patients. Med Sci Sports Exerc 2010;42:2149-55.

5 Toussirot E, Nguyen N, Dumoulin G *et al*. Relationship between growth hormone–IGF-I–IGFBP-3 axis and serum leptin levels with bone mass and body composition in patients with rheumatoid arthritis. Rheumatology 2005;44:120-25.

6 Baker JF, Long J, Ibrahim S *et al*. Are men at greater risk of lean mass deficits in rheumatoid arthritis? Arthritis Care Res 2015;67:112-19.

7 Elkan AC, Engvall IL, Tengstrand B *et al*. Malnutrition in women with rheumatoid arthritis is not revealed by clinical anthropometrical measurements or nutritional evaluation tools. Eur J Clin Nutr 2008;62:1239-47.

8 Elkan AC, Engvall IL, Cederholm T, Hafström I. Rheumatoid cachexia, central obesity and malnutrition in patients with low-active rheumatoid arthritis: feasibility of anthropometry, Mini Nutritional Assessment and body composition techniques. Eur J Clin Nutr 2009;48:315-22.

9 Lemmey AB, Marcora SM, Chester K *et al*. Effects of high-intensity resistance training in patients with rheumatoid arthritis: A randomized controlled trial. Arthritis Care Res 2009;61:1726-34.

10 Lemmey AB, Williams SL, Marcora SM *et al*. Are the benefits of a high-intensity progressive resistance training program sustained in rheumatoid arthritis patients? A 3-year followup study. Arthritis Care Res 2012; 64: 71-75.

11 Marcora SM, Lemmey AB, Maddison PJ. Dietary treatment of rheumatoid cachexia with β-hydroxy-β-methylbutyrate, glutamine and arginine: A randomised controlled trial. Clin Nutr 2005;24:442-54.

12 Marcora SM, Chester KR, Mittal G *et al*. Randomized phase 2 trial of anti-tumor necrosis factor therapy for cachexia in patients with early rheumatoid arthritis. Am J Clin Nutr 2006;84:1463-72.

13 Munro R, Capell H. Prevalence of low body mass in rheumatoid arthritis: association with the acute phase response. Ann Rheum Dis 1997;56:326-29.

14 Roubenoff R, Roubenoff RA, Cannon J *et al*. Rheumatoid cachexia: cytokine-driven hypermetabolism accompanying reduced body cell mass in chronic inflammation. J Clin Invest 1994;93:2379-86.

15 Summers G, Deighton C, Rennie M, Booth A. Rheumatoid cachexia: a clinical perspective. Rheumatology 2008;47:1124-31.

16 Stavropoulos-Kalinoglou A, Metsios GS, Panoulas VF *et al*. Underweight and obese states both associate with worse disease activity and physical function in patients with established rheumatoid arthritis. Clin Rheumatol 2009;28:439-44.

17 Giles JT, Allison M, Blumenthal RS *et al*. Abdominal adiposity in rheumatoid arthritis: association with cardiometabolic risk factors and disease characteristics. Arthritis Rheumatol 2010;62:3173-82.

18 Katz PP, Yazdany J, Trupin L *et al*. Sex differences in assessment of obesity in rheumatoid arthritis. Arthritis Care Res 2013;65:62-70.

19 Summers GD, Metsios GS, Stavropoulos-Kalinoglou A, Kitas GD. Rheumatoid cachexia and cardiovascular disease. Nat Rev Rheumatol 2010;6:445-51.

20 Baker JF, Von Feldt J, Mostoufi-Moab S *et al*. Deficits in muscle mass, muscle density, and modified associations with fat in rheumatoid arthritis. Arthritis Care Res 2014;66:1612-18.

21 Giles JT, Bartlett SJ, Andersen RE *et al*. Association of body composition with disability in rheumatoid arthritis: impact of appendicular fat and lean tissue mass. Arthritis Care Res 2008;59:1407-15.

22 Lusa AL, Amigues I, Kramer HR *et al*. Indicators of walking speed in rheumatoid arthritis: relative influence of articular, psychosocial, and body composition characteristics. Arthritis Care Res 2015;67:21-31.

23 Smolen JS, Aletaha D, Bijlsma JW *et al*. Treating rheumatoid arthritis to target: recommendations of an international task force. Ann Rheum Dis 2010;69:631-37.

24 Smolen JS, Breedveld FC, Burmester GR *et al*. Treating rheumatoid arthritis to target: 2014 update of the recommendations of an international task force. Ann Rheum Dis 2015;0:1-13.

25 Solomon DH, Bitton A, Katz JN *et al*. Review: treat to target in rheumatoid arthritis: fact, fiction, or hypothesis? Arthritis Rheum 2014;66:775-82.

26 Vermeer M, Kuper H, Moens H *et al*. Sustained beneficial effects of a protocolized treat-to-target strategy in very early rheumatoid arthritis: Three-year results of the Dutch Rheumatoid Arthritis Monitoring remission induction cohort. Arthritis Care Res 2013;65:1219-26.

27 Walsmith J, Abad L, Kehayias J, Roubenoff R. Tumor necrosis factor-alpha production is associated with less body cell mass in women with rheumatoid arthritis. J Rheumatol 2004;31:23-29.

28 Singh JA, Furst DE, Bharat A *et al*. 2012 Update of the 2008 American College of Rheumatology recommendations for the use of disease-modifying antirheumatic drugs and biologic agents in the treatment of rheumatoid arthritis. Arthritis Care Res 2012;64:625-39.

29 Chen YM, Chen HH, Hsieh CW *et al*. A close association of body cell mass loss with disease activity and disability in Chinese patients with rheumatoid arthritis. Clinics 2011;66:1217-22.

30 Matschke V, Murphy P, Lemmey AB *et al*. Muscle quality, architecture, and activation in cachectic patients with rheumatoid arthritis. J Rheumatol 2010;37:282-84.

31 Matschke V, Jones JG, Lemmey AB *et al*. Patellar tendon properties and lower limb function in rheumatoid arthritis and ankylosing spondylitis versus healthy controls: a cross-sectional study. Scientific World Journal 2013;514743.

32 Seto Y, Inoue E, Shidara K *et al*. Functional disability can deteriorate despite suppression of disease activity in patients with rheumatoid arthritis: a large observational cohort study. Mod Rheumatol 2013;23:1179-85.

33 Sugihara T, Ishizaki T, Hosoya T *et al*. Structural and functional outcomes of a therapeutic strategy targeting low disease activity in patients with elderly-onset rheumatoid arthritis: a prospective cohort study (CRANE). Rheumatology 2015;54:798-807.

34 Sokka T, Kankainen A, Hannonen P. Scores for functional disability in patients with rheumatoid arthritis are correlated at higher levels with pain scores than with radiographic scores. Arthritis Rheum 2000;43:386-89.

35 Wolfe F. A reappraisal of HAQ disability in rheumatoid arthritis. Arthritis Rheum 2000;43:2751-2761.

36 Van den Ende C, Breedveld F, Dijkmans B, Hazes J. The limited value of the Health Assessment Questionnaire as an outcome measure in short term exercise trials. J Rheumatol. 1997;24(10):1972-77.

37 Aletaha D, Neogi T, Silman AJ *et al*. 2010 rheumatoid arthritis classification criteria: an American College of Rheumatology/European League Against Rheumatism collaborative initiative. Arthritis Rheum 2010;62:2569-81.

38 Rikli RE, Jones CJ. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. Gerontologist 2013;53:255-67.

39 Matschke V, Thom JM, Lemmey AB *et al*. Adverse changes in tendon–muscle physiology and physical function caused by an isolated acute rheumatoid knee effusion: a case study. Arthritis Care Res 2012;64:117-21.

40 Pincus T, Sokka T, Kautiainen H. Further development of a physical function scale on a multidimensional health assessment questionnaire for standard care of patients with rheumatic diseases. J Rheumatol 2005;32:1432-39.

41 Engvall I, Elkan A, Tengstrand B *et al*. Cachexia in rheumatoid arthritis is associated with inflammatory activity, physical disability, and low bioavailable insulin-like growth factor. Scand J Rheumatol 2008;37:321-28.

42 Giles JT, Ling SM, Ferrucci L *et al*. Abnormal body composition phenotypes in older rheumatoid arthritis patients: association with disease characteristics and pharmacotherapies. Arthritis Care Res 2008;59:807-15.

43 Dao H-H, Do QT, Sakamoto J. Abnormal body composition phenotypes in Vietnamese women with early rheumatoid arthritis. Rheumatology 2011;50:1250-58.

44 Book C, Karlsson M, Nilsson JÅ *et al*. Changes in body composition after 2 years with rheumatoid arthritis. Scand J Rheumatol 2011;40:95-100.

45 ACSM's Guidelines for Exercise Testing and Prescription 9th Edition. Editors: Pescatello LS, Arena R, Riebe D, Thompson PD. Lippincott Williams & Wilkins; 2014.

46 Malm K, Bergman S, Andersson M, Bremander A. Predictors of severe self-reported disability in RA in a long-term follow-up study. Disabil Rehabil 2014;37:686-91.

47 Pincus T, Castrejon I, Yazici Y. Documenting the value of care for rheumatoid arthritis, analogous to hypertension, diabetes, and hyperlipidemia: is control of individual patient self-report measures of global estimate and physical function more valuable than laboratory tests, radiographs, indices, or remission criteria? J Rheumatol 2013;40:1469-74.

48 Steenbergen H, Huizinga T, Helm-van Mil A. Review: The Preclinical Phase of Rheumatoid Arthritis: What Is Acknowledged and What Needs to be Assessed? Arthritis Rheum 2013;65:2219-32.

49 Willer B, Stucki G, Hoppeler H *et al*. Effects of creatine supplementation on muscle weakness in patients with rheumatoid arthritis. Rheumatology 2000;39:293-98.

50 Wilkinson T. J., Lemmey A.B., Sheikh F. *et al*. Effects of oral creatine supplementation on body composition and objective physical function in Rheumatoid arthritis patients. A randomised controlled trial. Arthritis Care Res 2015; in press.

TABLE 1. Demographic and clinical characteristics for rheumatoid arthritis patients and sedentary, age- and sex-matched health controls

	RA (*n* = 82)	HC (*n* = 85)	*P*
Age (years)	60.9 (±11.7)	60.9 (±8.1)	0.962
Sex (*n* female) (%)	53 (65)	55 (65)	0.992
Disease duration (months)	23.8 (±19.0)	-	-
Seropositive RA; *n* (%)	67 (85)	-	-
DAS28 (0-10)	2.8 (1.0)	-	-
Medications, n (%)			
Methotrexate [a]	68 (83)	-	-
Hydroxychloroquine	26 (32)	-	-
Leflunomide	7 (9)	-	-
Sulfasalazine	5 (6)	-	-
Tacrolimus	3 (4)	-	-
Mycophenolate mofetil	1 (1)		
Biologic	0 (0)	-	-
Mono-DMARD therapy	48 (59)		
Combination DMARDs [b]	30 (37)	-	-
No DMARD	3 (4)		
Corticosteroids [c]	7 (9)	1 (1)	**0.026***
Analgesics/NSAIDs	44 (54)	8 (9)	**< 0.001***
Smoking status, n (%)			
Current smokers; *n* (%)	18 (22)	3 (5)	**< 0.001***
Ex-smokers; *n* (%)	39 (48)	25 (31)	**< 0.016***
Never smokers; *n* (%)	25 (30)	52 (61)	**< 0.001***

Subjective measure of disability			
MDHAQ score (/3)	0.57 (±0.54)	0.08 (±0.24)	**0.001***
Exercise frequency [d], n (%)			
Exercise frequency score (0-3)	1.1 (±1.3)	2.2 (±1.0)	**< 0.001***
Do not regularly exercise (0)	43 (52)	9 (11)	**< 0.001***
1-2 times a month (1)	6 (8)	7 (8)	0.825
1-2 times a week (2)	11 (14)	27 (32)	**0.005***
>3 times a week (3)	20 (25)	41 (49)	**0.001***

Unless stated, data presented as mean (±SD). Differences at baseline were assessed using analyses of variance or Chi-square test as appropriate. RA = rheumatoid arthritis; HC = healthy control group; Seropositive RA = rheumatoid factor and/or anti-CCP seropositive; DAS28 = Disease Activity Score in 28 joints; [a] = supplemented with folate; DMARD = disease modifying anti-rheumatic drug; [b] = double or triple DMARD therapy; [c] = current corticosteroid range 5.0 – 10.0 mg/d; NSAID = non-steroidal anti-inflammatory drug; MDHAQ = multi-dimensional health assessment questionnaire; [d] = self-reported exercise frequency taken from MDHAQ (not reported: RA = 2, HC = 1); Exercise frequency score: 0 = no regular exercise; 1 = 1-2 times a month; 2 = 1-2 times a week; 3 = >3 times a week; unless adjusted by Bonferroni adjustment * = significant ($P < 0.05$); [#] = trend ($P = 0.05$ - 0.10).

TABLE 2. Body composition measures for rheumatoid arthritis patients and sedentary, age- and sex-matched health controls

	RA (n = 82)	HC (n = 85)	% difference (CI for absolute difference)	P
Waist circ. (cm)	91.6 (±17.9)	83.9 (±10.8)	↑ 8.4 (3.2 – 12.2)	**0.001***
Hip circ. (cm)	101.9 (±12.7)	99.1 (±7.8)	↑ 2.7 (-0.4 – 6.1)	0.128
Waist: hip ratio	0.90 (±0.10)	0.85 (±0.08)	↑ 5.6 (0.0 – 0.1)	**< 0.001***
BM (kg)	76.5 (17.9)	71.7 (±11.1)	↑ 6.3 (0.2 – 9.3)	0.093#
Height (cm)	165.1 (±7.9)	168.1 (±8.6)	↓ 3.0 (0.5 – 5.5)	**0.019***
BMI (kg/m^2)	28.0 (±6.0)	25.4 (±3.4)	↑ 9.3 (-4.1 - -1.2)	**0.002***
DXA-assessed measures				
ALM (kg)	19.8 (±4.6)	20.9 (±5.2)	↓ 5.6 (-0.4 – 2.6)	0.158
ALM % (ALM/TBM %)	26.2 (±4.0)	28.8 (±4.2)	↓ 9.9 (1.4 – 3.9)	**< 0.001***
Total LM (kg)	48.7 (±9.8)	49.5 (±10.0)	↓ 1.6 (-2.2 – 3.9)	0.578
TLM % (LM/BM %)	64.4 (±7.5)	68.6 (±6.8)	↓ 6.5 (1.9 – 6.3)	**< 0.001***
Total FM (kg)	25.8 (±10.4)	20.4 (±6.2)	↑ 26.5 (-7.9 - -2.7)	**< 0.001***
BF%	32.7 (±7.8)	28.3 (±7.2)	↑ 15.5 (2.1 – 6.7)	**< 0.001***
Trunk FM (kg)	13.1 (±6.3)	9.9 (±3.7)	↑ 32.3 (1.6 – 4.8)	**0.001***

Data presented as mean (±SD). CI = 95 % confidence interval; RA = rheumatoid arthritis; HC = healthy control group; BM = body mass; BMI = body mass index; DXA = dual energy x-ray absorptiometry; ALM = appendicular lean mass; TLM = total lean mass; FM = fat mass; BF% = % body fat (i.e. FM/BM x 100); unless adjusted by Bonferroni adjustment * = significant (P < 0.05), # = trend (P = 0.05 - 0.10).

TABLE 3. Objective physical function and self-reported disability for rheumatoid arthritis patients and sedentary, age- and sex-matched health controls

	RA (n = 82)	HC (n = 85)	Absolute difference (*% difference*) (CI)	*P*
IKES (N)	380 (±140)	472 (±152)	↓ 92 *(24.3)* (46 – 138)	**< 0.001***
HGS (kg)	26.5 (±8.8)	33.2 (±9.9)	↓ 6.7 *(25.3)* (3.8 – 9.7)	**< 0.001***
STS-30 test (reps)	12.0 (±3.6)	16.1 (±4.3)	↓ 4.1 *(34.2)* (2.8 – 5.3)	**< 0.001***
8'UG (secs)	7.4 (±3.9)	5.1 (±1.0)	↑ 2.3 *(31.1)* (1.4 – 3.1)	**< 0.001***
50'W (secs)	10.7 (±5.3)	7.7 (±1.8)	↑ 3.0 *(28.0)* (1.8 – 4.3)	**< 0.001***

Data presented as mean (±SD). CI = 95 % confidence interval; RA = rheumatoid arthritis; HC = healthy control group; IKES = isometric knee extensor strength; HGS = handgrip strength; STS-30 = Sit-to-stands in 30 seconds; 8'UG = 8-foot up and go; 50'W = 50-foot walk: unless adjusted by Bonferroni adjustment * = significant ($P < 0.05$), $^{\#}$ = trend ($P = 0.05$ - 0.10).

TABLE 4. Demographic and clinical characteristics for rheumatoid arthritis patients in 'remission' (DAS28 < 2.6) or not (DAS28 ≥ 2.6)

	'In remission' vs 'Not in remission'			HC vs 'In remission'	
	'In remission' (*n* = 40)	'Not in remission' (*n* = 42)	*P*	HC (*n* = 85)	*P*
Age (years)	60.4 (±12.2)	61.4 (±11.3)	0.706	60.9 (±8.1)	0.764
Sex (*n* female) (%)	23 (58)	30 (71)	0.187	55 (65)	0.435
Disease duration (months)	23.1 (±17.5)	24.5 (±20.6)	0.740	-	-
Serpositive RA; *n* (%)	32 (80)	35 (83)	0.886	-	-
DAS28 (0-10)	2.0 (±0.4)	3.6 (±0.8)	**< 0.001***	-	-
CRP (mg/L)	7.3 (±7.7)	13.1 (±14.4)	**0.024***	-	-
Medications, n (%)					
Methotrexate [a]	34 (85)	34 (81)	0.626	-	-
Hydroxychloroquine	3 (8)	2 (5)	0.604	-	-
Leflunomide	3 (8)	4 (10)	0.743	-	-
Sulfasalazine	13 (33)	13 (31)	0.880	-	-
Tacrolimus	1 (3)	1 (2)	0.972	-	-
Mycophenolate mofetil	0 (0)	1 (2)	-	-	-
Biologic	0 (0)	0 (0)	-	-	-
Mono-DMARD therapy	24 (60)	25 (60)	0.930	-	-
Combination DMARDs [b]	15 (38)	15 (36)	0.930	-	-
No DMARD	1 (3)	2 (5)	0.586	-	-
Corticosteroids [c]	3 (8)	4 (10)	0.743	1 (1)	**0.061***
Analgesics/NSAIDs	16 (40)	28 (67)	**0.015***	8 (9)	**< 0.001***

Smoking status, n (%)					
Current smokers; *n* (%)	7 (18)	11 (26)	0.180	3 (5)	**0.014***
Ex-smokers; *n* (%)	19 (48)	20 (48)	0.493	25 (31)	**0.007***
Never smokers; *n* (%)	14 (35)	11 (26)	0.542	52 (61)	**0.001***
Subjective measure of disability					
MDHAQ score (/3)	0.32 (±0.32)	0.81 (±0.59)	**< 0.001***	0.08 (±0.04)	**0.001***
Exercise frequency[d], n (%)					
Exercise frequency score (0-3)	1.1 (±1.3)	1.2 (±1.3)	0.733	2.2 (±1.0)	**< 0.001***
Do not exercise (0)	22 (55)	21 (50)	0.733	7 (8)	**< 0.001***
1-2 times a month (1)	4 (10)	2 (5)	0.363	7 (8)	0.745
1-2 times a week (2)	4 (10)	7 (18)	0.376	27 (32)	**0.009***
>3 times a week (3)	10 (25)	10 (25)	0.900	41 (49)	**0.014***

Unless stated, data presented as mean (±SD). Differences at baseline were assessed using analyses of variance or Chi-square test as appropriate. Seropositive RA = rheumatoid factor and/or anti-CCP seropositive; DAS28 = Disease Activity Score in 28 joints; [a] = supplemented with folate; DMARD = disease modifying anti-rheumatic drug; [b] = double or triple DMARD therapy; [c] = current corticosteroid range 5.0 – 10.0 mg/d; NSAID = non-steroidal anti-inflammatory drug; MDHAQ = multi-dimensional health assessment questionnaire; [d] = self-reported exercise frequency taken from MDHAQ (not reported: RA = 2, HC = 1); Exercise frequency score: 0 = no regular exercise; 1 = 1-2 times a month; 2 = 1-2 times a week; 3 = >3 times a week; unless adjusted by Bonferroni adjustment * = significant ($P < 0.05$); [#] = trend ($P = 0.05$ - 0.10).

TABLE 5. Body composition measures for rheumatoid arthritis patients in 'remission' (DAS28 < 2.6) or not (DAS28 ≥ 2.6)

	'In remission' vs 'Not in remission'					HC vs 'In remission'		
	'In remission' (n = 40)	'Not in remission' (n = 42)	Absolute difference (CI)	P	$P^{¥}$	HC (n = 85)	Absolute difference (CI)	$P^{¥}$
Waist circ. (cm)	90.3 (±16.5)	92.9 (±19.2)	-2.6 (-10.5 – 5.3)	0.514	0.258	83.9 (±10.8)	-6.4 (-10.7– - 0.3)	**0.039***
Hip circ. (cm)	100.0 (±10.0)	103.8 (±14.7)	-3.9 (-9.4 – 1.7)	0.169	0.246	99.1 (±7.8)	-0.9 (-5.1 – 2.9)	0.592
Waist: hip ratio	0.90 (±0.12)	0.90 (±0.09)	0.00 (-0.05 – 0.04)	0.949	0.139	0.85 (±0.08)	-0.05 (-0.07- - 0.02)	**< 0.001***
BM (kg)	74.9 (±17.7)	78.0 (±18.2)	-3.2 (-11.1 – 4.7)	0.425	0.183	71.7 (±11.1)	-3.2 (-7.3 – 2.9)	0.397
Height (cm)	166.0 (±8.2)	164.2 (±8.2)	-1.8 (-5.5. – 1.7)	0.287	0.306	168.1 (±8.6)	2.1 (-1.1 – 5.2)	0.195
BMI (kg/m^2)	27.0 (±5.1)	29.0 (±6.7)	-2.0 (-4.6 – 0.7)	0.143	0.133	25.4 (±3.4)	-1.6 (-3.4 – 0.2)	0.084$^{\#}$
DXA-assessed measures								
ALM (kg)	19.7 (±4.6)	19.9 (±4.6)	-0.1 (-2.2 – 1.9)	0.905	0.148	20.9 (±5.2)	1.2 (0.6 – 2.8)	**0.003***
ALM % (ALM/TBM %)	26.9 (±3.9)	25.5 (±3.9)	1.3 (-0.4 – 3.1)	0.122	0.347	28.8 (±4.2)	1.9 (1.2 – 3.5)	**< 0.001***
TLM (kg)	48.2 (±9.4)	49.2 (±10.3)	-1.0 (-5.4 – 3.4)	0.650	0.071$^{\#}$	49.5 (±10.0)	1.3 (-0.2 – 4.6)	0.052$^{\#}$
Total LM % (LM/TBM %)	65.5 (±6.6)	63.3 (±8.0)	2.2 (-1.0 – 5.5)	0.179	0.458	68.6 (±6.8)	3.1 (1.5 – 5.8)	**0.001***
Total FM (kg)	24.2 (±9.2)	27.3 (±11.3)	-3.1 (-7.7 – 1.4)	0.176	0.241	20.4 (±6.2)	-3.8 (-7.1 - -0.8)	**0.014***
BF%	31.5 (±7.0)	33.8 (±8.5)	-2.4 (-5.8 – 1.0)	0.170	0.434	28.3 (±7.2)	-3.2 (-6.1 - -1.5)	**0.001***
Trunk FM (kg)	12.2 (±6.1)	13.9 (±6.4)	-1.6 (-4.4 – 1.1)	0.242	0.252	9.9 (±3.7)	-2.3 (-4.3 - -0.4)	**0.017***

Data presented as unadjusted mean (±SD). CI = 95 % confidence interval; RA = rheumatoid arthritis; HC = healthy controls; BM = body mass;

BMI = body mass index; DXA = dual x-ray absorptiometry; ALM = appendicular lean mass; TLM = total lean mass; FM = fat mass; BF% = %

body fat (i.e. FM/BM x 100); unless adjusted by Bonferroni adjustment * = significant ($P < 0.05$); [#] = trend ($P = 0.05$ - 0.10); $P^{¥}$ = adjusted significance value when sex included as co-variant due to a difference in the proportion of males to females.

TABLE 6. Objective physical function and self-reported disability for rheumatoid arthritis in 'remission' (DAS28 < 2.6) or not (DAS28 ≥ 2.6)

	'In remission' vs 'Not in remission'					HC vs 'In remission'		
	'In remission' (n = 40)	'Not in remission' (n = 42)	Absolute difference (CI)	P	$P^{¥}$	HC (n = 85)	Absolute difference (CI)	$P^{¥}$
IKES (N)	414 (±141)	343 (±130)	71 (10 – 132)	**0.023***	0.052[#]	477 (±155)	62 (26 - 117)	**0.002***
HGS (kg)	29.6 (±8.3)	22.9 (±9.3)	6.6 (2.7 – 10.5)	**0.001***	**0.002***	33.4 (±10.0)	3.8 (2.4 – 7.4)	**< 0.001***
STS-30 test (reps)	12.3 (±3.3)	11.7 (±3.9)	0.5 (-1.1 – 2.1)	0.513	0.459	16.1 (±4.3)	3.8 (2.3 – 5.3)	**< 0.001***
8'UG (secs)	6.6 (±2.1)	8.2 (±4.9)	-1.6 (-3.3 – 0.1)	0.057[#]	**0.042***	5.1 (±1.0)	-1.5 (-2.5 - -0.4)	**0.008***
50'W (secs)	9.5 (±2.4)	11.9 (±6.8)	-2.3 (-4.6 - - 0.1)	**0.042***	**0.037***	7.7 (±1.8)	-1.8 (-3.3 - -0.4)	**0.014***

Data presented as unadjusted mean (±SD). CI = 95 % confidence interval; RA = rheumatoid arthritis; HC = healthy controls; IKES = isometric knee extensor strength; HGS = handgrip strength; STS-30 = Sit-to-stands in 30 seconds; 8'UG = 8-foot up and go; 50'W = 50-foot walk; unless adjusted by Bonferroni adjustment * = significant ($P < 0.05$); [#] = trend ($P = 0.05$ - 0.10); $P^{¥}$ = adjusted significance value when sex included as co-variant due to a difference in the proportion of males to females.