

# Conservative hand therapy treatments in rheumatoid arthritis—a randomized controlled trial

A. V. O'Brien<sup>1,2</sup>, P. Jones<sup>3</sup>, R. Mullis<sup>4</sup>, D. Mulherin<sup>2</sup> and K. Dziedzic<sup>4</sup>

**Objective.** To evaluate the effectiveness of three different physiotherapeutic approaches in the management of the rheumatoid hand.

**Methods.** In a randomized controlled trial, participants with rheumatoid arthritis (RA) recruited from a rheumatology department in Mid-Staffordshire, UK (February 1999 to January 2001) were randomized to three groups. All received joint protection (JP) information delivered by a therapist at baseline. Group 1 participants received a set of additional hand-strengthening and mobilizing home exercises, group 2 a different set of additional hand-stretching exercises and group 3 the JP information alone. The primary outcome was the Arthritis Impact Measurement Scales II (AIMS II) (upper limb; hand and finger function subscales). Outcomes were assessed at baseline and 1, 3 and 6 months. Analysis was by intention to treat.

**Results.** Sixty-seven participants (mean age 59.6 yr) were recruited: group 1  $n = 21$ , group 2  $n = 24$  and group 3  $n = 22$ . A 78% follow-up was achieved at 6 months. There was a mean fall (SD) in AIMS II upper limb function 0–6 month change scores in group 1 of 1.00 (1.07). In groups 2 and 3 there was a mean increase in AIMS II scores of 0.18 (1.54) and 0.30 (1.22), respectively. The differences in AIMS change scores between group 1 and groups 2 and 3 were statistically significant ( $P = 0.007$ ) and remained so after adjustment for multiple testing ( $P = 0.012$ ).

**Conclusion.** Statistically significant improvements in arm function have been demonstrated following a programme of home-strengthening hand exercises in RA patients compared with simple stretches or advice alone.

KEY WORDS: Rheumatoid arthritis, Hand therapy, Exercise, Randomized controlled trial, Physiotherapy.

Rheumatoid arthritis (RA) affects approximately 0.81% of the adult population in the United Kingdom (UK) [1]. It is a disease with no cure, which affects people of working age; the prevalence increases with age and may reach 5% above the age of 55 [2]. It is estimated that the hands and wrists are affected in 80–90% of RA patients [3]. The synovitis associated with RA may cause disruption in articular ligaments, erosion of cartilage and subchondral bone, and an invasion of pannus onto the joint [4]. Patients complain of various symptoms including joint pain and stiffness, loss of range of movement [5] and reduction in muscle power and grip [6], all of which can lead to increasing difficulties in performing activities of daily living (ADL).

Hand function is recognized as being important to those diagnosed with RA [7]. Therapists aim to maximize this function through treatment programmes and education [8]. Comparatively little research, however, has been undertaken to identify the optimum therapeutic management. The treatment options available today for the rheumatological therapist are extensive and may include manual therapy, electrotherapy and injection therapy in addition to traditional exercise prescription. Physiotherapy may form an essential part of management in RA patients [9], but the evidence base for treatments remains one of the weakest, particularly when focusing on the hand [10, 11].

The effectiveness of hand exercises in RA has been recently reviewed [11, 12] and only nine eligible studies have incorporated the use of hand exercises as part of their treatment intervention. Methodological limitations exist for all the trials, and in particular the majority of studies lacked sufficient detail when describing

interventions to allow replication, making comparisons between studies very difficult. Studies of the therapeutic benefits of exercise in patients with non-inflammatory arthritis are encouraging and rehabilitation exercise therapy may delay or even prevent the onset of osteoarthritis (OA) [13], although its effectiveness in hand OA is still uncertain. The relevance of this to patients with inflammatory arthritis is not fully known, but recent work has concluded that lower limb rehabilitation exercises not only improve the quadriceps function, but do this without exacerbating disease activity [14].

The primary aim of this study was to evaluate the clinical effectiveness of three different hand therapy approaches (two of which employed different hand exercise regimes) on changes in impairment and activity limitation in patients with RA over a 6-month period.

## Methods

### Study participants

This was a single-blind, randomized controlled trial conducted in the rheumatology department of Mid-Staffordshire General Hospitals NHS Trust. The Local Research Ethics Committee approved all stages of the study. Eligible participants over the age of 18 yr with a diagnosis of RA as defined by the American College of Rheumatology criteria [15] were recruited. Written consent was obtained according to the Declaration of Helsinki [16]. Participants with recent changes in drug regime [including a change of disease-modifying anti-rheumatic drugs (DMARDs)]

<sup>1</sup>School of Health and Rehabilitation, Keele University, <sup>2</sup>Rheumatology Department, Mid-Staffordshire General Hospitals NHS Trust, <sup>3</sup>School of Computing and Mathematics and <sup>4</sup>Primary Care Sciences Research Centre, Keele University, UK.

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Correspondence to: A. V. O'Brien, School of Health and Rehabilitation, MacKay Building, Keele University, Keele, Staffordshire ST5 5BG, UK.  
E-mail: a.v.o'brien@shar.keele.ac.uk

in the previous 3 months, those currently on oral corticosteroid therapy >7.5 mg/day or those who had received a corticosteroid intra-articular or intramuscular injection within the previous month] were excluded. Additional exclusion criteria were surgery to the wrist, hand, elbow or shoulder within the previous 6 months, sensory impairment to the hand, uncontrolled pain affecting the joints of the wrist or hand and pregnancy.

### Recruitment

Participants from out-patient rheumatology clinics were recruited via the multidisciplinary clinical team and were then screened by telephone by the research physiotherapist (AOB). A subsequent assessment appointment was scheduled where written consent was obtained, following which participants were allocated a unique study number, and baseline demographic information, including medication, was collected.

### Randomization

A computer-generated randomization list with permuted blocks within strata [17] was devised which stratified by length of time since diagnosis (less than or more than 5 yr) as well as rheumatoid factor serology (positive or negative). Following screening and consent, the research physiotherapist telephoned a blinded third party (from a central administrative team) informing them of stratification details; this person then subsequently identified treatment allocation. The research therapist (AOB) then referred the participant to the treating therapist (JS) who undertook the allocated treatment according to a protocol. All outcome assessments were undertaken blinded at baseline, 1, 3 and 6 months following randomization by one of two additional therapists (CS and KM).

### Study protocol/interventions

The content of the hand exercise interventions was defined following a survey of 60 senior hand therapists (physiotherapists and occupational therapists) from a purposive sample of members of the British Association of Hand Therapists (Chadwick, unpublished).

All trial participants were randomized to one of three treatment groups. All subjects received a joint protection leaflet which covered the basic principles of joint protection, energy conservation, 'top tips' relating to personal and household activities, postural advice, types of splinting and issues related to sexuality. Group 1 received additional instruction on how to perform a total of eight simple strengthening and mobilizing (stretching) 'tendon gliding' exercises. These encouraged a maximum range of movement of all small joints of the fingers, thumb and wrist, as well as radial finger walking (fingers moving towards the radius only thus avoiding exacerbating ulnar deviation), pinch grip exercises, strengthening the intrinsic, and thenar eminence muscles (using a towel) and wrist extensor muscle groups with a 'Theratubes' resistive band (Promedics, UK). Group 2 participants received the joint protection leaflet together with a set of eight stretching exercises, without any specific strengthening exercises. Exercises included wrist flexion, extension and circumduction, pronation and supination, radial deviation as well as global flexion and abduction of all finger joints, thumb opposition and interphalangeal flexion to the end of the possible range. Group 3 participants received the joint protection literature alone.

All participants had a 30-min appointment with an experienced musculoskeletal therapist who delivered the intervention and discussed relevant issues from the leaflet. All participants were reviewed at a 15-min follow-up appointment 2 weeks later to monitor concordance. Participants were requested to inform the

outcome assessors of any treatment changes (including medication or additional out-patient therapy) and were reminded to do so at each follow-up appointment. Any reported changes were documented by the two assessors (CS and KM). Subjects in groups 1 and 2 undertook a graduated programme, increasing repetitions of the exercises from 5 at baseline to 10 at 1 month and 20 repetitions of the exercises from 3 months onwards. All were instructed to perform the exercises slowly, progressing to the end of the available range of movement. These were performed twice daily at home over the 6-month study period. All participants were asked to complete a daily study diary that included any additional treatment changes.

### Outcome measures

Outcome assessments were performed by two assessors (CS and KM) who were blind to treatment allocation at baseline, 1, 3 and 6 months. The primary outcome measure was the Arthritis Impact Measurement Scales II (AIMS II; upper limb, and hand and finger function subscales) [18]. Each subscale asks five functional questions relating to the previous month. Subscales range from a potential summated score of 5–25 (25 indicating severe functional difficulties). Each AIMS II subscale was calculated by adding the individual items to form an aggregate score. This score was then normalized so that the potential range of scores was 0–10 where higher scores indicate more problems [18].

Secondary outcome measures included the Jebsen–Taylor hand function test [19], measured in seconds, power grip (in pounds) using the Jamar dynamometer [20] and key pinch (in pounds) using a pinch gauge (B&L Engineering, Tustin, CA, USA) in addition to dominant hand index finger flexion goniometry [21] measured in degrees. The summated flexion score of metacarpophalangeal, proximal and distal interphalangeal joints is reported. Disease activity was additionally measured with swollen and tender joint scores as well as patients' perceptions of their own disease activity.

### Statistical analysis

No appropriate data were available on the primary outcome prior to the study. Hence the sample size was based on an interim analysis after 15 participants had completed all three arms of the study. The sample size was based on a 0–6 month change in the primary outcome measure (AIMS II subscales). Using NCSS-Pass v6.0 (1996 NCSS, Kaysville, UT, USA) to carry out a power calculation for analysis of variance (ANOVA), the final sample size of 20 participants per arm was considered sufficient to estimate a large effect size with 80% power and 5% significance. Analysis was performed using SPSS version 10.0 for Windows (SPSS Inc., Chicago, IL, USA). An intention to treat analysis was undertaken. Statistical significance was set at the 5% level (two-tailed). The one-way ANOVA identified differences between the three treatment groups for approximately normally distributed data where mean and standard deviations were stated. Between-group differences in baseline characteristics were calculated using Kruskal–Wallis for the non-normal data where median and interquartile ranges were used to summarize the data. Analysis of covariance was used to generate significance levels adjusted for baseline differences in the three groups for AIMS II upper limb function and hand and finger function scores as well as the index finger flexion range of movement scores. Where statistically significant differences were found, the data were further analysed in paired groups using the *t*-test or Mann–Whitney U-test with non-normal data and *P* values were reported using Bonferroni adjustment for multiple testing in the primary outcome measure.

**Results**

*Recruitment*

The multidisciplinary team identified 167 consecutive participants with RA between February 1999 and January 2001. Of these, 125 patients gave permission to be contacted by telephone. Of those contacted, 52 declined to take part and 73 agreed to participate. The mean overall age for participants was 59.6 yr and 69% were female.

Figure 1 shows the progress of participants through the study. The follow-up rate of the sample at 6 months was 78% (52/67). There were no statistically significant differences between groups.

*Baseline characteristics*

Table 1 illustrates the baseline characteristics of the randomized participants. Baseline characteristics were similar between groups; participants in group 1 were older and had longer mean disease duration and higher scores for all disease activity measures

compared with participants in groups 2 and 3, although differences were not statistically significant.

*Primary outcome measure*

*AIMS II upper limb function.* Normalized mean and standard deviation (SD) AIMS II 0–6 month change scores for group 1 reduced by 1.0 point (1.07) indicating an improvement in upper limb function over the 6-month study period. This is in contrast to groups 2 and 3 whose mean change scores increased. For group 2, this was increased by 0.18 (1.54) and by 0.30 (1.22) for group 3, implying deterioration in function. This difference between groups was statistically significant ( $P=0.007$ ) (Table 2, Fig. 2). When adjusted for baseline values a statistically significant difference remained between groups for change scores over 6 months ( $P=0.012$ ).

Further analysis using the independent *t*-test revealed a statistically significant difference in upper limb function lay between subjects in groups 1 and 3 ( $P=0.002$ ). These pairwise

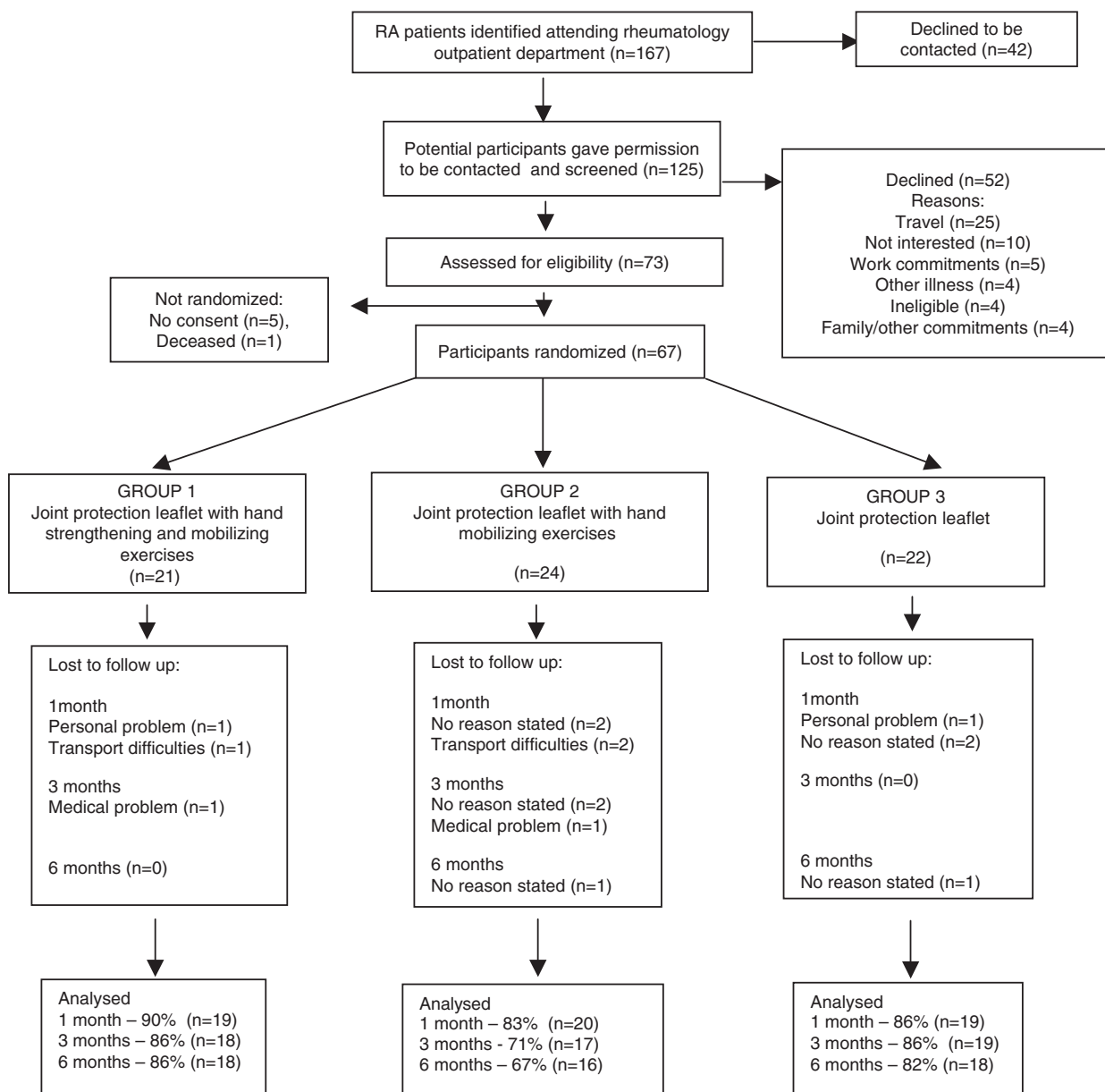


FIG. 1. Trial profile.

TABLE 1. Baseline characteristics of participants according to treatment group

Treatment group	Group 1 (n=21)	Group 2 (n=24)	Group 3 (n=22)
Male:female	6:15	9:15	6:16
Mean age (yr) (SD)	62.3 (9.95)	57.3 (8.24)	59.5 (12.92)
Mean disease duration (yr) (SD)	17.7 (14.21)	13.2 (11.63)	9.7 (7.59)
Mean hand pain VAS <sup>a</sup> (SD)	3.86 (2.19)	3.86 (2.36)	3.35 (2.32)
Baseline AIMS II ULF <sup>b</sup> mean scores (SD) (normalized to 0–10 scale)	5.90 (2.40)	5.05 (1.84)	5.40 (2.09)

<sup>a</sup>VAS, visual analogue scale (10 cm line).

<sup>b</sup>ULF, upper limb function.

TABLE 2. Outcome measures: results of change scores between baseline, 1, 3 and 6 months

Outcome measures	0–1 month	<i>P</i> (adjusted) <sup>a</sup>	0–3 months	<i>P</i> (adjusted) <sup>a</sup>	0–6 months	<i>P</i> (adjusted) <sup>a</sup>
AIMS upper limb function (0–10) mean (SD)						
Group 1	0.31 (1.14)		0.63 (1.59)		1.00 (1.07)	
Group 2	−0.25 (1.08)	0.295	−0.56 (1.47)	0.066	−0.18 (1.54)	0.007*
Group 3	−0.22 (1.25)	(0.370)	−0.06 (1.21)	(0.080)	−0.30 (1.22)	(0.012)**
AIMS hand and finger function (0–10) mean (SD)						
Group 1	0.97 (1.04)		0.47 (1.60)		0.97 (1.72)	
Group 2	−0.13 (1.54)	0.062	−0.47 (1.41)	0.180	0.18 (2.07)	0.414
Group 3	0.53 (1.37)	(0.106)	0.34 (1.67)	(0.226)	0.38 (1.68)	(0.729)
Jebesen–Taylor <sup>b</sup> (right hand, s) median (IQR)						
Group 1	5.92 (10.78)		7.62 (15.97)		7.92 (16.56)	
Group 2	3.74 (7.28)	0.260	5.47 (13.16)	0.942	3.38 (15.26)	0.627
Group 3	2.85 (14.06)		4.75 (11.82)		3.46 (13.73)	
Right index finger flexion (degrees) mean (SD)						
Group 1	13.35 (36.15)	0.376	20.08 (34.18)	0.051	8.97 (10.17)	0.599
Group 2	3.50 (16.92)	(0.342)	15.00 (25.06)	(0.130)	7.47 (12.02)	(0.761)
Group 3	1.80 (18.08)		−3.18 (22.78)		4.25 (18.07)	
Dominant gross grip <sup>b</sup> (lb) median (IQR)						
Group 1	3.30 (9.15)		6.20 (19.25)		9.70 (11.50)	
Group 2	3.30 (11.15)	0.946	5.00 (6.45)	0.126	6.70 (17.35)	0.300
Group 3	3.34 (8.83)		0.00 (16.88)		3.40 (21.32)	
Dominant key grip <sup>b</sup> (lb) median (IQR)						
Group 1	−0.50 (5.48)		0.15 (5.25)		1.00 (2.97)	
Group 2	0.00 (1.70)	0.863	−0.30 (2.50)	0.742	0.30 (2.60)	0.014*
Group 3	0.30 (3.50)		−1.00 (5.70)		−1.00 (2.45)	

Group 1, joint protection plus hand-strengthening exercises; group 2, joint protection plus hand-mobilizing exercises; group 3, joint protection advice alone.

IQR, interquartile range.

<sup>a</sup>Change scores, adjusted using analysis of covariance (ANCOVA) for baseline AIMS II upper limb and hand and finger function and finger goniometry are quoted in brackets.

\* $P \leq 0.01$ . Statistically significant between-group analysis—ANOVA was used for parametric data and the Kruskal–Wallis test for data that were non-normal<sup>b</sup> at baseline.

\*\* $P \leq 0.05$ .

differences also revealed statistically significant differences between groups 1 and 2 ( $P=0.013$ ). No statistically significant difference was found between groups 2 and 3 ( $P=0.806$ ).

### Secondary outcomes

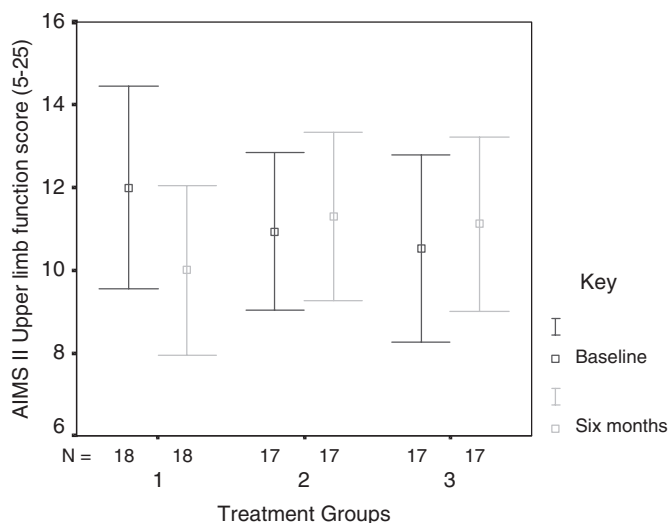
Statistically significant differences were also found in dominant hand key grip change scores ( $P=0.014$ ) between baseline and 6 months using non-parametric between-group analysis (Table 2). No other statistically significant differences were established when analysing between-group comparisons for any of the outcome measures at any of the time points. Normality testing revealed that the data for key grip were not normally distributed in group 3 subjects ( $P=0.001$ ). Figure 3 illustrates the range of values for key grip over baseline and 6-month assessment. Further analysis revealed that a significant difference existed between group 1 and group 3 subjects ( $P=0.007$ ), but also between group 2 and group 3 subjects ( $P=0.032$ ). No adjustment for multiple testing was undertaken.

There were no differences in medication between groups at 6 months (Table 3) or in disease activity scores, although the

6-month scores for both swollen and tender joint counts were lower in both exercising groups (groups 1 and 2) when compared with baseline scores, but had increased in the non-exercising group (group 3). During the course of the trial no participants reported having received any additional therapy.

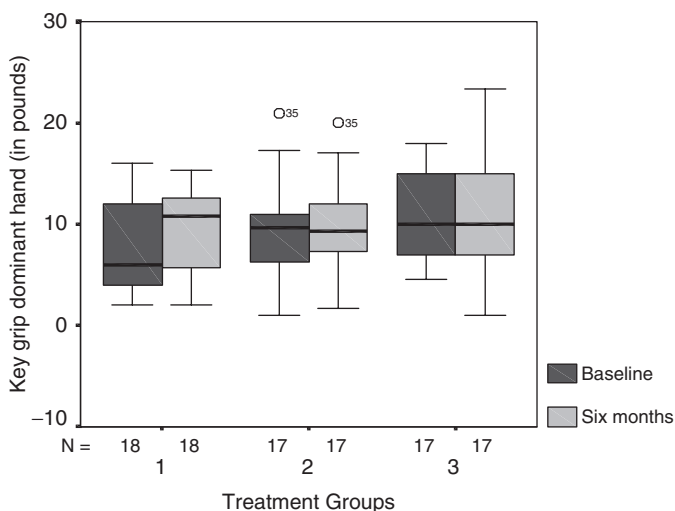
### Discussion

This randomized controlled trial addressed an important clinical question about the effectiveness of hand exercises in the management of patients with RA. This pragmatic study has demonstrated a statistically significant difference between groups undertaking three different types of conservative hand treatments. In summary, we found that participants who undertook hand-strengthening and hand-mobilizing exercises achieved a statistically significant improvement in AIMS II upper limb function (0–6 month change) compared with the other two treatment groups. In addition, change in key grip strength over the 6-month period also showed statistically significantly greater improvement in this group compared with participants who did not undertake any strengthening exercises in the other two groups. Similar trends in



GROUP 1: Joint protection leaflet with hand strengthening and mobilizing exercises  
 GROUP 2: Joint protection leaflet with hand mobilizing exercises  
 GROUP 3: Joint protection leaflet

FIG. 2. Error bar graph illustrating AIMS II upper limb function change scores (not normalized) between baseline and 6 months (mean ± SD)



GROUP 1: Joint protection leaflet with hand strengthening and mobilizing exercises  
 GROUP 2: Joint protection leaflet with hand mobilizing exercises  
 GROUP 3: Joint protection leaflet

FIG. 3. Box plots illustrating dominant hand key grip scores for baseline and 6 months (median scores and interquartile ranges).

other secondary outcomes were noted in the strengthening exercise group, compared with the other two treatment groups, but none reached statistical significance.

Although previous studies have demonstrated evidence for the use of joint protection, there has been less evidence to support the use of hand exercises in the management of patients with RA [22–25]. Additionally, the lack of published detail relating to exercise studies in RA has created difficulty with replication [11, 12]. Every attempt has been made to describe clearly the interventions in the present study, the precise subject exercise instructions, frequency of exercising, dosage and timing for progression.

We acknowledge that our sample size is small and that random errors may have produced a positive result overestimating the treatment effect. The effects of medication and any other

concomitant therapies on the study findings are also unknown. However, the size of this study compares favourably with previous randomized controlled studies involving hand exercises in patients with RA [11, 12, 26]. Disease duration for participants in group 1 was greater than for participants in the other groups, as were the disease activity scores at baseline, but despite this group 1 demonstrated a statistically significant greater improvement than groups 2 and 3. Additionally, disease activity scores all improved in both exercising groups (group 1 and 2), but interestingly deteriorated in the non-exercising group (group 3).

Disease duration is not always reported in exercise studies involving RA patients [23, 26, 27], which hampers the evaluation of the generalizability of the findings. Given that the mean age of this cohort and their mean disease duration was very similar to that defined for a UK population [1, 28], the results of this study may be generalizable to a wider RA population. Radiographic scores have not been reported in this study. The impact of hand exercises in RA on joint damage warrants further investigation.

Randomized studies with specifically exercise-focused interventions are rare [23, 24]. Studies have opted to use measures of impairment of both grip strength and joint range of movement as outcomes. The current study chose valid and reliable disease-specific measures for use in an RA population with a combination of measures of impairment and activity limitation that are of more relevance to the patient [29]. Measurement of patient-perceived function is not only a high priority for research [11] but also for clinical practice. Using self-administered instruments with minimal time implications for the clinician is also attractive for clinical practice.

The Jamar dynamometer is considered to be the ‘gold standard’ in hand-held dynamometers [30–32]. In the present RA study, a ‘floor’ effect was evident in this measurement. The more disabled participants were unable to register any reading from the Jamar. Interestingly, all subjects managed to register a key grip measure using a pinch gauge measurement, albeit a very weak one. An alternative instrument for gross grip may therefore need to be developed in order to be more appropriate and sensitive in this patient population.

An unexpected finding in the present study was that 0–6 month change scores in the AIMS II upper limb function consistently improved more than the hand and finger function scores. The important role that the shoulder and elbow joints have in dynamic movement and total performance of the hand has been previously highlighted [33]. Further work to explore additional associations between the joints of the upper limb and hand in RA is needed. The sensitivity to change of the AIMS II hand and finger function subscale in RA may also warrant further investigation. Whilst statistical significance has been demonstrated in this study, the actual clinical significance of such reductions in AIMS II scores is largely unknown.

Our study has demonstrated that a simple home exercise programme (with minimal equipment) can enhance the hand function of the patient with RA. The patient need only attend appointments for instruction on two occasions. This has obvious additional economic benefits for both the patient and the National Health Service.

### Conclusions

This three-arm randomized controlled trial suggests there is a role for strengthening hand exercises in the management of RA. Hand function is of utmost importance to the RA patient and this study contributes to the existing evidence to guide the therapist in management programmes.

Hand therapy in RA is delivered daily by therapists throughout the UK and this study provides further evidence for such treatments. Future studies detailing optimal numbers of repetitions of hand exercises as well as dosage are needed.

TABLE 3. Medication and disease activity scores

Variable	Group 1 (n = 21)	Group 2 (n = 24)	Group 3 (n = 22)
Medication for participants at baseline:			
Single DMARD (n)	14	17	17
Participants at baseline on combination DMARD (n)	1	3	5
Steroids (5–10 mg prednisolone) (n)	2	2	2
Participants at baseline on anti-TNF therapy (n)	0	0	0
Missing data, any medication (n)	7	7	5
Change in DMARD over 6 months:			
Yes (n)	5	4	6
No (n)	10	12	12
Missing data (n)	6	8	4
Disease activity:			
Patient perception of global assessment of disease activity (VAS)			
Baseline, mean (SD)	4.71 (2.12)	3.95 (2.62)	3.37 (1.63)
Six months, mean (SD)	4.25 (2.41)	3.41 (2.52)	4.31 (2.71)
Mean (SD) swollen joint count <sup>a</sup> (n)			
Baseline	3.50 (3.02)	3.00 (3.58)	3.05 (4.56)
Six months	2.33 (3.52)	1.44 (1.75)	3.27 (5.59)
Mean (SD) tender joint count <sup>a</sup> (n)			
Baseline	5.05 (5.82)	3.38 (5.84)	2.00 (2.45)
Six months	2.53 (3.66)	1.19 (2.10)	2.53 (4.50)

Group 1, joint protection plus hand-strengthening exercises; group 2, joint protection plus hand-mobilizing exercises; group 3, joint protection advice alone.

<sup>a</sup>European League Against Rheumatism (1995) swollen joint count [34].  
TNF, tumour necrosis factor; VAS, 10 cm visual analogue scale.

A combination of strengthening and mobilizing exercises with advice on joint protection improves hand function and grip strength in an individual with RA more effectively than advice with simple stretches or advice alone.

<i>Rheumatology</i>	Key messages
	<ul style="list-style-type: none"> <li>• Hand-strengthening exercises in RA can improve functional ability of the upper limb.</li> <li>• Two appointments with a therapist teaching a simple home exercise programme for hand RA can be effective over 6 months.</li> </ul>

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### References

1. Symmons DPM, Turner G, Webb R. The prevalence of rheumatoid arthritis in the United Kingdom—new estimates for a new century. *Rheumatology* 2002;41:793–800.
2. Jones JV, Covert A. Diagnosis and management of arthritic conditions. In: Walker KM, Helewa A, eds. *Physical Therapy in Arthritis*. Philadelphia: WB Saunders, 1996:47–80.

3. Maini RN, Feldmann M. Rheumatoid arthritis. In: Maddison PJ, Isenberg DA, Woo P, Glass DN, eds. *Oxford Textbook of Rheumatology*, 2nd edn. Oxford: Oxford University Press, 1998:983–1036.
4. Creemers MCW, van de Putte LBA. Rheumatoid arthritis—the clinical picture. In: Isenberg DA, Maddison PJ, Woo P, Glass D, Breedveld FC, eds. *Oxford Textbook of Rheumatology*, 3rd edn. Oxford: Oxford University Press, 2004:697–718.
5. Herbison GJ, Ditunno JF, Jaweed MM. Muscle atrophy in rheumatoid arthritis. *J Rheumatol* 1987;14(Suppl. 15):78–81.
6. Hakkinen A, Hannonen P, Hakkinen K. Muscle strength in healthy people and in patients suffering from recent-onset inflammatory arthritis. *Br J Rheumatol* 1995;34:355–60.
7. Jones E, Hanly JG, Mooney R *et al.* Strength and function in the normal and rheumatoid hand. *J Rheumatol* 1991;18:1313–18.
8. Fransen M. When is physiotherapy appropriate? *Best Pract Res Clin Rheumatol* 2004;18:477–89.
9. Smith-Pigg J. Role of nursing and allied health professions in the treatment of arthritis. In: McCarthy DJ, ed. *Arthritis and Allied Conditions*. London: Lea & Febiger, 1989:787.
10. Stewart M. Researches into the effectiveness of physiotherapy in rheumatoid arthritis of the hand. *Physiotherapy* 1996;82:666–72.
11. Wessel, J. The effectiveness of hand exercises for persons with rheumatoid arthritis: a systematic review. *J Hand Ther* 2004; 17:174–80.
12. Chadwick A. A review of the history of hand exercises in rheumatoid arthritis. *Musculoskeletal Care* 2004;2:29–39.
13. Hurley MV. The role of muscle weakness in the pathogenesis of osteoarthritis. *Rheum Dis Clin North Am* 1999;25:283–98.
14. Bearne LM, Scott DL, Hurley MV. Exercise can reverse quadriceps sensorimotor dysfunction that is associated with rheumatoid arthritis without exacerbating disease activity. *Rheumatology* 2002; 41:157–66.
15. Arnett FC, Edworthy SM, Bloch DA *et al.* The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis. *Arthritis Rheum* 1988;31:315–24.
16. Vollmann J, Winau R. Informed consent in human experimentation before the Nuremberg code. *Br Med J* 1996;31:1448–9.
17. Pocock SJ. *Clinical trials—a practical approach*. London: Wiley, 1984.

18. Meenan RF, Mason JH, Anderson JJ, Guccione AA, Kazis LE. AIMS2. The content and properties of a revised and expanded Arthritis Impact Measurement Scales Health Status Questionnaire. *Arthritis Rheum* 1992;35:1–10.
19. Jebsen R, Taylor N, Triegchmann R. An objective and standardized test of hand function. *Arch Phys Med Rehab* 1969;50:311.
20. Schmidt RT, Toews JV. Grip strength as measured by the Jamar dynamometer. *Arch Phys Med Rehab* 1970;51:321–7.
21. Groth GN, Van Deven KM, Phillips EC, Ehretzman RL. Goniometry of the proximal and distal interphalangeal joints, Part II: placement preferences, interrater reliability, and concurrent validity. *J Hand Ther* 2001;14:23–9.
22. Hammond A, Lincoln N. The effect of a joint protection education programme for people with rheumatoid arthritis. *Clin Rehab* 1999; 13:392–400.
23. Dellhag B, Wollersjo I, Bjelle A. Effect of active hand exercise and wax bath treatment in rheumatoid arthritis patients. *Arthritis Care Res* 1992;5:87–92.
24. Brighton SW, Lubbe JE, van der Merwe CA. The effect of a long-term exercise programme on the rheumatoid hand. *Br J Rheumatol* 1993;32:392–5.
25. Hoenic H, Groth G, Pratt K, Goldberg E, Franck W. A randomised controlled trial of home exercise on the rheumatoid hand. *J Rheumatol* 1993;20:785–9.
26. Hamilton DE, Bywaters EGL, Please NW. A controlled trial of various forms of physiotherapy in arthritis. *Br Med J* 1959;1:542–4.
27. Hawkes J, Care G, Dixon JS, Bird HA, Wright V. A comparison of three different physiotherapy treatments for rheumatoid arthritis of the hands. *Physiother Pract* 1986;2:155–60.
28. Symmons DP, Barrett EM, Bankhead CR, Scott DG, Silman AJ. The incidence of rheumatoid arthritis in the United Kingdom: results from the Norfolk Arthritis Register. *Br J Rheumatol* 1994;33:735–9.
29. Stucki G, Cieza A, Geyh S *et al.* ICF core sets for rheumatoid arthritis. *J Rehabil Med* 2004;44:87–93.
30. Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of grip and pinch strength evaluations. *J Hand Surg Am* 1984;9:222–6.
31. Fess EE. Grip strength. In: Casanova JS, ed. *Clinical Assessment Recommendations*, 2nd edn. Chicago: American Society of Hand Therapists, 1992:41–6.
32. Peolsson A, Hedlund R, Oberg B. Intra- and inter-tester reliability and reference values for hand strength. *J Rehabil Med* 2001;33:36–41.
33. Kauranen K, Vuotikka P, Hakala M. Motor performance of the hand in patients with rheumatoid arthritis. *Ann Rheum Dis* 2000; 59:812–16.
34. Scott DL, van Riel PL, van der Heijde D, Benke AS. Assessing disease activity in rheumatoid arthritis. *The EULAR Handbook of Standard Methods*, 2nd edn. Uppsala: Pharmacia, 1995.