

The effects of knee extensor and flexor muscle training on the *timed-up-and-go* test in individuals with rheumatoid arthritis

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ABSTRACT Background and Purpose. *Rheumatoid arthritis frequently results in functional impairment. This study investigated the effect of a specific exercise regimen on function. Method.* A randomized controlled assessor-blinded ($N = 36$) compared the effect of knee extensor and flexor muscle training on pain, the timed up and go (TUG) test and the Health Assessment Questionnaire in subjects with non-acute rheumatoid arthritis. **Results.** Knee extensor and flexor muscle training increased isokinetic torques at speeds of $60^\circ/\text{sec}^{-1}$ and $120^\circ/\text{sec}^{-1}$ as measured by an isokinetic dynamometer ($p = 0.02-0.003$). The experimental group experienced a reduction in pain ($p = 0.03$), an improvement in TUG time ($p = 0.01$) and in function as measured by the Health Assessment Questionnaire ($p = 0.04$). **Conclusions.** Specific knee muscle training can be administered safely in people with non-acute rheumatoid arthritis, and may produce functional benefits.

Key words: function, muscle training, rheumatoid arthritis

INTRODUCTION

The inflammatory process which characterizes rheumatoid arthritis leads to progressive symmetrical joint destruction, muscle atrophy, loss of strength and increasing functional impairment. Difficulty in performing everyday activities is common and is typically associated with pain, weakness and reduced exercise tolerance. Whilst it is now understood that muscle weakness may be due to a combination of factors, including pain, disuse atrophy (Ekblom et al., 1974) and corticosteroid management (Danneskiold-Samsøe and Grimby, 1986a, 1986b), exercise has been promoted as a means of maintaining and enhancing function (Swezey, 1990). A clear link between specific exercise regimens and validated functional tests has not been established, although recently Komatireddy et al. (1997) and Van den Ende et al. (1997) have evaluated the effects of general exercise programmes on a number of tests. Van den Ende and colleagues (1997) included the Health Assessment Questionnaire and Komatireddy and co-workers (1997) investigated change in sit-to-stand time. We

postulated that a training programme focusing on improving strength and speed of action of the knee musculature would improve function as reflected in the timed up and go (TUG) test in subjects with rheumatoid arthritis affecting the knees.

Although all movements require synergistic activity, the quadriceps muscle group serves as the prime mover of the knee for several major functional activities, including standing, walking, lifting, transferring loads and rising from a chair. Strength of movement has been assessed in patients with rheumatoid arthritis (Rothstein *et al.*, 1983a; Hsieh *et al.*, 1987) but the effects of specific muscle training regimens have not been documented.

A wide variety of methods are available to strengthen muscle in general, and the quadriceps musculature in particular, but in this formal investigation it was essential to select a reliable protocol where the parameters of the method could be precisely quantified. The KinCom (KinCom Chattanooga Corporation, USA) dynamometer satisfied this objective. This apparatus is an electronic computer-controlled dynamometer designed to apply resistance throughout a selected range of movement, and at a predetermined constant speed. Most importantly, the associated computer may be programmed to provide specific and reproducible assessment and treatment regimens. Reliability of the KinCom measurement system has also been established (Farrell and Richards, 1986; Nitschke, 1992; Mayhew *et al.*, 1994). The reliability of a protocol for assessment of knee flexion and extension torque within the range 10° – 80° at a constant speed of $60^{\circ}/\text{sec}^{-1}$ was established for normal knees by Harding *et al.* (1988) (and described below) — the intraclass correlation coefficients (ICC) for knee extension between different test sessions was 0.96 for peak torque, and 0.94 for average torque. Tredinnick and Duncan (1988) determined that the ICC[1,1] of knee extensor muscle concentric torque at $120^{\circ}/\text{sec}^{-1}$ was 0.97 in normal male subjects on the KinCom dynamometer. Giles *et al.* (1990) investigated the reproducibility of isokinetic knee extensor muscle strength using the Cybex apparatus (another type of electromechanical dynamometer), and determined a coefficient of variation of $\pm 20\%$ for mean torque scores >54 Nm.

By use of the KinCom dynamometer, McMeeken *et al.* (1998) established that intra-rater reliability of thigh muscle activity in subjects with rheumatoid arthritis is acceptable for determination of the results from clinical interventions. The intra-session ICC [3,1] following eight repetitions of peak torque was 0.99 for extensor muscles (lower 95% confidence limit = 0.98) and 0.99 for flexor muscles (lower 95% confidence limit = 0.96). Comparison between right and left lower limbs of 18 subjects showed no significant difference in peak concentric muscle torque of knee extensors or flexors at $6^{\circ}/\text{sec}^{-1}$ and $120^{\circ}/\text{sec}^{-1}$. Inter-session reliability for peak concentric torque for knee extensor and flexor muscles (measured at two sessions six weeks apart) by ICC [2,3] was high for extensors ($60^{\circ}/\text{sec}^{-1} = 0.97$; $120^{\circ}/\text{sec}^{-1} = 0.97$) and flexors ($60^{\circ}/\text{sec}^{-1} = 0.94$; $120^{\circ}/\text{sec}^{-1} = 0.97$). This study indicated that a change >20 Nm in knee extensor muscles and >15 Nm in knee flexor muscles is likely to represent a real change.

Despite earlier concerns that exercise might exacerbate joint symptoms or accelerate the rheumatoid process, it has been shown that strengthening exercises can be safely prescribed in patients whose rheumatoid joint disease is not undergoing an

acute exacerbation (Lyngberg et al., 1994; Ytterberg et al., 1994). Recently, Rall et al. (1996) administered high-resistance training to eight rheumatoid arthritis subjects and demonstrated that self-reported pain was reduced by 21% and functional performance by a 20% reduction in 50-foot walking times.

The TUG test reflects the capacity for lower limb function and has been shown to be reliable in assessing such capacity in frail, elderly people, and in patients with arthritis (Mathias et al., 1986; Berg 1989; Podsiadlo and Richardson, 1991; Berg et al., 1992). This test measures the time taken in seconds for a subject to rise from an arm chair, walk 3 m at a safe comfortable pace, return to the chair, then sit down. During the test the subject wears normal footwear and uses any customary walking aid. No physical assistance is given. Normal individuals, aged from 70 to 84 years have a TUG time of 10 sec or less (Podsiadlo and Richardson, 1991). The TUG test, which has high inter-rater reliability (ICC 0.99) and intra-rater reliability (ICC 0.99) (Podsiadlo and Richardson, 1991), was included in this study as a reliable indicator of the functional consequences of the knee muscle exercise regimen. The correlation between the TUG with measures of balance (Berg Balance Scale, $r = -0.81$), walking speed ($r = -0.61$) and functional capacity (Barthel Index $r = -0.78$) further demonstrate its functional validity (Podsiadlo and Richardson, 1991).

Knee extension from approximately 80° to 0° is needed when rising from a standard armchair (Nuzik et al., 1986), and places particular demands on the knee extensor muscles. The frequently observed slowness and difficulty exhibited by patients with rheumatoid arthritis when rising from a chair may be linked to some combination of pain, muscle weakness, reduced speed and control of movement, muscular inflammation, and underlying joint disruption. Although rheumatoid or post-steroidal neuropathy may occur in these patients, significant neurological muscle weakness is rare.

Roche (1990) determined that normal subjects aged 70.6 years (SD 6.3 years) display a peak knee angular velocity of $123.1^\circ/\text{sec}^{-1}$ (SD $36.7^\circ/\text{sec}^{-1}$) during knee extension in rising from sitting. Our preliminary data on normal middle-aged individuals indicated values ranging from $120^\circ/\text{sec}^{-1}$ to $170^\circ/\text{sec}^{-1}$. The peak angular velocity of knee extension when rising to standing at a self-selected pace was considered to represent a further objective measure of quadriceps function during this activity.

Despite the known relationship between tibial length, chair height and ease of rising from a chair (Rodosky et al., 1989), most people of different heights are obliged to use standard height chairs in their daily activities. Hence the same chair was used for all subjects. Whilst the knee extensor muscles make a major contribution to rising from a chair (Salmon, 1995), the knee flexors were included with the quadriceps muscles in the training routine based on the assumption that such exercise might maintain muscle balance and enhance the dynamic stability of the knee (Seto et al., 1988).

Although it was considered that exercise for muscles associated with the knee were most likely to affect the TUG time and the peak velocity of knee extension during rising from a chair, several other measures were used to evaluate the exercise

programme. Pain and the Health Assessment Questionnaire (HAQ) were monitored at the beginning and end of the study. A 10 cm line visual analogue scale was used to measure subject's pain in the last week (Huskisson, 1974; Scott and Huskisson, 1976; Flandry *et al.*, 1991). The disability categories in the HAQ developed by Fries *et al.* (1980) were used to assess dressing, grooming, arising, eating, walking, hygiene, reach, grip, activities, and the requirement of aids or devices or help from another person. This disability index has been well-validated, is widely used, is sensitive to change and has been recommended by the British Outcome Study Group (Bellamy, 1993).

In order to measure the average amount of walking undertaken by subjects, a simple pedometer (Micronta, International Australia Ltd, Tandy Corporation) was used to collect the number of steps walked during each week of the study. Reliability of the pedometers was assessed before the commencement of the study when it was established that they were reliable to $\pm 5\%$ of the stated count. As the focus of exercise was on the knee musculature, non-weightbearing activity was not measured in the study.

METHOD

Subjects

Following approval by the Royal Melbourne Hospital Research Ethics Committee, 36 subjects were recruited and randomly allocated to control and experimental groups. Potentially suitable subjects were invited to participate following outpatient visits to their rheumatologists. A second source of subjects was from inpatients identified by the hospital physiotherapy staff who advised potential subjects of the study after acute exacerbations of their rheumatoid arthritis conditions had settled. Seventeen subjects completed the six-week exercise protocol and 18 subjects formed a control group. The details of the study population are shown in Table 1.

Inclusion criteria were:

- Seropositive or seronegative inflammatory rheumatoid arthritis according to the revised American Rheumatism Association 1987 criteria (Arnett *et al.*, 1988).
- Joint disease requiring long-term medication.
- A TUG test time ≥ 10 sec.

TABLE 1: The study population

Characteristic	Exercise group	Control group
Number	17	18
Females (males)	15 (2)	14 (4)
Age (mean \pm SD) (years)	51.4 (\pm 11.1)	49.7 (\pm 15.3)
Body weight (mean \pm SD) (kg)	71.0 (\pm 23.4)	69.4 (\pm 17.9)
Height (mean \pm SD) (m)	1.63 (\pm 0.6)	1.66 (\pm 0.8)

Potential participants were excluded if they had previous joint replacement surgery, major non-rheumatoid pathologies affecting the lower limbs, an acute exacerbation of joint disease (identified as active synovitis of their knees, joints hot on palpation or morning stiffness increasing), fragile skin or major changes in pharmacological management in the three months before the study.

The experimental and control groups were tested twice as described below; the first session was on entry to the study and the second six weeks later. Members of the control group were contacted weekly and queried as to their general health and well-being in order to minimize the Hawthorne effect on the experimental group (Portney and Watkins, 1993). Subjects and the physiotherapists responsible for testing were blind to group allocation.

Procedure

Subjects wearing shorts were seated on a chair with arm rests, floor to seat height of 47 cm and floor to arm rest height of 72 cm was used. With the subject sitting comfortably in the chair, the subject's toes were aligned to the start of a 3 m walkway. Reflective reference markers were positioned on the lateral aspect of the right lower limb and videotaped during the sit-to-stand motion which, along with TUG test, was performed at each subject's self-selected pace.

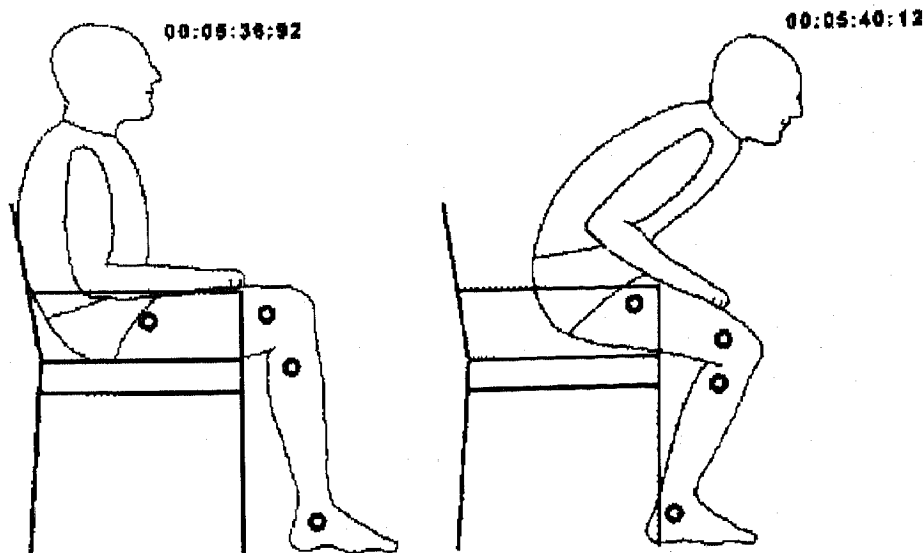


FIGURE 1: Marker placement for the sit-to-stand test.

The PEAK 2D measurement system (Peak Performance Technologies Incorporated, 7388 S Revere Parkway, Suite 801, Englewood, Colorado 80112, USA) used to automatically analyse the peak knee flexion-extension angular velocity

(expressed as degrees per second) produced during the sit-to-stand movement based on the location of two reflective markers positioned to identify the long axis of the thigh, and two reflective markers positioned to represent the long axis of the leg. (See Stillman and McMeeken (1995) for details of marker placement and Stillman *et al.*, (1998) for reliability of this video measurement protocol.) The TUG test was performed according to the protocol of Podsiadlo and Richardson (1991). The TUG test was videotaped from the right lateral aspect and a video time code superimposed on the videotape to facilitate precise determination of the TUG time (Stillman and McMeeken, 1996).

Following routine calibration as advised by the manufacturer, the KinCom isokinetic dynamometer was used to measure knee muscle peak torques in Newton metres (Nm). The testing protocol initially established by Harding *et al.* (1988) was followed with the exception of the chest belt (McMeeken *et al.*, 1998). The seat, table position and lap-stabilizing belt placements were standardized, and the lever arm length specific for each subject was reproduced at each session. One physiotherapist was responsible for all training and a team of two physiotherapists, who were blind to group allocation, undertook all initial and final testing.

Peak torque of knee extensor muscle activity on both legs was determined using speeds of $60^{\circ}/\text{sec}^{-1}$ and $120^{\circ}/\text{sec}^{-1}$. After four submaximal repetitions, the average of three maximal repetitions was determined for the quadriceps and hamstring musculature. Thus the following tests were delivered at the beginning and end of the study for both groups:

- Visual analogue scale for pain (P_{VAS}) in the last week.
- HAQ to assess overall function in the last week.
- TUG test to assess function related to knee musculature.
- Peak torque of knee extensor and flexor muscle activity at constant speeds of $60^{\circ}/\text{sec}^{-1}$ and $120^{\circ}/\text{sec}^{-1}$.

All subjects wore a pedometer during waking hours for the period of the study. Pedometer readings were recorded weekly.

In the experimental group the results of the peak angular velocity of knee extension during sit-to-stand assessment was used as a basis for establishing the speed for muscle training. The training session commenced on the second day. Quadriceps and hamstring muscles were trained concentrically in both limbs. Following a warm-up of two sets of ten repetitions at 25% of the previously determined peak angular knee speed, each subject then trained at 70% of maximum speed. In each session the experimental subjects completed four sets of five repetitions with 10-second rests following each extension or flexion movement, and one-minute rests after each set. Training sessions occupying approximately 45 minutes were conducted at the same time approximately every three days so that 14 sessions were completed within a maximum six-week period.

Data analysis

Differences between groups on peak speed, TUG, pain and HAQ were analysed using a one-way analysis of covariance (ANCOVA-1WOR), with pre-test values as the covariate. Differences between groups on the muscle torque variables as a set were analysed using a one-way multivariate analysis of covariance (MANCOVA-1WOR), with pre-test values as the covariates.

RESULTS

Three subjects experienced a change in their medications — one experimental subject had salazopyrin withdrawn, one control subject had a steroid injection to one knee and a further control subject had a diuretic prescribed. The experimental subject displayed increased pain, decreased function and no change in quadriceps torque when her individual measures before and after intervention were inspected. The control subject who had the steroid injection was the least stable subject in the study and therefore her results decreased the reliability of measurements. The control subject who had a diuretic prescribed showed some improvement in her pain and TUG scores but no change in overall peak torque scores. This subject would have reduced the difference in results between control and experimental groups. As similar events may occur during a clinical intervention programme, it was decided to retain these three subjects in the study.

Descriptive statistics for the non-torque dependent variables are presented in Table 2.

Measure	Control group		Experimental group	
	Pre-test	Post-test	Pre-test	Post-test
Peak speed ($^{\circ}$ /sec $^{-1}$)	125.2 (\pm 33.9)	121.6 (\pm 27.7)	132.0 (\pm 40.6)	154.0 (\pm 45.8)
TUG (sec)	12.6 (\pm 1.5)	12.2 (\pm 1.3)	11.7 (\pm 1.9)	10.4 (\pm 1.8)
P _{VAS} (mm)	4.1 (\pm 2.4)	3.9 (\pm 2.4)	4.3 (\pm 2.2)	2.4 (\pm 2.1)
HAQ	0.7 (\pm 0.4)	0.8 (\pm 0.3)	1.0 (\pm 0.6)	0.7 (\pm 0.6)

At post-test the experimental group showed greater peak speed, faster TUG, less pain and better quality of life as measured by HAQ. One-way analysis of covariance, with pre-test as the covariate, was used to identify statistically significant differences between groups on peak speed, TUG, pain and HAQ. These results are presented in Table 3. All variables differed between the control and experimental groups at post-test when adjusted for pre-test values.

TABLE 3: Analysis of covariance (ANCOVA) results for post-test group differences

Measure	F	df	p value
Peak speed	9.20	1,32	0.005
TUG	7.48	1,32	0.01
P _{VAS}	5.08	1,32	0.031
HAQ	4.78	1,32	0.036

Descriptive statistics for the torque dependent variables are presented in Table 4.

TABLE 4: Mean (\pm SD) for the muscle torque variables measured in the control and experimental subjects before and after completion of the study

Measure (Nm)	Control group		Experimental group	
	Pre-test	Post-test	Pre-test	Post-test
Extensor torque 60°/sec ⁻¹	75.6 (\pm 33.4)	78.3 (\pm 31.3)	75.1 (\pm 29.2)	96.1 (\pm 33.2)
Extensor torque 120°/sec ⁻¹	62.7 (\pm 28.4)	64.3 (\pm 26.2)	63.6 (\pm 27.1)	79.6 (\pm 28.0)
Flexor torque 60°/sec ⁻¹	29.9 (\pm 16.0)	33.7 (\pm 14.7)	33.2 (\pm 12.5)	45.8 (\pm 18.5)
Flexor torque 120°/sec ⁻¹	30.7 (\pm 15.2)	31.1 (\pm 15.4)	31.0 (\pm 11.6)	43.6 (\pm 17.8)

At post-test the experimental group showed generally greater muscle torque values than both their pre-test values and the post-test values of the control group. One-way multivariate analysis of covariance, again with pre-test values as the covariates, was used to identify differences between groups on the muscle torque variables as a set. A significant group difference was found ($F = 3.50$; $df = 4, 26$; $p = 0.02$) with the experimental group showing greater torque at post-test. Univariate analyses (Table 5) indicated that this group difference was apparent on all dependent variables.

TABLE 5: Univariate *F*-tests of muscle torque variables included in the MANCOVA

Measure	F	df	p
Extensor torque 60°/sec ⁻¹	6.27	1,29	0.018
Extensor torque 120°/sec ⁻¹	10.18	1,29	0.003
Flexor torque 60°/sec ⁻¹	7.97	1,29	0.008
Flexor torque 120°/sec ⁻¹	10.74	1,29	0.003

DISCUSSION

In common with earlier studies (Hsieh et al., 1987; Lyngberg et al., 1994; Ytterberg et al., 1994; Rall et al., 1996), this study presented no particular difficulties in the testing process or in administering a knee extensor and flexor muscle exercise regi-

men to subjects with rheumatoid arthritis. Subjects in the study showed no clinical evidence of exacerbation of joint symptoms. The experienced clinical physiotherapists testing the subjects were blind to their allocation to control or experimental group. Neither subjects nor therapists perceived any increase in joint stiffness, synovitis, joint temperature or pain, or any change in range of movement. The fact that change in medication was required by only three subjects, including one in the experimental group, further supports the argument that these subjects experienced no deleterious effects as a result of the research intervention. Moreover, subjects in the experimental group displayed a significant reduction in pain and improvement in function as indicated by the measurement tools of this study.

Peak torque

The KinCom training was chosen to enable a rigorous quantifiable training schedule to be accomplished. After participating in this schedule, the experimental group increased strength of their knee flexors and extensors as reflected by a significant change in actual torque scores. The control group exhibited no such changes. Whilst both measurement and training were undertaken on the KinCom, the two protocols differed substantially and a learning effect of the training regimen on the testing process was not anticipated. Previous studies, such as those of Ekblom et al. (1975) and — more latterly — of Komatireddy et al. (1997) and Van den Ende et al. (1997) have concentrated on the use of general exercises for people with rheumatoid arthritis. With reduced funding for clinical services it was considered desirable to investigate whether a short six-week focused intervention programme for training the knee muscles would affect pain experience and a key functional outcome measurement — the TUG test. The results of this study indicate that isokinetic training is suitable for intensive knee muscle training. Further studies are required to determine if similar results may be achieved following analogous exercise of other rheumatoid arthritic joints. Whether similar results can be achieved more simply and less expensively such as following an educational session and home exercises needs further investigation. Van den Ende and colleagues (1998) undertook a systematic review of randomized controlled trials to determine if dynamic exercise therapy assisted in improving (amongst other items) muscle strength and function in patients with rheumatoid arthritis. They concluded that dynamic exercise was effective in improving muscle strength without detrimental effects on disease activity or pain. They also indicated that further research, such as is reported here, is required to establish the benefits of dynamic exercise therapy on function.

Pain

A significant reduction in pain as measured by the VAS was noted in the experimental group, but not the control subjects. It is always possible in inflammatory joint disease that pain may be reduced as a result of patients reducing their level of activity, however, there is no evidence to this effect from pedometer measurement of

walking, the post-exercise HAQ or the TUG scores. Although there was no evidence that the experimental subjects walked greater distances over the duration of the study, this should not automatically be construed as representing a negative (or neutral) result. The exercise may have left these subjects able to walk with less discomfort, and perhaps greater speed since they manifested significantly reduced TUG times. Moreover, the experimental subjects may not have needed (wanted) to walk further distances in their daily life. More detailed monitoring of the subjects' walking patterns would be necessary to confirm or refute these possible beneficial gains with respect to walking.

TUG

The positive results of the TUG test in the experimental as compared to the control group further support the contention that this simple test is a valuable measure of lower limb function in clinical assessment and research trials. The test is highly applicable to the clinical environment where measurement of test time can be undertaken with a stopwatch (Podsiadlo and Richardson, 1991). Further investigation of the relative contribution of the components of the TUG test to the change in total time would be valuable and may support the work of Komatireddy *et al.* (1997) who demonstrated a decrease in sit-to-stand time in subjects who had participated in a 12-week circuit training programme. Such a decrease in sit-to-stand time may parallel the significant increase in peak velocity of knee extension observed in our experimental group during the sit-to-stand component of the TUG test. The authors consider that on theoretical grounds it might be postulated that to stand from a chair successfully, a critical (threshold) momentum is required and that that momentum might be expressed as a specific threshold peak velocity of knee extension. If this is the case, peak extension velocity would not be expected to increase in a simple linear manner during improvement. Rather, it would be expected that the velocity would increase to a specific plateau determined by the individual subject's body dimensions, body weight and the energy cost of performing the activity. Further improvement in functional capacity would not be expected to further increase the peak extension velocity. This proposition deserves further study.

Health Assessment Questionnaire

The HAQ as a quality of life measure showed a significant improvement in the experimental group. Significant improvement was also observed by Van den Ende *et al.* (1997) who demonstrated that the HAQ was significantly associated with increases in quadriceps strength following a 12-week exercise programme. The HAQ is a further measurement tool that assesses health and a wide range of functional activities. It can readily be employed in the clinical environment. The results of our study support the inclusion of a multi-dimensional measure such as the HAQ in assessing change from a treatment intervention.

CONCLUSION

This randomized controlled study of subjects with rheumatoid arthritis demonstrated that isokinetic knee muscle training increased peak muscle torques. The group that undertook the training programme also improved their scores in the TUG test, a test which is considered to be highly relevant in daily activities. The experimental group experienced a reduction in pain and improvement in overall health. There was no exacerbation of pain and subjects were not compromised in their normal daily activities. Thus, the study supports the use of muscle training in subjects with non-acute rheumatoid arthritis.

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