

A randomized controlled trial of eccentric vs. concentric graded exercise in chronic tennis elbow (lateral elbow tendinopathy)

Clinical Rehabilitation
2014, Vol. 28(9) 862–872
© The Author(s) 2014
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0269215514527595
cre.sagepub.com


Magnus Peterson¹, Stephen Butler², Margaretha Eriksson¹ and Kurt Svärdsudd¹

Abstract

Objective: To analyse treatment effects of eccentric vs. concentric graded exercise in chronic tennis elbow.

Design: Randomized controlled trial.

Setting: Primary care in Uppsala County, Sweden.

Subjects: A total of 120 subjects with tennis elbow lasting more than three months were recruited from primary care and by advertisement.

Intervention: Eccentric ($n = 60$) or concentric exercise ($n = 60$), by lowering or lifting a weight, at home daily, for three months with gradually increasing load.

Main measures: Pain during muscle contraction and muscle elongation, as well as strength, was assessed at baseline and after one, two, three, six, and 12 months. Function and quality of life was assessed at baseline and after three, six and 12 months.

Results: The eccentric exercise group had faster regression of pain, with an average of 10% higher responder rate at all levels of pain reduction, both during muscle contraction and elongation, ($p < 0.0001$ and $p = 0.006$, respectively). Significant differences were found in Cox's analysis from two months onwards (HR 0.78, 95% confidence interval (CI) 0.63–0.96, $p < 0.02$). This represents an absolute pain reduction of 10% in the eccentric vs. the concentric group and a number-needed-to-treat of 10. The eccentric group also had a greater increase of muscle strength than the concentric ($p < 0.02$). The differences persisted throughout the follow-up period. There were no significant differences between the groups regarding function or quality of life measures.

Conclusion: Eccentric graded exercise reduced pain and increased muscle strength in chronic tennis elbow more effectively than concentric graded exercise.

Keywords

Concentric, concentric exercise, eccentric, eccentric exercise, pain, randomized controlled trial, tendinopathy, tennis elbow

Received: 3 March 2013; accepted: 19 February 2014

¹Department of Public Health and Caring Sciences, Uppsala University, Uppsala, Sweden

²Department of Surgical Sciences/Anesthesiology and Intensive Care Medicine, Uppsala University Hospital, Uppsala, Sweden

Corresponding author:

Magnus Peterson, Department of Public Health and Caring Sciences, Section of Family Medicine and Preventive Medicine, Uppsala University, Box 564, Uppsala SE-751 22, Sweden.
magnus.peterson@pubcare.uu.se

Introduction

Tennis elbow is a common disorder. Typical symptoms are pain at the lateral epicondyle of the humerus aggravated by loading of the common extensor tendinous origin of the forearm extensor muscles.¹ The incidence is 1–3% in the population.^{1–3} and peak prevalence is between 35 and 45 years of age.^{2,4} The cause is primarily repetitive overuse, and heavy manual labour increases the risk of being affected.^{3,5,6}

The acute stage comprises inflammatory processes, and treatment by rest, anti-inflammatory medication or injection with steroids may in this stage be appropriate.⁷ However, tennis elbow often persists or recurs beyond the normal time for healing.⁸ Up to 20% of cases may persist after one year.^{9,10} In this chronic stage (defined as lasting more than three months), histological samples show very few inflammatory changes and the aetiology of pain is still largely unknown. This may explain why there is such a multitude and diversity of treatment options available,^{9,11,12} many not yet properly evaluated.^{9,11} The disadvantages of anti-inflammatory treatment will, in this stage, outweigh the advantages.^{13–15}

Eccentric exercise (i.e. exercise using the elongation phase of muscle activity by lowering weights) as treatment for chronic tendon pain was proposed by Stanish et al.,¹⁶ and Alfredson and co-workers have developed the concept.^{17,18}

Whether eccentric graded exercise is superior to conventional concentric graded exercise (i.e. using the contraction phase of muscle activity by lifting weights according to a graded protocol), or a combination of both, as treatment in the chronic stage of tendon pain has been a matter of debate.^{19,20,21} In a previous small-scale study of short duration, no significant differences between eccentric and concentric exercise were found.²² The present study is a randomized controlled trial of the effects of eccentric vs. concentric exercise on pain and function in chronic tennis elbow.

Methods

The study was performed in the city of Uppsala, Sweden. All 150 general practitioners and 90 physiotherapists at primary healthcare centres in

Uppsala county were asked to report potential subjects with long-lasting tennis elbow problems. In addition, potential subjects with tennis elbow symptoms were invited to participate in the study through advertisements in the main local newspaper in order to recruit a sufficiently large number of subjects.

Inclusion criteria were age 20–75, symptoms of tennis elbow for more than three months, and a verified diagnosis according to diagnostic criteria below. Exclusion criteria were any of concomitant supinator syndrome, compartment syndrome of musculus anconeus, rhizopathy, inflammatory joint disease, fibromyalgia, previous elbow surgery, and inability to understand Swedish. At a first appointment, the diagnosis was checked by pain on palpation, pain on stretching (Mill's test), pain on loading, and Maudsley's middle finger test, by the same physician, a general practitioner and pain specialist (MP). A total of 173 patients were evaluated, 53 of whom were excluded owing to incorrect diagnosis, other concomitant pain diagnoses, or interfering treatment, leaving 120 subjects as the final study population. All subjects gave written informed consent before entering the study. The Uppsala Regional Research Ethics Board approved the study. The trial is registered as NCT00888225 at <http://clinicaltrials.gov/>.

The subjects were randomly assigned to eccentric or concentric exercise by means of a random block design. The SAS software 'ranuni' function, generating random numbers with equal probability distribution, was programmed so that for each four consecutive participants, two were randomly allocated to the eccentric group and two to the concentric group.²³ Enrolment, allocation, and follow-up procedure are presented in Figure 1.

Both groups received an exercise regime to be performed at home for three months with progressively increasing load on the affected forearm extensor muscles. The loading equipment consisted of a plastic water container with a handle. The initial load was standardised to 1 kilogram (one litre of water) for women and 2 kilograms for men. The participants sat in a chair and supported the forearm on the armrest or on an adjacent table. Both groups were instructed to hold the handle of

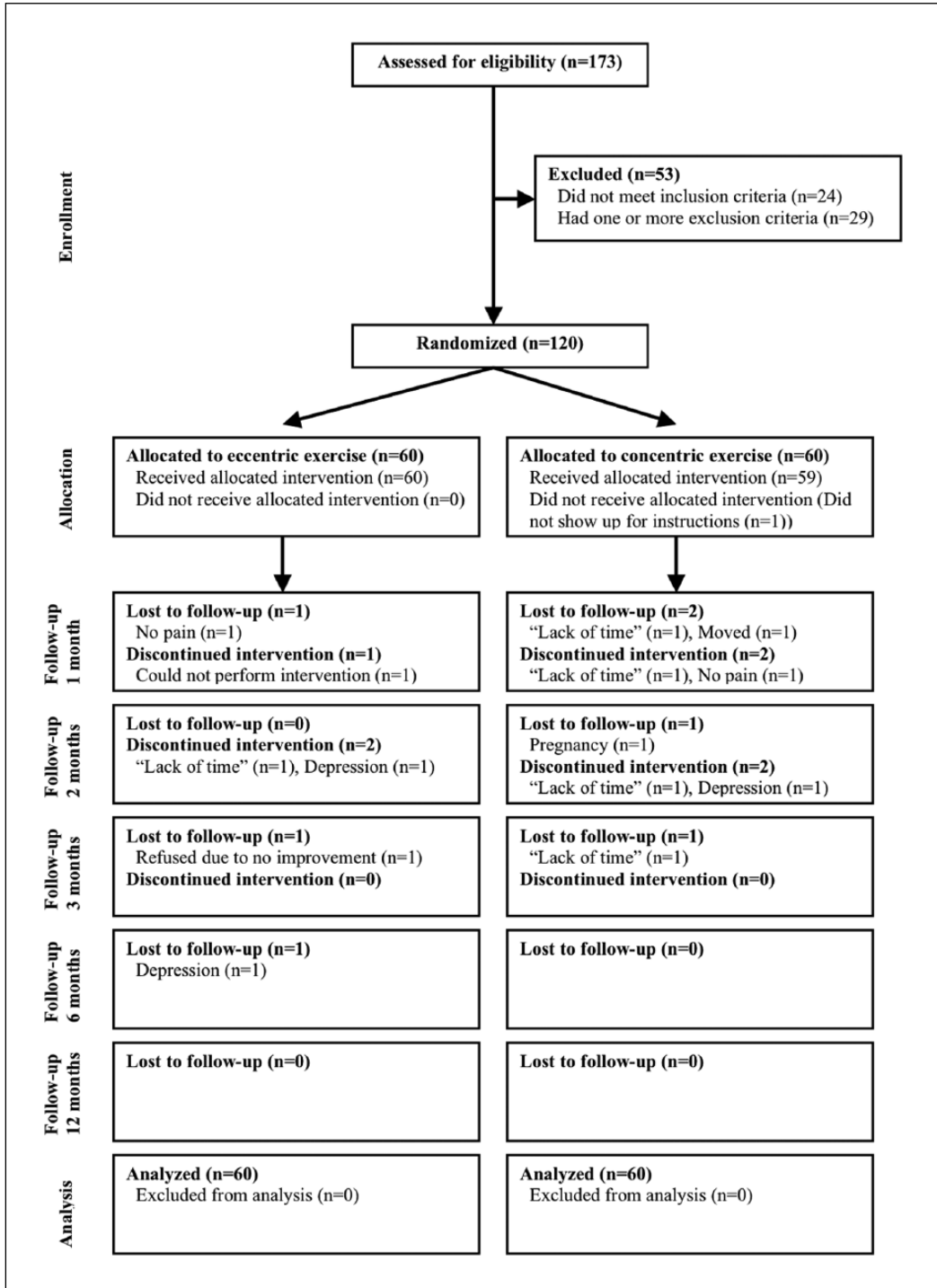


Figure 1. Flowchart of the study.



Figure 2. Photograph showing exercise set-up with the patient seated in an armchair with forearm support, holding the dumbbell (a plastic container with a specified amount of water) in the affected arm, and performing exercise by lifting and lowering the container by extension or flexion of the wrist.

the plastic water can with a clenched fist in pronation and the container hanging freely in front of the armchair or below the tabletop (Figure 2).

The eccentric exercise group was instructed to lower the weight by flexing the wrist of the affected arm downwards and to lift it back again with the unaffected arm in three sets of 15 repetitions, in total 45 weight lowering manoeuvres, once daily.

The concentric group was instructed to lift the weight by extending the wrist of the affected arm upwards and to lower it back again with the unaffected arm in three sets of 15 repetitions, in total 45 weight lifting manoeuvres, once daily.

In both groups the load was increased weekly by one hectogram (one decilitre of water). The subjects were asked to report other competing treatments and were instructed not to use pain relieving or anti-inflammatory medication other than acetaminophen (paracetamol).

Data were collected by an un-blinded assessor (MP) at baseline and at five follow-up appointments at one, two, three, six, and 12 months after the baseline appointment. At baseline, information was collected regarding educational level, marital status, smoking habits, tennis elbow history, and previous treatment given during the current episode. Education was classified on a four-point

scale, ranging from compulsory education only to college or university education. Marital status was classified as never married, married or cohabiting, divorced, or widowed. Smoking habits were classified as never smoked, ex-smoker, currently smoking 1–14 cigarettes/day, 15–24 cigarettes/day, or 25 cigarettes/day or more.²⁴ The tennis elbow history included number of previous episodes, time since last episode, and duration of the present one. Information on previous treatments during the current episode was given in a free text format.

The primary outcome of the study, pain reduction, was measured at all visits with two 100 mm Visual Analogue Scales (VASs) ranging from ‘no pain’ (= 0) to ‘worst imaginable pain’ (= 100). The first scale pain was measured during maximum voluntary contraction of the forearm extensor muscles (Cozen’s test), and the second scale pain during maximum muscle elongation of the extensor carpi radialis brevis and longus muscles with a load (90° abduction of the arm followed by full pronation of the forearm with a 3-kilogram dumbbell, i.e. a modified empty can test). Both pain measures were developed in cooperation with an experienced hand surgeon to simulate the most accurate pain provoking manoeuvres in tennis elbow. Based on the six measurements per subject across the study period, the coefficient of variation for pain during maximum voluntary contraction, adjusted for the effect of time, was 16.7%, and for pain during maximum muscle elongation 12.5%.

The secondary outcome, muscle strength of the forearm extensor muscles, was also measured at all visits using a Chatillon MSE 100 handheld dynamometer (AMETEK Measurement & Calibration Technologies Division, Florida, USA), with the arm positioned as in the maximum voluntary contraction pain score above. An analysis of repeated muscle strength measurements in three volunteers by three observers gave a coefficient of variation of 8.2% after adjustment for observer effect, similar to previous assessments of test-retest and inter-rater reliability concerning handheld dynamometry.^{25,26}

The tertiary outcomes, general arm function and quality of life aspects, were measured at baseline, and at the three-, six-, and 12-months follow-up

visits with the Disability of Arm, Shoulder, and Hand questionnaire^{27,28} and the Gothenburg Quality of Life instrument²⁹⁻³¹ questionnaires. The Disability of Arm, Shoulder, and Hand questionnaire contains 30 questions on the ability to perform activities using a five-point Likert scale ranging from 'no problem' to 'impossible'. Responses were summarised and standardised so that the sum score, indicating overall degree of restriction, ranged from 0 to 100, low scores indicating a low degree of restriction.

The Gothenburg Quality of Life instrument with its three sub-scales, complaint score, well-being score, and activity score, was used to measure quality of life aspects. The instrument has been validated in various study populations and is widely used. The complaint score lists 30 general symptoms. The respondents were asked to indicate which of these they had experienced during the last three months, with possible responses 'yes' or 'no'. The well-being sub-scale has nine items, of which self-rated health was used for this report. The response was given on a seven-point Likert scale ranging from 'very bad' to 'excellent, could not be better', with no verbal description of the intervening steps. The activity score lists 32 specified leisure time activities and two open alternatives, covering six areas. The subjects were asked to indicate which of these activities they had performed during the last year with response alternatives 'never' (= 0), 'occasionally' (= 1), and 'often or regularly' (= 2). The scores were summed to an overall activity score, high scores indicating an active lifestyle.

Data were analysed using the SAS software, version 9.3.²³ Data loss owing to partial non-response (missing data in returned questionnaires or protocols) was 1.3%. No competing treatments or adverse events were reported. Simple differences between groups in continuous variables were computed with Student's *t*-test and differences in proportions with the chi-square test. The intention-to-treat approach was followed. The few missing data points were replaced with data from the nearest previous non-missing data measurement occasion.

Data were analysed with the proportional hazards regression analysis (Cox's analysis) and multiple linear regression (the SAS procedure

'General linear model'). The statistical analysis was performed taking data at all six measurement occasions into account, providing hazards ratio, confidence intervals (CIs) (95% CI), and estimates with 95% CIs, adjusted mean values for each measurement occasion, and adjusted mean values across the whole study period, in order to compare temporal differences in pain regression and muscle strength improvement between the group. Adjustments were made for differences between the groups of variables affecting outcome other than exercise, by including these as covariates in the analyses. These variables were: age, sex, smoking habits, education, marital status, number of previous tennis elbow episodes, time since last episode, duration of the present one, and previous treatments (Table 1 and 2), and baseline differences in the outcome variable.

As there are different opinions on what is a clinically meaningful pain decrease and muscle strength increase, a cumulative proportion of responder analysis was performed. In this analysis the percentage of pain change from baseline to end of follow-up was computed. The distribution of this change was then plotted against the proportion of subjects in the two groups who had that percentage change or a larger one, allowing for comparison between groups at any desirable cut-off point.^{32,33} The difference in the graph between the two groups represents the absolute risk reduction, which can be used to calculate the number needed to treat (number needed to treat = 1/absolute risk reduction).³²

For pain, muscle strength, Disability of Arm, Shoulder, and Hand questionnaire score, activity score, and complaint score, all continuous variables, multiple linear regression was used with outcome as dependent variable and the covariates as independent variables. Since the well-being score is an ordinal variable, it was analysed with ordinal multiple logistic regression, as well as with multiple linear regression, both giving the same result. Therefore only the results from the multiple linear regression analysis are shown. To avoid analysis model overload, non-significant covariates were excluded by backward elimination. All statistical tests were two-tailed. $P < 0.05$ was regarded as statistically significant.

Table 1. Characteristics of the study population.

| | Eccentric group | | Concentric group | | <i>p</i> |
|---------------------------|-----------------|----------------|------------------|----------------|----------|
| | <i>n</i> | Mean (SD) or % | <i>n</i> | Mean (SD) or % | |
| N | 60 | | 60 | | |
| Age (years) | | 48.8 (6.7) | | 47.0 (9.4) | |
| Women (%) | 34 | 56.7 | 23 | 38.3 | 0.04 |
| Educational level | | | | | 0.25 |
| Compulsory education only | 3 | 5.0 | 9 | 15.0 | |
| Vocational training | 12 | 20.0 | 9 | 15.0 | |
| Upper secondary school | 16 | 26.7 | 18 | 30.0 | |
| College or university | 29 | 48.3 | 24 | 40 | |
| Marital status | | | | | 0.22 |
| Never married | 4 | 6.7 | 3 | 5.0 | |
| Married or cohabiting | 48 | 80.0 | 55 | 91.7 | |
| Divorced or widowed | 8 | 13.3 | 2 | 3.3 | |
| Smoking habits | | | | | 0.17 |
| Never smoked | 55 | 91.7 | 49 | 81.7 | |
| Ex-smokers | 0 | – | 0 | – | |
| Current smokers | 5 | 8.3 | 11 | 18.3 | |

Table 2. Tennis elbow history and previous treatments during the present episode.

| | Eccentric group | | Concentric group | | <i>p</i> |
|---|-----------------|----------------|------------------|----------------|----------|
| | <i>n</i> | Mean (SD) or % | <i>n</i> | Mean (SD) or % | |
| Lateral elbow tendinopathy history | | | | | |
| Number of previous episodes (%) | | 1.8 (4.1) | | 0.8 (2.4) | 0.10 |
| Time since last episode (weeks) | | 43.1 (138.1) | | 60.8 (179.5) | 0.55 |
| Duration of present episode (weeks) | | 95.3 (172.9) | | 108.7 (159.1) | 0.66 |
| Previous treatments given | | | | | |
| NSAID | 30 | 50.0 | 26 | 43.3 | 0.46 |
| Acupuncture | 18 | 30.0 | 23 | 38.3 | 0.34 |
| Steroid injections | 21 | 35.0 | 20 | 33.3 | 0.85 |
| Stretching | 15 | 25.0 | 16 | 26.7 | 0.83 |
| Orthosis or other fixative | 14 | 23.3 | 15 | 25 | 0.83 |
| Manual treatment (deep friction, massage, manipulation) | 10 | 16.7 | 10 | 16.7 | 1.00 |
| Exercise | 3 | 5.0 | 9 | 15.0 | 0.07 |
| Rest | 6 | 10.0 | 5 | 8.3 | 0.75 |
| Ultrasound or laser | 2 | 3.3 | 7 | 11.7 | 0.08 |
| Other treatments | 5 | 8.3 | 5 | 8.3 | 1.0 |

NSAID: Non-steroidal anti-inflammatory drugs.

Results

Baseline characteristics of the study population are shown in Table 1. There were no significant differences between the treatment groups regarding mean age, educational level, marital status, or smoking habits, but there were significantly larger proportion of women in the eccentric exercise group ($p < 0.05$). There were no significant differences between the groups in medical history or in previous treatments given, Table 2. The eccentric group had a higher baseline level of the two pain scores and the Disability of Arm, Shoulder, and Hand questionnaire score, and lower muscle strength than the concentric group, while the baseline levels of the quality of life measures were similar, Table 3. Adherence to instructions and the intervention programme was monitored. Mean retention in the follow-up visits was 94% (96% in the eccentric and 92% in the concentric exercise group), and mean retention in the exercise programme was 93% (95% in the eccentric and 92% in the concentric exercise group).

As shown in Table 3, both groups improved regarding pain during maximum voluntary contraction and maximum muscle elongation, as well as muscle strength between baseline and the 12-months follow-up; but the eccentric group tended to have a faster crude decrease of pain during maximum voluntary contraction and maximum muscle elongation, as well as a faster increase of muscle strength than the concentric group. This tendency was most striking at the two-months follow-up. For the Disability of Arm, Shoulder, and Hand questionnaire score and the quality of life measures the differences in trend were small and of variable direction. However, there were no significant crude differences between the groups in any of the outcome measures, as measured by change from baseline to end of follow-up.

In order to compare the timing of the reduction of pain and the increase of muscle strength, linear regression analyses utilising measurements from all six measurement occasions were performed. Measured in this way, the eccentric group had significantly lower mean level of pain during maximum voluntary contraction ($p < 0.0001$) and maximum muscle elongation

Table 3. Crude outcome data by measurement occasion and treatment group. Numbers are means (standard deviation).

| | Eccentric group | | | | | | Concentric group | | | | | |
|--------------------|-----------------|-------------|--------------|--------------|--------------|--------------|------------------|--------------|--------------|--------------|--------------|--------------|
| | Baseline | 1 month | 2 months | 3 months | 6 months | 12 months | Baseline | 1 month | 2 months | 3 months | 6 months | 12 months |
| Pain score, MVC | 47.9 (26.8) | 33.4 (24.9) | 26.6 (22.0) | 21.2 (22.9) | 14.4 (21.2) | 9.8 (19.5) | 46.1 (27.5) | 37.2 (28.4) | 32.8 (28.3) | 23.7 (28.2) | 17.8 (23.4) | 12.8 (24.8) |
| Pain score, MME | 40.6 (27.0) | 23.4 (24.9) | 16.5 (20.8) | 12.8 (20.8) | 8.1 (20.4) | 4.7 (12.4) | 38.8 (28.6) | 31.9 (28.0) | 25.3 (26.1) | 15.8 (25.6) | 10.5 (22.9) | 6.6 (18.9) |
| Muscle strength, N | 119.9 (44.1) | 129 (45.3) | 133.8 (47.1) | 127.8 (48.1) | 128.7 (46.4) | 128.8 (50.0) | 133.7 (48.4) | 142.4 (46.4) | 147.3 (47.4) | 135.7 (44.2) | 137.1 (49.3) | 138.3 (49.3) |
| DASH score | 28.8 (18.4) | - | - | 14.6 (17.9) | 11.9 (17.9) | 9.6 (17.8) | 27.5 (17.3) | - | - | 13.4 (17.2) | 10.3 (16.7) | 9.6 (16.3) |
| Activity score | 28.4 (6.9) | - | - | 26.3 (7.4) | 25.2 (7.3) | 24.9 (7.6) | 27.4 (7.0) | - | - | 23.9 (7.1) | 23.6 (7.5) | 23.0 (7.4) |
| Well-being score | 5.3 (1.5) | - | - | 5.1 (1.5) | 5.0 (1.4) | 5.1 (1.6) | 5.5 (1.4) | - | - | 5.3 (1.3) | 5.1 (1.4) | 5.4 (1.3) |
| Complaint score | 6.6 (5.8) | - | - | 4.5 (5.4) | 4.6 (5.5) | 4.2 (5.5) | 6.3 (4.9) | - | - | 4.6 (5.7) | 4.1 (5.4) | 4.9 (6.1) |

DASH: Disability of Arm, Shoulder, and Hand; MME: maximum muscle elongation; MVC: maximum voluntary contraction.

($p < 0.001$), as well as greater mean muscle strength ($p < 0.05$).

The effects in the two groups are shown in Figure 3, where the distribution of pain reduction (horizontal axis) is plotted against the proportion of subjects with that or a larger pain reduction (vertical axis). The eccentric group had, on average, a 10% unit higher responder rate at all levels of pain reduction than the concentric group for maximum voluntary contraction, as well as maximum muscle elongation. This represents an absolute pain reduction of 10% and a number-needed-to-treat of $1/(0.10) = 10$. No significant differences regarding the Disability of Arm, Shoulder, and Hand questionnaire score or any of the quality of life measures were found.

Discussion

Both groups improved significantly regarding pain and strength, but the crude difference was not significant between the groups at the 12-months follow-up. Adjusted for confounding factors and for change over time, however, the eccentric exercise group had significantly faster recovery from pain during maximum voluntary contraction and maximum muscle elongation, and improvement of muscle strength as compared with the concentric group. There were no significant differences between the groups regarding physical functioning and quality of life aspects.

The strengths of the study include that the study population was recruited from among chronic tennis elbow patients in primary healthcare. Although this was not a random population sample, it may be regarded as fairly representative of this type of patient in the general population. The same observer did all measurements, thereby avoiding interobserver variation. The monitoring was intense, resulting in a high participation rate. The data loss in the trial was low. Moreover, the intention-to-treat analysis strategy was used, thereby minimising the bias risk. Pain scoring using visual analogue scales (VAS) has previously been validated.^{34,35} The scoring has considerable inter-patient variability, but intra-patient variability over time, as used in this study, is low. Strength measurements

with a hand-held dynamometer have reliable reproducibility in test-retest and between-day measurements.^{25,26} The Disability of Arm, Shoulder, and Hand questionnaire has been recommended by the American Academy of Orthopedic Surgeons' Outcomes Research Committee and the Institute for Work and Health, and both the English and Swedish versions have been tested for reliability and validity.^{27,28} The Gothenburg Quality of Life instrument is a validated and extensively used measure of general health and well-being.²⁹⁻³¹

A possible limitation is that the data collection could not be blinded, since the observer monitored the adherence to the exercise procedure at baseline and the first follow-up visit. However, during the following four follow-up visits no group allocation data were available, and it was, in practice, more or less impossible for the observer to keep track of the group allocation. The risk of bias owing to non-blinding is therefore probably small.

To gain maximum effect of the exercise, the starting weight should be individually tailored, for instance as a percentage of one repetition maximum (1RM), the weight one can manage to lift once only.³⁶ To simplify clinical application, the starting weight in this study was standardised. This may have had the effect that the load, and accordingly the stimulus, in this study was smaller or larger than would have been required for optimum effect. However for clinical application this seems to be a useful simplification.

In spite of some methodological weaknesses, a number of studies support the effect of exercise in tendinosis.^{4,9,11,19,37} A previous small-scale study of short duration found no significant differences between eccentric and concentric exercise in chronic tennis elbow.²² In the present study, eccentric exercise reduced pain faster than concentric exercise in chronic tennis elbow. This supports previous studies on Achilles tendinosis showing eccentric exercise to be superior to concentric exercise.^{38,39}

In conclusion, chronic tennis elbow responds favourably to physical input by loading according to a graded exercise programme, whether this is based upon concentric or eccentric exercise. However, eccentric graded exercise provides an advantage by

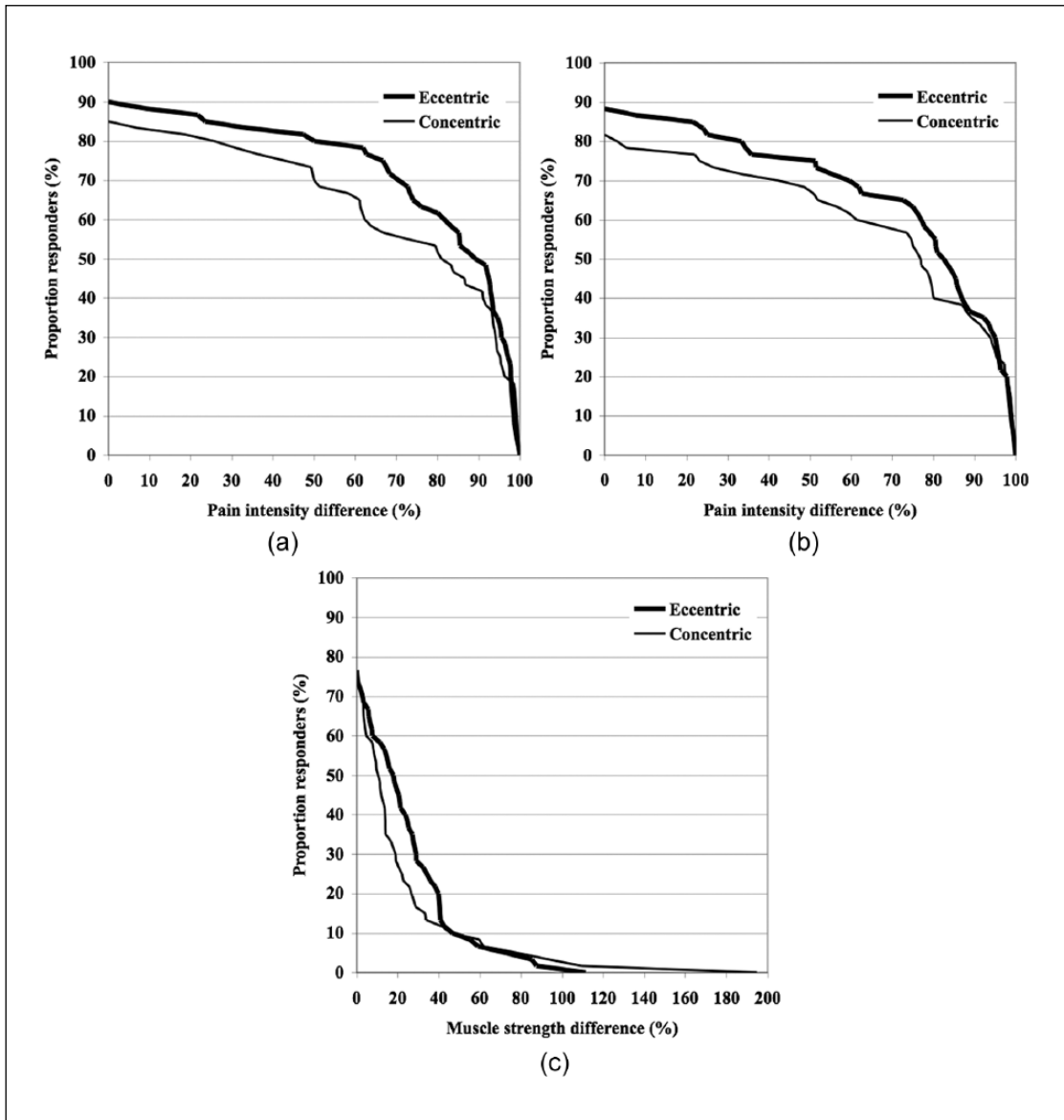


Figure 3. (a)–(c) Cumulative proportion of responders analysis graph. The horizontal axis shows the change of pain or muscle strength from baseline to end of follow-up. The vertical axis shows the proportion of subjects who had a change of that magnitude or more. For instance, in (a) 10% of the eccentric group had no change vs. 15% in the concentric group, 80% of the eccentric group had a 50% decrease or more of pain vs. 70% of the concentric group, etc. Overall, the eccentric exercise group had a higher responder rate at all levels of change in pain score during maximum voluntary contraction (a) and maximum muscle elongation (b) and of muscle strength (c).

faster and greater improvement in pain and strength. In conclusion, an exercise programme for chronic tennis elbow should be designed to gradually put

load on the affected painful tissue, and should stress the eccentric work phase, but need not exclude the concentric work phase.

Clinical messages

- Chronic tennis elbow responds more favourably to a graded eccentric exercise programme than to a concentric one.
- Both modes of exercise may be used in order to simplify the execution of the exercise, but stressing the eccentric work phase will provide an advantage.

Contributors

MP was involved in the design of the study and the recruitment of the subjects, implemented the intervention, oversaw the baseline and follow-up testing and drafted the manuscript. SB was involved in critically reviewing the manuscript. ME was involved in monitoring the study and critically reviewing the manuscript. KS designed the study, monitored its progress, completed the statistical analysis, and critically reviewed the manuscript.

Conflict of interest

The author declares that there is no conflict of interest.

Funding

This study was supported by grants from the Swedish Research Council (grant no. K2005-27X-15293-01A), The Amersham Fund at Uppsala University, The Research Fund at Uppsala County Council, The Family Medicine Foundation, and Uppsala University. The funding sources had no involvement in study design, data collection, analysis, interpretation of data, manuscript preparation, or decision to publish.

References

1. Verhaar JA. *Tennis elbow*. Maastricht University, 1992.
2. Allander E. Prevalence, incidence, and remission rates of some common rheumatic diseases or syndromes. *Scand J Rheumatol* 1974; 3: 145–153.
3. Shiri R and Viikari-Juntura E. Lateral and medial epicondylitis: role of occupational factors. *Best Pract Res Clin Rheumatol* 2011; 25: 43–57.
4. Kingma JJ, de Knikker R, Wittink HM and Takken T. Eccentric overload training in patients with chronic Achilles tendinopathy: a systematic review. *Br J Sports Med* 2007; 41: e3.
5. Abate M, Silbernagel KG, Siljeholm C, et al. Pathogenesis of tendinopathies: inflammation or degeneration? *Arthritis Res Ther* 2009; 11: 235.
6. Dimberg L. The prevalence and causation of tennis elbow (lateral humeral epicondylitis) in a population of workers in an engineering industry. *Ergonomics* 1987; 30: 573–579.
7. Kjaer M, Langberg H, Skovgaard D, et al. In vivo studies of peritendinous tissue in exercise. *Scand J Med Sci Sports* 2000; 10: 326–331.
8. Rees JD, Wilson AM and Wolman RL. Current concepts in the management of tendon disorders. *Rheumatol (Oxford, England)* 2006; 45: 508–521.
9. Peterson M, Elmfeldt D, Svardsudd K. Treatment practice in chronic epicondylitis: a survey among general practitioners and physiotherapists in Uppsala County, Sweden. *Scandinavian journal of primary health care* 2005; 23: 239–241.
10. Haahr JP and Andersen JH. Prognostic factors in lateral epicondylitis: a randomized trial with one-year follow-up in 266 new cases treated with minimal occupational intervention or the usual approach in general practice. *Rheumatol (Oxford, England)* 2003; 42: 1216–1225.
11. Maffulli N, Longo UG and Denaro V. Novel approaches for the management of tendinopathy. *J Bone Joint Surg* 2010; 92: 2604–2613.
12. Peterson M, Elmfeldt D and Svardsudd K. Treatment practice in chronic epicondylitis: a survey among general practitioners and physiotherapists in Uppsala County, Sweden. *Scand J Primary Health Care* 2005; 23: 239–241.
13. Coombes BK, Bisset L and Vicenzino B. Efficacy and safety of corticosteroid injections and other injections for management of tendinopathy: a systematic review of randomised controlled trials. *Lancet* 2010; 376: 1751–1767.
14. Christensen B, Dandanell S, Kjaer M and Langberg H. Effect of anti-inflammatory medication on the running induced rise in tendon collagen synthesis in humans. *J Appl Physiol* 2011; 110: 137–141.
15. Sostres C, Gargallo CJ, Arroyo MT and Lanás A. Adverse effects of non-steroidal anti-inflammatory drugs (NSAIDs, aspirin and coxibs) on upper gastrointestinal tract. *Best Practice Res* 2010; 24: 121–132.
16. Stanish WD, Rubinovich RM and Curwin S. Eccentric exercise in chronic tendinitis. *Clinic Orthop Related Res* 1986; (208): 65–68.
17. Alfredson H, Pietila T, Jonsson P and Lorentzon R. Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med* 1998; 26: 360–366.
18. Jonsson P and Alfredson H. Superior results with eccentric compared to concentric quadriceps training in patients with jumper's knee: a prospective randomised study. *Br J Sports Med* 2005; 39: 847–850.
19. Woodley BL, Newsham-West RJ and Baxter GD. Chronic tendinopathy: effectiveness of eccentric exercise. *Br J Sports Med* 2007; 41: 188–198; commentary 199.

20. Kjaer M, Langberg H, Heinemeier K, et al. From mechanical loading to collagen synthesis, structural changes and function in human tendon. *Scand J Med Sci Sports* 2009; 19: 500–510.
21. Raman J, MacDermid JC and Grewal R. Effectiveness of different methods of resistance exercises in lateral epicondylitis—a systematic review. *J Hand Therapy: Official J Am Soc Hand Therapists* 2012; 25: 5–25; quiz 26.
22. Martinez-Silvestrini JA, Newcomer KL, Gay RE, Schaefer MP, Kortebein P and Arendt KW. Chronic lateral epicondylitis: comparative effectiveness of a home exercise program including stretching alone versus stretching supplemented with eccentric or concentric strengthening. *J Hand Ther* 2005; 18: 411–419.
23. SAS (statistical analysis system). SAS Institute Inc. Available at: <http://support.sas.com/software/93/index.html> (accessed 2 March 2014). <http://www.sas.com/presscenter/guidelines.html>.
24. Rose GA. *Cardiovascular survey methods*. Geneva: WHO, 1982.
25. Bohannon RW. Test-retest reliability of hand-held dynamometry during a single session of strength assessment. *Physical Therapy* 1986; 66: 206–209.
26. Bohannon RW and Endemann N. Magnitude and reliability of hand-held dynamometer measurements within and between days. *Physiotherapy Practice* 1989; 5: 177–181.
27. Atroshi I, Gummesson C, Andersson B, Dahlgren E and Johansson A. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: reliability and validity of the Swedish version evaluated in 176 patients. *Acta Orthop Scand* 2000; 71: 613–618.
28. Hudak L, Amadio PC and Bombardier C. Development of an upper extremity outcome measure: the DASH (Disability of the Arm, Shoulder and Hand). *Am J Industr Med* 1996; 29: 602–608.
29. Tibblin G, Tibblin B, Peciva S, Kullman S and Svärdsudd K. “The Göteborg quality of life instrument” – An assessment of well-being and symptoms among men born in 1913 and 1923. Methods and validity. *Scand J Primary Health Care* (Suppl 1) 1990; 33–38.
30. Sullivan M, Karlsson J, Bengtsson C, Furunes B, Lapidus L and Lissner L. “The Göteborg Quality of Life Instrument”—a psychometric evaluation of assessments of symptoms and well-being among women in a general population. *Scand J Primary Health Care* 1993; 11: 267–275.
31. Haywood KL, Garratt AM and Fitzpatrick R. Quality of life in older people: a structured review of generic self-assessed health instruments. *Qual Life Res* 2005; 14: 1651–1668.
32. Farrar JT, Dworkin RH and Max MB. Use of the cumulative proportion of responders analysis graph to present pain data over a range of cut-off points: making clinical trial data more understandable. *J Pain Symptom Manag* 2006; 31: 369–377.
33. Farrar JT, Young JP Jr, LaMoreaux L, Werth JL and Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain* 2001; 94: 149–158.
34. Price D, Long S and Harkins S. A comparison of pain measurement characteristics of mechanical visual analogue and simple numerical rating scales. *Pain* 1994; 56: 217–226.
35. Price D, McGrath P and Rafii A. The validation of visual analog scales as ratio scales measures for chronic and experimental pain. *Pain* 1983; 17: 45–56.
36. Åstrand P-O, Rodahl K, Dahl HA and Strömme S. *Textbook of work physiology*. 4th revised edn. IL, US: Human Kinetics Publishers, 2003.
37. Kjaer M, Langberg H, Miller BF, et al. Metabolic activity and collagen turnover in human tendon in response to physical activity. *J Musculoskeletal Neuronal Interact* 2005; 5: 41–52.
38. Mafi N, Lorentzon R and Alfredson H. Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. *Knee Surg Sports Traumatol Arthrosc* 2001; 9: 42–47.
39. Niesen-Vertommen SL, Taunton, JE, Clement DB, and Mosher RE. The effect of eccentric versus concentric exercise in the management of Achilles tendinitis. *Clin J Sport Med* 1992; 2: 109–113.