INTRODUCTION

Background

Tennis elbow or lateral epicondylopathy (LE) is experienced as lateral elbow pain and affects between 1% and 3% of adults per year in the general population of the UK. A typical episode of LE may last between 6–24 months, but most patients recover within a year [1 2]. It is associated with considerable morbidity and affects both non-sporting and sporting populations. It is reported in people taking part in throwing sports as well as racket sports, with incidence rates in tennis players reported as high as 35% to 57%[3]. LE is also associated with substantial economic and social burden. The symptoms of lateral elbow pain and weakness of wrist extension and elbow supination is considered to primarily occur as a result of tendinopathy involving the extensor carpi radialis brevis (ECRB) tendon[4 5]. Treatment for this condition involves surgical and non-surgical options. Surgery should generally be considered only when conservative treatment has failed. Non-surgical options include rest, Non-Steroidal Anti Inflammatory Drugs, corticosteroid injections, taping and bracing, exercise and physical therapy [4 6-8]. Although the short term effect of corticosteroids appears beneficial, the longer (one year) results suggest a poorer response than no injection and this practice may need to be reconsidered [4 9 10]. Short term benefit has also been reported with bracing and mobilisation[1 4 11]. Based on a continuum model for treating tendinopathy [12 13] a graduated exercise loading programme appears to be effective in pain control and restoration of function. With respect to LE, rehabilitation programmes focus on loading the wrist extensors and elbow supinator's. Although loading programmes have been suggested, to date the electromyographic (EMG) response of a system to deliver an easily accessible (in clinic and at home) graduated exercise programme has not been tested.

The aim of this investigation is to assess the effectiveness of a prototype device developed by one of the authors (JL) to deliver a graduated exercise programme for the wrist extensors and elbow supinators.

METHOD

Setting

The study was conducted between November 2011 and January 2012, and took place in the Physiotherapy Department of Charing Cross Hospital, London, UK.

Participants Participants were included in the study if they were aged 16 to 65, had no cervical or upper limb symptoms in the past 3 months, no past history of LE, no forearm fractures within the previous 12 months, and competency in written and spoken English. Exclusion criteria included a Beighton score greater than 4, any systemic inflammatory condition, a history of carpal tunnel syndrome and wrist and hand deformities (that would prevent holding the device).

Study Design

A quantitative cross sectional experimental study design was used. All participants provided written informed consent prior to study inclusion (Research Ethics Committee number 09/H0707/3). All participants were then assessed for dominant handedness using the Edinburgh Handedness Inventory [14].

The study incorporated two elements: a wrist extensor exercise programme and a supination to pronation exercise programme.

A convenience sample of five participants from the group repeated the study protocol to provide reliability data.

Participant start position

Participants were asked to stand upright against a wall with their dominant arm supported by an adjustable height table with their elbow flexed to 90 degrees and their shoulder rested against a wall in 0 degrees of flexion, abduction and rotation [15-17]. The height of the supporting table was adjusted so as to support the dominant arm and maintain the shoulder girdle at approximately the same level as the non-dominant side and also ensure that the dominant wrist was free to fully flex over the table and when in the pronated position.

EMG

Surface electrodes (Ambu N-10-A; Ballerup Denmark) were used to record EMG activity from the extensor muscles of the forearm. They were placed with the recording area 2 cm apart and positioned in a standardised way[18], with the midpoint of the two electrodes placed 47.6% of the distance on a line between the midpoint of the supracondylar ridge and the radial styloid [19]. The aim of this position was to bias the recording such that it measured EMG activity from Extensor Carpi Radialis Brevis (ECRB[19]). The EMG was amplified and filtered with a bandwidth of 30 Hz to 6 KHz (Digitimer; Herts UK). The data were collected at a sampling frequency of 4 KHz using an analogue to digital converter (1401, Cambridge Electronic Design; Cambridge UK) and stored using Spike 2 software (Cambridge Electronic Design; Cambridge UK). EMG activity was normalized to the level of EMG activity achieved at maximum voluntary contraction. Therefore, each participant was asked to clench their hand into a fist and hold the wrist in neutral and pronation in order to activate ECRB[20]. The participant was then asked to maximally contract their wrist extensors by pushing up against the investigator's resistance and the maximum EMG was recorded.

A modified Coopers elbow crutch was developed for this investigation as the prototype device. Numbers were assigned to four holes that were evenly spaced apart on the crutch to allow for an increase in the moment arm to graduate the exercise protocol. These four numbers were placed on every third hole. The highest number was assigned to the longest position of the extendable arm.

Eccentric wrist extensor exercise programme

Participants were asked to grip the elbow crutch in the dominant hand at the handle with the stick over the lateral aspect of the hand. It was held with the wrist in full extension and slowly lowered to full wrist flexion. To standardise the time taken to complete the movement participants were instructed to keep in time with a computer driven metronome which counted up from 0 to 5 seconds. Sixteen different sets of exercises were performed, giving the subject as much time as they needed to recover between each exercise (generally 1-2 minutes). The level of exercise was varied by changing the length of the crutch using the four predefined lengths. In addition, the exercise was varied by changing the weight of the crutch by using no weight or attaching a 0.5kg or a 1.0kg or 1.5kg weight at a fixed position to the end of the crutch. The order of the length of the crutch and the order of the weight of the crutch was chosen at random.

Supination to pronation exercise programme

The participants' positions were as previously described. However, participants would grip the crutch in their dominant hand with the wrist in full supination and the crutch positioned at right angles to their forearm, holding the crutch over a rubber grip placed just inferiorly to the crutch handle. The participant then actively rotated the crutch to full wrist pronation in time with the metronome counting from 0 to 5 seconds. The participant then repeated this process for each of the four-positions of the extendable arm and the four weight levels at each of these positions.

Statistical Analysis

The EMG activity at each exercise level was normalized to the EMG activity at maximum voluntary contraction (MVC). A repeated-measures ANOVA was undertaken using SPSS version 19 (IBM, UK) to determine if surface EMG activity as a percentage of MVC differed across the graded exercise sequences. In addition, regression analysis was used to explore the change between one level of exercise and the next in sequence. These changes were tested against relationship models including linear models to explore the best curve fit. Statistical significance was accepted at $p \leq 0.05$.

Intra-class correlation was used to indicate the reliability of the data with Bland and Altman graphs created to interpret the reliability of the data.

RESULTS

Eighteen participants aged 23 to 41 completed the study and five participants repeated the study to provide reliability data. No adverse effects were reported.

Both of the exercise programmes demonstrated an increase in percentage EMG activity (see Figure 1, $p< 0.01$). Neither programme was found to produce a linear or incremental relationship between the EMG activity and the sequential load. However, in post hoc analysis a selected combination of both programmes were found to have a statistically linear relationship as seen in Figure 2 ($p<0.001$). Here, the exercise programme begins with the eccentric exercise of the wrist extensors using the crutch at length 1 through to length 4 without a weight (exercise 1 to 4, figure 3). The programme then changes to the supination to pronation protocol at length 1 through to 4 with a 0.5kg weight (exercise 5 to 8, figure 3). It progresses to the 1kg weight using length 1 through to 3 (exercise 9 to 11, figure 3) before reverting to the wrist extensor exercise with the crutch at length 1 and the addition of a 0.5kg weight (exercise 12, figure 3). The programme then continues using the wrist extensor protocol of incrementally increasing the length before increasing weight.

Reliability of the study

The mean ICC value (Model 2 individual) of the five subjects was 0.78. (95% Confidence Limits 0.67-0.87). This indicates strong agreement between the data. The Bland and Altman plot is presented in Figure 5.

DISCUSSION

Many studies advocate the use of exercises in the treatment of LE [4 17 21]. However, we were unable to identify any research that has investigated if a purpose built device designed to incrementally increase load on the ECRB muscle-tendon unit produces a graded exercise programme. A recent systematic review of resistance exercises in the treatment of Lateral Epicondylosis [22] concluded that optimum dose data and progression for exercises had limited supporting data. This study is the first to identify a systematic and linear graded exercise progression and so presents a validated graded exercise programme for ECRB which may be useful in the treatment of people with LE.

It is interesting to note that the participants did not achieve more than an average of 30% of the EMG activity at maximum voluntary contraction (see figure 3). This maximum was collected at a mid-point in range isometrically however; the data was collected during eccentric contractions particularly during the extension to flexion exercise. EMG activity during an eccentric contraction is often lower than during other types of contractions[23]. Nevertheless, given the difficulty that some subjects had in completing the exercise protocol, it is surprising that a greater level of EMG was not achieved.

It is important to note that EMG activity and not the load going through the musculo-tendinous junction was measured here. It is unclear if there is a linear relationship between EMG activity and such a load; however it seems reasonable to suggest that this programme may represent a systematic and graded increase in load. Importantly, the reliability data suggests that the outcomes of the study are likely to be reproducible.

Limitations of the study

Research using surface EMG is not without limitations. These include recording EMG from other muscles as well as ECRB[24]. However, this is unlikely to confound the result presented here as electrode position remained constant throughout the recording procedure and the recording of cross talk is likely to have been stable throughout.

This study was conducted on healthy participants and further studies recruiting people suffering with LE is required to determine whether the same graded increase in EMG activity is found in the presence of a pathological tendon. Finally, more robust conclusions may be derived with a larger study population.

Conclusion

Graduated loading is considered to be the keystone for the management of overuse tendinopathies. This study investigated the EMG activity of the ECRB muscle in people without symptoms using a novel purpose built device. Selected exercises produced a linear increase in surface EMG of ECRB. In addition the results suggest that the technique is reliable. At present we are unable to determine the response in people with symptoms or its effectiveness in clinical practice.

What are the new Findings?

• A combination of eccentric wrist extension and pronation exercises produces a graded increase in surface EMG activity in the healthy ECRB muscle.

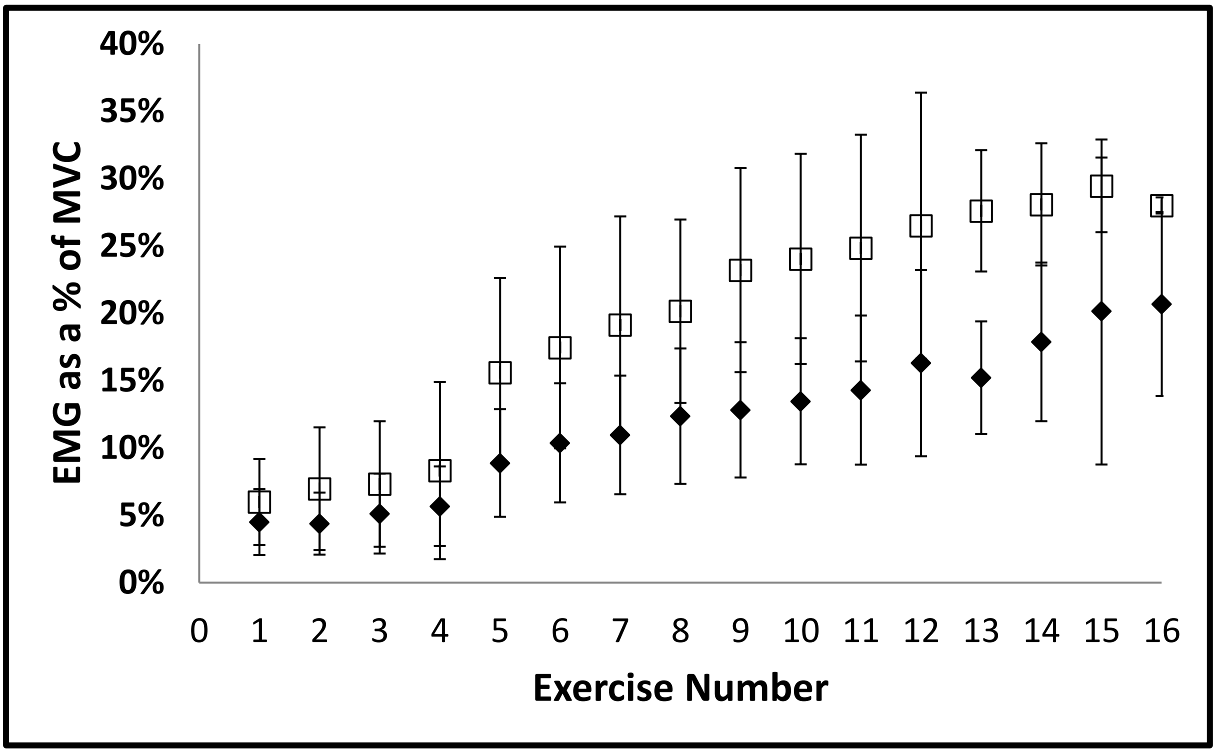
• The proposed graded exercise programme is reliable.

How might it impact clinical practice in the near future?

• Clinical studies are currently being conducted to determine if this approach is effective in the treatment of lateral epicondylopathy.

Fig.1

Fig.3



40%
35%
30%
25%
20%
15%
10%
5%
0%
EMG as a % of MVC
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Exercise Number

Fig .4

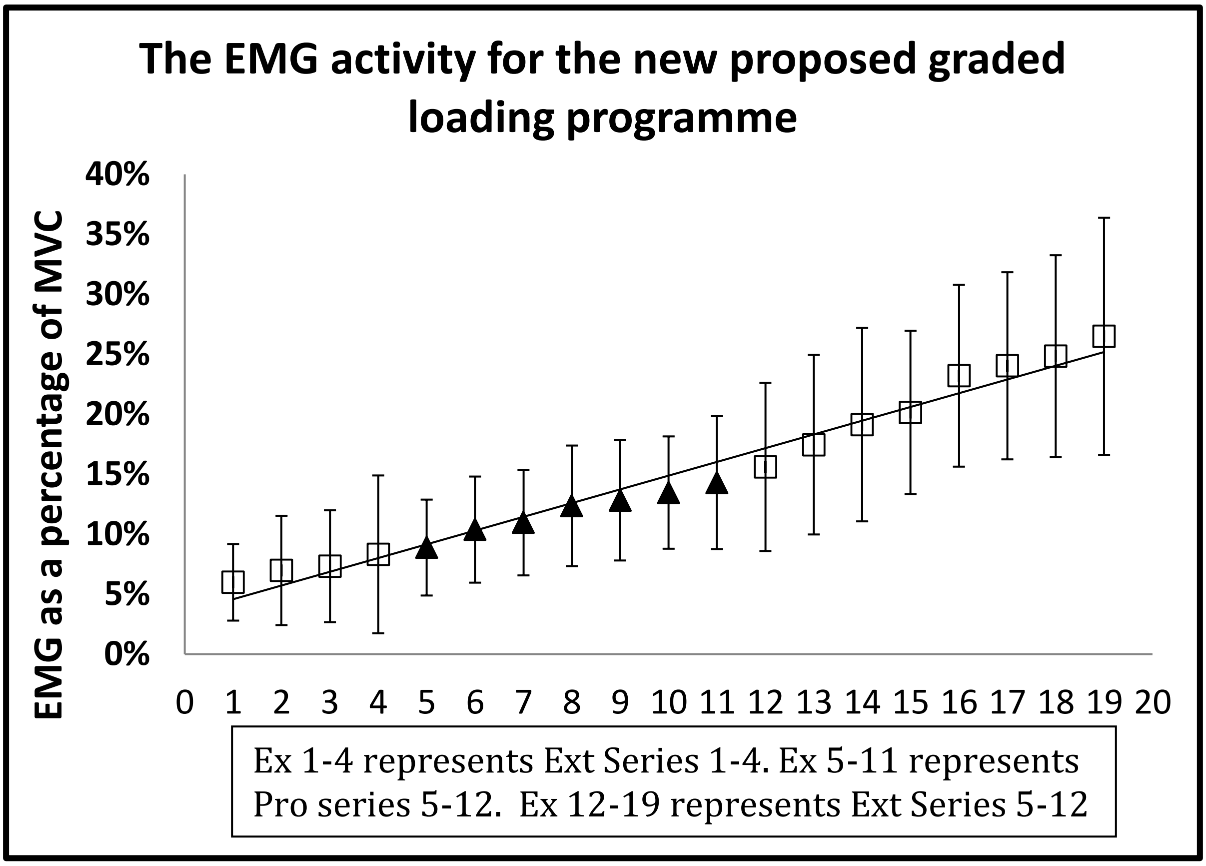
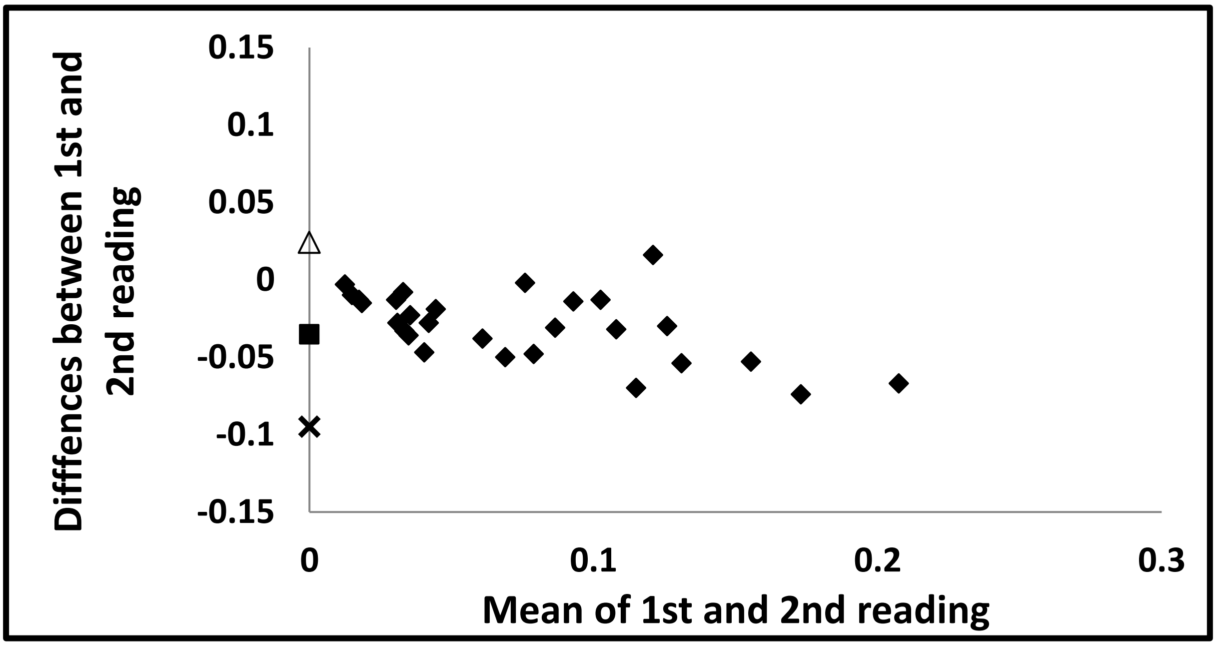

The EMG activity for the new proposed graded loading programme
EMG as a percentage of MVC
40%
35%
30%
25%
20%
15%
10%
5%
0%
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Ex 1-4 represents Ext Series 1-4. Ex 5-11 represents Pro series 5-12. Ex 12-19 represents Ext Series 5-12

Fig.5


Diffences between 1st and 2nd reading
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0
0.1
0.2
0.3
Mean of 1st and 2nd reading

Legends:

Figure 1. The prototype training device used in this study.

Figure 2. The positioning for the prototype training device used during the wrist extensor exercise series is seen to the left (A). The positioning for the prototype training device used during the pronation exercise series is seen to the right (B).

Figure 3. The surface electromyographic (EMG) activity of Extensor Carpi Radialis Brevis (ECRB) during two graded exercise programmes. The EMG activity is a percentage of EMG at maximum voluntary contraction. The exercise number represents an increase in crutch length with increasing load. The unfilled squares represent EMG activity of ECRB during eccentric exercise of the wrist extensors. The diamonds represent EMG activity of ECRB during pronation from a supinated position.

Figure 4. The surface EMG activity of Extensor Carpi Radialis Brevis (ECRB) for the proposed graded exercise programme. The EMG activity is a percentage of EMG at maximum voluntary contraction. The unfilled squares represent EMG activity of ECRB during eccentric exercise of the wrist extensors. The diamonds represent EMG activity of ECRB during pronation from a supinated position.

Figure 5. A Bland and Altman plot. The triangle represents 2 standard deviations above the mean, the x represents 2 standard deviations below the mean. The square represents the mean.

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