ELSEVIER
Clinical Biomechanics 17 (2002) 304–308
CLINICAL BIOMECHANICS
www.elsevier.com/locate/clinbiomech

A pilot study of the manual force levels required to produce manipulation induced hypoalgesia

Sionnadh McLean [a], Robert Naish [a], Lloyd Reed [b], Stephen Urry [b], Bill Vicenzino [a,*]

[a] *Department of Physiotherapy, Musculoskeletal Pain and Injury Research Unit, University of Queensland, Brisbane, Qld 4072, Australia*
[b] *Department of Podiatry, School of Public Health, Queensland University of Technology, Kelvin Grove, Australia*

Received 25 July 2000; accepted 7 March 2002

Abstract

Objective. A pilot investigation of the influence of different force levels on a treatment technique's hypoalgesic effect.

Design. Randomised single blind repeated measures.

Background. Optimisation of such biomechanical treatment variables as the point of force application, direction of force application and the level of applied manual force is classically regarded as the basis of best practice manipulative therapy. Manipulative therapy is frequently used to alleviate pain, a treatment effect that is often studied directly in the neurophysiological paradigm and seldom in biomechanical research. The relationship between the level of force applied by a technique (e.g. biomechanics) and its hypoalgesic effect was the focus of this study.

Methods. The experiment involved the application of a lateral glide mobilisation with movement treatment technique to the symptomatic elbow of six subjects with lateral epicondylalgia. Four different levels of force, which were measured with a flexible pressure-sensing mat, were randomly applied while the subject performed a pain free grip strength test.

Results. Standardised manual force data varied from 0.76 to 4.54 N/cm, lower–upper limits 95 CI, respectively. Pain free grip strength expressed as a percentage change from pre-treatment values was significantly greater with manual forces beyond 1.9 N/cm ($P = 0.014$).

Conclusions. This study, albeit a pilot, provides preliminary evidence that in terms of the hypoalgesic effect of a mobilisation with movement treatment technique, there may be an optimal level of applied manual force.

Relevance

This study indicates that the level of applied manual force appear to be critical for pain relief.

Keywords: Manual therapy; Mobilisation with movement; Lateral epicondylalgia; Tennis elbow; Force; Pain free grip strength

1. Introduction

Despite an emerging evidence base for manual therapy in the treatment of musculoskeletal disorders, little is known about the mechanisms through which manual therapy achieves its clinically beneficial effects [1]. Research of the effects and mechanisms of manual therapy appears to be compartmentalised into two paradigms: biomechanical or neurophysiological [2,3]. Manual therapy is frequently sought and provided for relief of musculoskeletal pain [4]. Interestingly, the direct pain relieving effects have been largely studied in the neurophysiological paradigm and not in the biomechanical.

The biomechanical approach to studying manual therapy has followed two discrete paths, one for high velocity thrust techniques and the other for mobilisation treatment techniques. In brief, the biomechanical study of high velocity thrust techniques has focused on quantifying the forces used by practitioners during the execution of the treatment technique, and investigating the relationship between the applied manual forces and various outcomes of the treatment technique [2,5,6]. For example, this research has shown that there is significant variation in the forces that are used when manipulating the different regions of the spine; that the audible release

* Corresponding author.
E-mail address: vicenzino@physio.therapies.uq.edu.au (B. Vicenzino).

0268-0033/02/$ - see front matter
PII: S0268-0033(02)00017-7

(i.e., joint cracks and pops) that occurs with high velocity thrust techniques is inconsistently related to the applied forces; and that electromyographic activity of a muscle was increased during manipulation [2,7–9]. In contrast to research on high velocity thrust techniques, and with few exceptions, biomechanical analysis of mobilisation therapy has used a mechanised treatment technique applicator [10,11]. Although the use of a mechanical treatment technique provides a consistent standardised force, which is desirable in the study laboratory, its application has been restricted to posteroanterior mobilisation techniques of the thoracic and lumbar spines. Some examples of the findings of this research to date are that induced motions occur at spinal regions beyond that of the treatment segment and that with higher rates of application there is a considerably increased stiffness at the local motion segment being treated [10]. To date, the relationship between the biomechanics of a manual therapy treatment technique and its direct initial pain relieving effects has not been investigated [3].

Biomechanical research to date has focused on spinal techniques. Peripheral treatment techniques have largely been ignored. This is somewhat surprising since it would seem that peripheral joints would appear easier to visualise and measure biomechanically.

Recently, a new type of treatment technique, mobilisation with movement, has been developed [12]. Mobilisation with movement treatment techniques are particularly remarkable because they exert strong hypoalgesic effects as demonstrated by several single case studies, case reports and clinical trials [13–17]. The lateral glide treatment technique of the elbow in subjects who had chronic lateral epicondylalgia has been the focus of these studies. The lateral glide treatment technique involves the application of a lateral glide across the elbow joint complex, which is then held while the patient performs a pain-provoking manoeuvre such as a gripping action or movement of the elbow. Technically, in its clinical application, the success of the mobilisation with movement treatment technique appears to depend upon the accurate localisation of the manual contact, the amount of force application and the direction of the force application.

Classically, lateral epicondylalgia is characterised as pain over the lateral epicondyle, a painfully weak gripping action, and tenderness to palpation over the lateral epicondyle [18]. Grip strength testing invariably reveals the reproduction of pain and weakness and identifies the predominant functional impediment of this condition.

The aim of this pilot study was to test the assertion that the amount of manual force applied during the mobilisation with movement of the elbow was a critical factor in the technique's ability to produce hypoalgesia.

2. Methods

A randomised, single blind repeated measures study design was used to evaluate the effect on treatment induced hypoalgesia of a range of different levels of manual force exerted during the performance of a manual therapy treatment technique.

2.1. Subjects

Four females and two males, age range 39–58 years, who had unilateral lateral epicondylalgia of greater than six weeks duration, as determined by a clinical examination, participated in this study. Subjects were included in the study if they had unilateral elbow pain over the lateral epicondyle and physical signs of a painful grip strength deficit, tenderness to palpation over the lateral epicondyle and reproduction of pain with either a stretch of the forearm extensor muscles or resisted static contraction of extensor carpi radialis brevis or longus [13,18,19]. Subjects were excluded if they had an injury or pain of the cervical spine, radiculopathy, any concurrent pain or injury in the limb, or a corticosteroid injection of the elbow in the past eight weeks.

The Human Ethics Committees of the University of Queensland and the Queensland University of Technology granted ethical approval for this study. All subjects signed a consent form before entering the experiment.

2.2. Dependent variable: pain free grip strength

Manual therapy induced hypoalgesia was determined by pain free grip strength as measured with an electronic digital grip dynamometer (MIE Medical Research Ltd, Leeds, UK) with the upper limb in a standardised position of elbow extension and forearm pronation [13,18,19]. On each occasion the dynamometer was placed in the subject's hand and the subject was then asked to grip the dynamometer handles with increasing force until elbow pain was first elicited, sustain it for approximately one second and then release. In addition to being used as a measure of pain and dysfunction in patients with lateral epicondylalgia, pain free grip strength has been shown to be a valid measure of improvement in these patients [13,19,20].

2.3. Independent variable: four force levels of the manual therapy treatment technique

The manual therapy treatment technique under investigation in this study was the lateral glide mobilisation with movement treatment technique of the elbow [12–14]. The technique involved stabilisation of the lateral aspect of the distal humerus by the therapist with one hand, while the other hand applied a laterally

Fig. 1. The application of the mobilisation with movement lateral glide treatment technique with the flexible pressure mat in situ and the patient gripping the grip dynamometer.

directed glide to the medial aspect of the proximal ulna (Fig. 1). The subject was instructed to perform a pain free grip strength test while the glide was sustained. At the onset of pain the subject relaxed their grip on the dynamometer and the therapist then removed the manual force. The duration of each treatment technique application was no more than 10 s. The manual force applied to the subject's elbow was measured by a flexible pressure-sensing mat (EMED PEDAR, Novel, Munich, Germany), which was interposed between the therapist's hand and the subject's medial aspect of the proximal ulna (Fig. 1). This equipment has previously been used to measure forces during the application of spinal manipulative therapy techniques [13,14]. The PEDAR flexible pressure mat conforms to the contours of the subject's forearm while allowing the therapist to maintain a feel of the underlying body part, an important feedback mechanism utilised by manual therapists during the application of treatment techniques.

To accommodate the supposition that the manual therapist may adjust the level of force applied to the elbow in order to allow for inter-subject differences in elbow size, the circumference of the subject's elbow was measured at the level of the epicondyles and used to standardise the level of applied force in the analysis of the data.

2.4. Experimental protocol

Subjects attended the laboratory on two occasions. On the first occasion, they were examined so as to ascertain compliance to inclusion and exclusion criteria, to become familiar with the experimental procedures, apparatus and investigators, and also to determine the levels of force that would be used for that subject in the study. To determine the force levels that would be used in the study, the therapist exerted the maximum force that he was prepared to use in the application of the lateral glide treatment technique on the asymptomatic elbow. This force was measured with the flexible pressure-sensing mat, repeated three times and averaged before being used to calculate the four force levels used on the symptomatic side in this study. The levels of force used on the symptomatic elbow were arbitrarily assigned as the maximum force (100%) and approximately 33%, 50% and 66% of the maximum force. These levels of applied force were chosen in order to get a range of force levels across which the hypoalgesic effect would most likely be observed. These force levels served as targets to which the therapist aimed.

On the second visit a pre-treatment pain free grip strength test of the symptomatic arm was performed three times as a baseline measure. Then, two applications of the four force levels of the lateral glide treatment technique were applied to the symptomatic arm in a random order. Approximately 2 min was allowed between each treatment application. Although measures were to pain threshold and adequate rest was allowed between contractions, we chose to limit the number of overall contractions to these 11 in order to lessen the possibility of any delayed or latent increase in pain and dysfunction. The subject remained blind to the scores obtained on the pain free grip strength test throughout the duration of the experimental session.

2.5. Data management

Pain free grip strength data was averaged across the three repetitions pre-treatment and the two repetitions during the treatment application. The pain free grip strength during treatment was then expressed as a percentage change from the pre-treatment values and used as the indicator of manual therapy induced hypoalgesia. The Novel software output of the mean force applied to the elbow during the technique's application was expressed as raw data and standardised data, and grouped into four categories (approximately 33%, 50%, 66% and 100%; see Table 1). Standardisation of the force data was achieved by dividing the raw data by the circumference of the elbow and expressed as N/cm. This sought to reduce any variability of the applied force that may be due to the therapist modifying his force levels to account for different sized elbows. The variability across subjects was described as the mean, 95% confidence intervals and coefficient of variation. Coefficient of variation, which is in essence a standard deviation score standardised to the group mean, was chosen because of expected differences in mean values for pain free grip strength at each force level. In order to evaluate the assumption that the therapist would vary, the applied force based on the elbow size of each subject, a single tailed, paired *t*-test was used to evaluate the differences in coefficient of variation between raw and standardised data.

Table 1
Mean, upper and lower bounds of the 95% confidence intervals (CI) and the coefficient of variation (CV) for the four levels (categories: approximate % of maximum force) of applied manual force expressed in measured units (N) and standardised to the subject's elbow circumference (N/cm)

Categories	33%	50%	66%	100%
Force				
Mean	36.8	55.6	74.5	113.2
95% CI	22.2–51.3	41.6–69.5	62.2–86.8	91.6–134.8
CV	49.4	31.3	20.7	23.8
Force/ circumference				
Mean	1.2	1.9	2.5	3.8
95% CI	0.8–1.7	1.4–2.3	2.2–2.8	3.1–4.5
CV	47.5	28.6	16.4	23.5

Mean circumference was 29.67 cm with the lower and upper limits of the 95% CI of 27.99 and 31.34 cm, respectively.

The main aim of this study was to ascertain if four different levels of manual force that the therapist used during the application of the lateral glide treatment technique produced different hypoalgesic effects as measured by the pain free grip strength test. Orthogonal a priori contrasts for repeated measures analysis were used for this purpose. The experiment-wise type I error rate was set at 0.05.

3. Results

The manual forces used in the lateral glide treatment of the elbow are presented in Table 2. The mean raw force data ranged from 36.8 N for the lowest force levels to 113.2 N for the highest force levels. The standardised force data was 1.2 N/cm at the lowest force level and 3.8 N/cm at the highest force level. The coefficient of variation was less for the standardised force data than for the raw data. This difference was statistically significant ($P = 0.0385$), and the standardised data were therefore used for the presentation of the results.

The changes in pain free grip strength from pretreatment baseline values for the four force levels are shown in Fig. 2. The lower two standardised force levels (1.2 and 1.9 N/cm) were associated with a drop in pain free grip strength (−16% and 2 %, respectively) whereas the higher two standardised force levels (2.5 and 3.8 N/cm) produced an increase of pain free grip strength test (15 and 18, respectively). A priori contrasts revealed that

Table 2
The mean square, F and P-value for the orthogonal a priori contrasts

Contrasts between	MS	$F_{(1,5)}$	P
Level 1 and Level 2	1103.5	1.727	0.246
Level 3 and Levels 1 & 2	3541.2	7.989	0.037
Level 4 and Levels 1, 2 & 3	2094.7	5.309	0.069

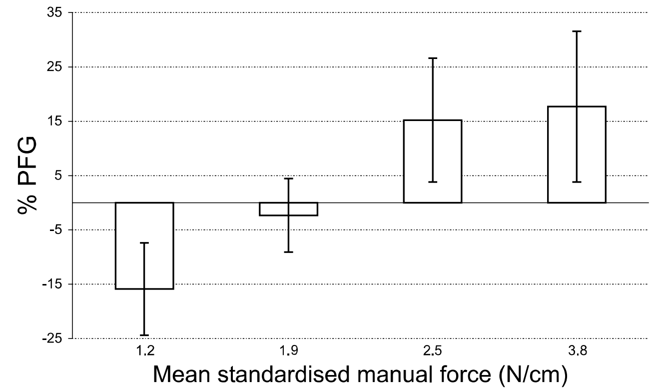

Fig. 2. The mean percentage change in pain free grip strength (%PFG) and standard error of the mean error bars for the four force level categories expressed as the mean standardised manual force.

the change in pain free grip strength was not significantly different between the two lower force levels ($F_{(1,5)} = 1.727$, $P = 0.246$), but that the change in pain free grip strength was significantly greater for the third force level (2.5 N/cm) when compared to the first two levels ($F_{(1,5)} = 7.989$, $P = 0.037$) (Table 2). The maximum force level (3.8 N/cm) did not significantly add to the treatment effect beyond that of the 2.5 N/cm force level ($F_{(1,5)} = 5.309$, $P = 0.069$).

4. Discussion

This pilot study has demonstrated that the level of force applied manually during the application of the lateral glide treatment technique in chronic lateral epicondylalgia is a determinant of the technique's hypoalgesic effect. In addition, the data suggest that there may exist a critical level of force below which the treatment technique is ineffectual at reducing pain free grip strength and that beyond which the application of further force results in comparatively diminishing returns in hypoalgesic effect. In this study, the standardised force level that appeared to be the critical level in terms of the hypoalgesic effect was somewhere between 1.9 and 2.5 N/cm, that is, between approximately 50% and 66% of the therapist's maximum force. The data provide further information about manual therapy techniques, which may be relevant in the investigation of the underlying mechanisms of action by which manual therapy treatment techniques achieve their clinically beneficial effects. The results of this study are the first that have directly linked the applied force of a manual therapy treatment technique to its pain relieving effect. The pain relieving effect represents a clinically meaningful outcome of manual therapy.

The grip strength changes observed in this study (15–18%) are comparable to the 20% reported by Abbot et al. [16] but lower than the 58% we have previously found in our laboratory [15]. The reasons for these differences were not addressed in this study but may result from the different subject samples or therapists in the studies.

It has to be acknowledged that in this pilot study only one of the possible critical variables of the mobilisation with movement treatment techniques was evaluated. Other technique variables, such as the direction of force application and exact point of application of the manual force at the elbow, which have been identified by clinicians to be important for successful outcome to treatment [12] require attention.

5. Conclusion

This study provides important preliminary evidence of a relationship between applied manual force level and the treatment induced hypoalgesia. There exists a possibility that a critical level of applied force is required to produce hypoalgesia.

Acknowledgements

The authors would like to thank Novel (Munich) for the pressure mat equipment used in the study and also acknowledge the subjects who volunteered for the study.

References

[1] Zusman M. What does manipulation do? The need for basic research. In: Boyling J, Palastanga N, editors. Grieve's modern manual therapy: the vertebral column. second ed. Edinburgh: Churchill Livingstone; 1994. p. 651–9.
[2] Herzog W. Mechanical and physiological responses to spinal manipulative treatments. J Neuromusculoskelet System 1995;3:1–9.
[3] Vicenzino B, Neal R, Collins D, Wright A. The displacement, velocity and frequency profile of the frontal plane motion produced by the cervical lateral glide treatment technique. Clin Biomech 1999;14:515–21.
[4] Zusman M. Spinal pain patients' beliefs about pain and physiotherapy. Aust J Physiother 1984;30:145–51.
[5] Kawchuk GN, Herzog W, Hasler EM. Forces generated during spinal manipulative therapy of the cervical spine: a pilot study. J Manipulative Physiologic Therapeut 1992;15:275–8.
[6] Herzog W, Conway PJ, Kawchuk GN, Zhang Y, Hasler EM. Forces exerted during spinal manipulative therapy. Spine 1993; 18:1206–12.
[7] Gal JM, Herzog W, Kawchuk GN, Conway PJ, Zhang YT. Movements of verterbrae during manipulative thrusts to unembalmed human cadavers. J Manipulative Physiologic Therapeut 1997;20:30–40.
[8] Herzog W. On sounds and reflexes. J Manipulative Physiologic Therapeut 1996;19:216–8.
[9] Conway P, Herzog W, Zhang Y, Hasler E, Ladly K. Forces required to cause cavitation during spinal manipulation of the thoracic spine. Clin Biomech 1993;8:210–4.
[10] Lee M, Steven G, Crosbie J, Higgs R. Towards a theory of lumbar mobilisation - the relationship between applied manual force and movements of the spine. Manual Ther 1996;2:67–75.
[11] Edmondston SJ, Allison GT, Gregg CD, Purden SM, Svansson GR, Watson AE. Effect of position on the posteroanterior stiffness of the lumbar spine. Manual Ther 1998;3:21–6.
[12] Mulligan B. Manual therapy—"NAGS", "SNAGS", "MWMS", etc. forth ed. Wellington: Plane View Services; 1999.
[13] Vicenzino B, Wright A. Effects of a novel manipulative physiotherapy technique on tennis elbow: a single case study. Manual Ther 1995;1:30–5.
[14] Stephens G. Lateral epicondylitis. J Manual Manipulative Ther 1995;3:50–8.
[15] Vicenzino B, Paungmali A, Buratowski S, Wright A. Specific manipulative therapy treatment for chronic lateral epicondylalgia produces uniquely characteristic hypoalgesia. Manual Ther 2001; 6:205–12.
[16] Abbott JH, Patla CE, Jensen RH. The initial effects of an elbow mobilization with movement technique on grip strength in subjects with lateral epicondylalgia. Manual Ther 2001;6:163–9.
[17] Abbott JH. Mobilization with movement applied to the elbow affects shoulder range of movement in subjects with lateral epicondylalgia. Manual Ther 2001;6:170–7.
[18] Haker E. Lateral epicondylalgia: diagnosis, treatment and evaluation. Crit Rev Phys Rehabilit Med 1993;5:129–54.
[19] Vicenzino B, Collins D, Wright A. The initial effects of a cervical spine manipulative physiotherapy treatment on the pain and dysfunction of lateral epicondylalgia. Pain 1996;68:69–74.
[20] Stratford P, Levy D, Gowland C. Evaluative properties of measures used to assess patients with lateral epicondylitis at the elbow. Physiother Canada 1993;45:160–4.