Hypoalgesic and Sympathoexcitatory Effects of Mobilization With Movement for Lateral Epicondylalgia

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Research Report

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Background and Purpose. Mulligan has proposed the use of mobilization with movement for lateral epicondylalgia. In this study, mobilization with movement for the elbow was examined to determine whether this intervention was capable of inducing physiological effects similar to those reported for some forms of spinal manipulation. Participants. Seven women and 17 men (mean age=48.5 years, SD=7.2) with chronic lateral epicondylalgia participated in the study. Methods. A placebo, control, repeated-measures study was conducted to evaluate whether mobilization with movement at the elbow produced concurrent hypoalgesia and sympathoexcitation. Results. The treatment demonstrated an initial hypoalgesic effect and concurrent sympathoexcitation. Improvements in pain resulted in increased pain-free grip force and pressure pain thresholds. Sympathoexcitation was indicated by changes in heart rate, blood pressure, and cutaneous sudomotor and vasomotor function. Discussion and Conclusion. This study showed that a mobilization with movement treatment technique exerted a physiological effect similar to that reported for some spinal manipulations. [Paungmali A, O'Leary S, Souvlis T, Vicenzino B. Hypoalgesic and sympathoexcitatory effects of mobilization with movement for lateral epicondylalgia. *Phys Ther.* 2003;83:374–383.]

Key Words: *Lateral epicondylalgia, Manual therapy, Mechanism, Pain, Tennis elbow.*

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Mulligan[1] has recently described an intervention in which a therapist applies a passive glide mobilization to a joint (usually an accessory motion) and sustains it while the client performs a physical task involving the limbs. The techniques, called "mobilization with movements" (MWM), are claimed to bring about improvements in pain and function immediately following their application in the clinic,[1] but there is a lack of experimental data reported in peer-reviewed publications. The MWM group of techniques are claimed to achieve this rapid improvement in persistent musculoskeletal pain states that have been recalcitrant to other forms of therapy.[2,3] To date, the postulated mechanism(s) of action of this treatment approach has focused on mechanical effects such as the restoration of bony positional faults.[4,5] The physiological effects have largely been ignored.

Much of the research about manipulation over the past decade has not focused on evaluating the subluxation theory of spinal manipulation, but rather such research has concentrated on elucidating the physiological effects of spinal manipulations.[6–13] Most of this research, however, has not dealt with the effects of the MWM technique. Several authors[6–13] have reported data that have been interpreted as reflecting possible neurophysiologic mechanism(s) for hypothesized actions. Some studies[6,7] have shown that passive mobilization treatments of the cervical spine, techniques frequently used by physical therapists, may produce an initial hypoalgesia and concurrent excitation in the motor system and the sympathetic nervous system (SNS).[6,7]

Any concurrent initial hypoalgesic and physiological effects have not been studied in manipulation of peripheral joints. Our study represents an initial investigation of the effect of a MWM treatment technique at the elbow

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on both pain and the SNS simultaneously. Recently, a MWM treatment technique for chronic lateral epicondylalgia has been described in the peer-reviewed and non–peer-reviewed literature.[1–3,14] These authors[1–3,14] contended that a MWM treatment technique applied at the elbow produced substantial and rapid pain relief immediately following application of the technique.

The aim of our study was to describe the physiological effects of a MWM treatment technique for chronic lateral epicondylalgia by measuring concurrent changes in measurements of pain and SNS function. We did not set out to determine the benefit of the intervention on function or other outcomes over a course of several treatments.

Methods

A placebo, control, repeated-measures study was used to evaluate the initial pain-relieving effects and changes in SNS function during and immediately following the application of MWM for chronic lateral epicondylalgia.

Participants

Twenty-four participants, 7 female and 17 male (mean age=48.5 years, SD=7.2), with unilateral lateral epicondylalgia of 8.9 months' (SD=8.4) duration participated in the study. All participants were right-handed, and 83.33% of the participants (n=20) had lateral epicondylalgia on the right-hand side. Participants were recruited from the metropolitan and suburban areas of Brisbane, Australia, by media releases and on referral from local health care practitioners. This sample size was determined a priori on the basis of a pilot study (alpha=.05, power=80%, effect size=0.44).[14] The effect size for pressure pain threshold was chosen because it was considered to be a more conservative choice than one based on pain-free grip force, which had a larger effect size.[14]

We defined *lateral epicondylalgia* as pain over the lateral side of the elbow that was provoked by palpation of the lateral epicondyle region and gripping tasks. In addition, pain had to be experienced over the lateral epicondyle during at least one of the following: resisted static contraction of the wrist extensors or extensor carpi radialis brevis muscle or stretching of the forearm extensor muscles.[15,16] Volunteers were excluded from the study if they had cervical spine or upper-limb problems (eg, referred pain, conditions other than lateral epicondylalgia). Other exclusion criteria included neurological impairments, neuromuscular diseases, cardiovascular diseases, health conditions that would have precluded treatment (eg, osteoporosis, malignancies, hemophilia, diabetes), recent steroid injection, using prescription medications such as beta-adrenoceptor blocking agents or anti-inflammatory or analgesic drugs, aversion to manual contact, and previous therapy for the elbow joint (to minimize expectation bias). All participants provided written consent prior to participation.

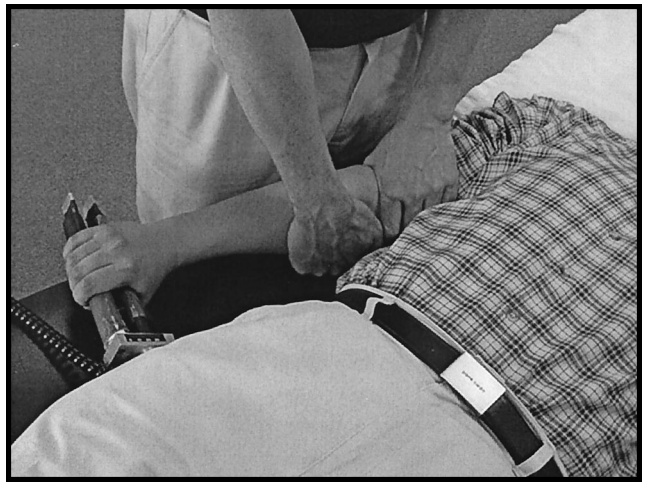

Figure 1.
The mobilization with movement treatment technique for the elbow joint. The therapist's right hand is applying a lateral glide across the elbow joint while the left hand is stabilizing the distal humerus on the lateral side. The participant's right arm is in medial (internal) rotation at the shoulder joint and in pronation at the forearm. The dynamometer is included as a way of reproducing the participant's pain, but only to threshold levels.

Experimental Conditions

The experimental conditions were the treatment condition (elbow MWM), a placebo condition, and a control condition. All conditions were administered by a physical therapist with 8 years of clinical experience and postgraduate tertiary qualification in manipulative physical therapy. The treatment condition involved a lateral glide MWM technique for the elbow as described by Mulligan.[1] To apply this treatment, the physical therapist used one hand to stabilize the distal end of the humerus on the lateral side just proximal to the elbow joint line while using the other hand to apply a laterally directed glide of the proximal ulna and radius (Fig. 1). The hand applying the lateral glide was situated just distal to the elbow joint line on the medial side of the ulna. The glide was painlessly applied and sustained for approximately 6 seconds while the participant performed a pain-free gripping action. The gliding pressure was then maintained until the participant completely released the grip. Ten repetitions of the treatment technique were applied, with approximately 15-second rest intervals between repetitions.[3] The placebo condition was applied by the same physical therapist and consisted of a firm manual contact with both hands over the participant's elbow while the participant performed a pain-free gripping action. The therapist was told to take particular care not to cause loading across the elbow joint like that applied during the MWM. The control condition involved the pain-free gripping action by the participant in the identical upper-limb position to that in the

treatment and placebo conditions, but with no manual force being applied.

At no time during the application of the experimental conditions were the participants supposed to experience any pain or discomfort other than that transiently experienced when performing the tests of pain-related measures. No such symptoms were reported.

Outcome Measures

There were 2 categories of outcome measures: those that measure pain threshold and those that measure SNS function.

Pain-related measures. The pain-related measures were all pain threshold measures consisting of pain-free grip force (PFGF), pressure pain threshold (PPT), and thermal pain threshold (TPT).

Pain-free grip force is a measure of the grip force required to produce the onset of pain. Pain-free grip force has been used as an outcome measure in laboratory and clinical studies because it is purported to reflect the degree of impairment associated with lateral epicondylalgia among other pathologies.[16–18] An electronic digital dynamometer* that was factory calibrated to ±1 N and checked at the commencement of each experiment session was used to measure PFGF over 3 repetitions with 30-second rest intervals. The test was performed with the participant's arm placed by his or her side with the elbow extended and forearm pronated. Stratford et al[19] have conducted a study of the intratester reliability and validity of data obtained with the PFGF measure in 32 people with lateral epicondylalgia. The reliability of the measurements was evaluated over 2 trials within 4 days apart, and a coefficient of .87 was reported, indicating an acceptable level of repeatability of PFGF measurements. Stratford et al[19] also studied the construct validity of data obtained with the PFGF measure and its sensitivity to detect change over time in the participants' condition. The PFGF measurements correlated with self-perceived pain-free function as measured by a questionnaire (R=.68) and with function levels as measured by a visual analog scale (R=.66), and they correlated moderately with pain as measured on a visual analog scale (R=−.47). The data implied sound construct validity for PFGF as a measure used in lateral epicondylalgia. In terms of detecting change over time in lateral epicondylalgia, PFGF and the pain free function rating were the most sensitive of all measures evaluated in this study (eg, maximum grip strength of the affected and unaffected arms, visual analog scales for pain and function).[19] Thus, PFGF is an appropriate and relevant measure to use in detecting change following treatment in patients with lateral epicondylalgia.[7,15]

Pressure pain threshold was measured with an electronic algometer (strain-gauge type I†). This measure is somewhat akin to the manual palpation often performed by physical therapists in that it measures the amount of pressure required to cause pain. This is done by applying the algometer probe tip over the most sensitive point of the lateral epicondyle.[15] The pressure stimulus was applied at a rate of 40 kPa/s. Pressure pain threshold was measured 3 times, with a rest interval of approximately 30 seconds between measurements. The algometer is factory calibrated to ±3% of readout and is regularly recalibrated in the laboratory with a 100-kPa calibrating weight before experimentation. Although PPT has been used in evaluating outcomes in a number of studies of lateral epicondylalgia,[7,14,15,18] there have been no studies in this patient population that have specifically addressed its reliability and validity. Ohrbach and Gale[20] studied the reliability and validity of measurements of PPT in 45 participants with unilateral muscle pain associated with temporomandibular joint dysfunction. Repeated trials of the measure were done and found to yield reliable measurements, with correlation coefficients ranging from .79 to .89. The validity of data obtained with the measure was evaluated by testing the measure's ability to distinguish between normal muscle in otherwise pain-free control subjects and affected muscle in patients with myogenic pain as well as by testing its ability to differentiate between the affected and unaffected muscle within the same patient. Ohrbach and Gale[20] reported that there was a difference between these groups and concluded that the PPT measure had strong discriminating validity. Studies in our laboratory have consistently shown the differences PPT between the affected elbow and the unaffected elbow.[7,14,15]

Thermal pain threshold also was measured 3 times with 30-second rest intervals at the lateral epicondyle using a Thermotest System.‡ Each participant was instructed to press a hand-controlled switch when the heat sensation first became painful.[6] The analog signals of TPT were collected on an IBM-compatible PC.§ The Thermotest System is factory calibrated to ±0.2°C with a control resolution of greater than 0.2°C. Park et al[21] evaluated the reliability of repeated measurements of heat pain threshold at a site on the volar aspect of the left forearm in 19 otherwise pain-free participants. Using a modified Bland-Altman plot,[22] Park et al[21] reported that TPT demonstrated good reliability, with difference scores expressed as a percentage of the mean of the values

* MIE Medical Research Ltd, 6 Wortley Moor Rd, Leeds, LS12 4JF, United Kingdom.

† Somedic Production, Box 14162, Stockholm, S-10441, Sweden.
‡ Somedic AB, Frestavagen 69, Box 519, Sollentuna, S-19205, Sweden.
§ Rosh-Tech, 17 Duncan St, West End, Queensland 4101, Australia.

forming a cluster around "0" (ie, mean difference score ±95% confidence interval=2.41±15.56%).

Sympathetic nervous system indicators. The SNS function measures were cutaneous blood flux (monitoring of tissue blood flow), skin conductance, skin temperature, blood pressure, and heart rate. Cutaneous blood flux, skin conductance, and skin temperature were measured throughout the experimental session, whereas blood pressure and heart rate were measured at predefined intervals. All SNS data were outputted from the measurement equipment as analog data and acquired by a National Instruments AD card[‖] at the same sampling rate (20 Hz) used in previous neurophysiological studies.[6,7,9]

Skin conductance, which is an indicator of sweat gland activity,[23] was measured with a skin conductance monitor (AT64[#]). The skin conductance activity was recorded bilaterally by attaching silver skin conductance electrodes to the glabrous (hairless) skin over the index and middle fingers (the skin was initially prepared with a skin cleansing swab containing 70% isopropyl alcohol and allowed to dry before attaching the electrodes).[11]

Blood flux was measured on the affected side over the thumb (glabrous skin) and over the lateral epicondyle (pileous or skin with hair). This skin blood flux was measured with a laser Doppler blood flow monitor.[**,7]

The device used to measure skin temperature was a skin temperature monitor (AT42[#]). The skin temperature sensors were placed over the palmar surface of both thumbs and bilaterally over the skin of lateral epicondyles. Skin preparation was performed in the same manner as described for skin conductance.[11]

Blood pressure was measured with a semiautomatic digital sphygmomanometer (model DS-115[††]). The cuff was applied to the unaffected side and released after each measurement to avoid interference with SNS measurements.[12,13]

Heart rate was monitored using a heart rate monitor (Polar Beat[‡‡]). The transmitter belt was placed around the chest over the level of xiphoid process to detect the cardiac activity.[12,13]

Experimental Procedure

A physical therapist with postgraduate qualification in orthopedic physical therapy and 7 years of experience working with musculoskeletal problems initially screened all volunteers for the study. Participants, if included into the study, then were familiarized with the laboratory environment and testing procedures.

Each participant attended the laboratory on 3 occasions at the same time of the day (no more than 2-hour difference) and with at least a 48-hour interval between sessions. This scheduling assisted in the control of any influence of diurnal variation and any carryover effects on the outcome measures. During each of the 3 sessions, the participant experienced a treatment condition that was determined by concealed randomization (drawing lots). In total, 72 experimental sessions were undertaken (ie, 24 participants × 3 conditions).

At each experimental session, the participant was positioned in a supine position. The pretreatment measurements of PFGF, PPT, and TPT were taken first on the unaffected side and then the affected side. Blood pressure and heart rate then were measured, followed by a 2-minute baseline period for measuring the SNS functions (ie, blood flux, skin conductance, and skin temperature). Following the pretreatment measurements, the physical therapist applied to the affected arm one of the randomly selected treatment conditions (ie, treatment, placebo, or control). During application of each treatment condition, the PFGF was again measured on the affected (treated) side. Blood flux, skin conductance, and skin temperature also were monitored throughout the technique application period. Following the application of the treatment condition (ie, treatment, placebo, or control), blood pressure and heart rate were recorded (ie, within 15 seconds), followed by measurement of pain thresholds (ie, PFGF, PPT, TPT). Participants were then reminded of their next experimental session time.

The measurement of pain and SNS function, in our view, requires control of behavioral and environmental factors before and during the experiment sessions. Participants were required to avoid certain behaviors such as consuming stimulants (eg, caffeine and nicotine products) and taking analgesic drugs for at least 6 hours before the study, as well as to avoid heavy exercise about 4 hours prior to the study.[24] Adherence to these prohibitions was evaluated by way of questionnaires completed before each experiment session. Any failure in adherence was managed by rescheduling the session. Care was taken to not allow participants to fall asleep, cough, sneeze, deep breath, or talk during measurement of the SNS functions.[25,26] The study was conducted in an environmentally controlled laboratory (noise attenuated, temperature=23.3°±0.5°C, relative humidity=62.1%±5.0%).

The investigator (AP) responsible for collecting the data was unaware of the applied treatment condition. Participants were unaware of the outcome measures and the

[‖] National Instruments, 6504 Bridge Point Pkwy, Austin, TX 78730.
[#] Autogenics, 620 Wheat Ln, Wood Dale, IN 60191.
** Moor Instruments Ltd, Milwey, Axminster, Devon, EX13 5HU, United Kingdom.
[††] Omron Nohgata Co Ltd, 2770 Kamizakai, Tobikuma, Nohgata-shi, Fukuoka, 822-0006, Japan.
[‡‡] Polar Electro Oy, Professorintie 5, Kempele 90440, Finland.

true intent of the study in that they were only made aware of the ethical implications of the study without revealing that a treatment was being evaluated.

Data Management and Analysis

Data management. All 24 participants completed the study, and their data were analyzed in the assigned conditions as allocated, using the SPSS statistical package (version 10.0).[§§] The triplicate measurements of PFGF, PPT, and TPT were averaged prior to further analysis. The single measurements of heart rate, systolic blood pressure, and diastolic blood pressure taken immediately before and immediately after the application were used in the statistical analyses.

The indicator of sympathetic effect that was used in this study, as in previous studies, was the maximum effect, which was the maximum increase or decrease of SNS response based on the relative direction of the response.[7,10] The maximum value for each measure was derived from the acquired data by the data acquisition program.

Statistical procedures. A 2-way, within-subjects analysis of variance (ANOVA) was used to evaluate the differences in outcome measurements between pretreatment and posttreatment measurement times (ie, independent variable of time) for the 3 treatment conditions (ie, treatment, placebo, and control). Pain-free grip force varied from this model in that the time factor had 3 levels: before, during, and after treatment.

Because skin conductance and skin temperature were measured on both upper limbs, an additional factor, side (affected, unaffected), was included in the ANOVA for these sympathetic indicators, making it a 3-way, within-subjects ANOVA.

Tests of simple effects were used to further evaluate any significant 2-way or 3-way interaction effects.[27] This involved *post hoc* analyses with the Tukey honestly significant difference (HSD) test for PFGF, which required comparisons among 3 measurement times (ie, before, during, and after treatment). Paired t tests with Bonferroni corrections for type I error rate were used for multiple comparisons of pretreatment and posttreatment data. For example, the alpha level was set at .017 for 3 pair-wise comparisons (pretreatment and posttreatment comparisons for treatment, placebo, and control), and the alpha level was set at .0083 for the 6 pair-wise comparisons of measures of SNS function.

To evaluate the assumption of repeated-measures design that each individual participant was the same between levels of the primary factor being evaluated (ie, treatment, placebo, and control), we conducted 2 ANOVAs, both on the pretreatment data, with one ANOVA comparing differences among conditions (ie, treatment, placebo, and control) and the other ANOVA comparing differences among days (ie, days 1, 2, and 3).

Reliability

Commensurate with the primary aims of the study and in the context of the study design, the reliability of the outcome measures was evaluated from repeated measurements taken on the same day before the application of the experimental conditions and with only one investigator taking all measurements from all participants in this study. Intraclass correlation coefficients (ICCs) and standard errors of measurement (SEMs) were used as indicators of reliability and error, respectively. The ICC and SEM for PFGF were .95 and 2.5 N, respectively. Pressure pain threshold had an ICC of .90 and a SEM of 9.4 kPa, and TPT had an ICC and SEM of .85 and 0.39°C, respectively. The ICCs for heart rate, systolic blood pressure, and diastolic blood pressure were reasonable at .68, .84, and .74, respectively, whereas the SEMs were low at 2.5 beats per minute (bpm), 1.6 mm Hg, and 1.8 mm Hg, respectively. Blood flux, skin conductance, and temperature were stable across the pretreatment period, with very high ICCs (.98, .88, .99, respectively) and small SEMs (0.008 flux units/min, 0.011 μsiemens, and 0.0002°C, respectively).

Results

The results of the within-subjects ANOVA and the means and standard deviations for all data are presented in Tables 1 through 5. Interaction plots are presented in Figures 2 through 5. The pretreatment data for all outcome measures were not different between conditions (treat, placebo, or control) or between experimental session days (days 1, 2, and 3).

Pain Measures

Pain-free grip force. The PFGF increased from 127.1 N to 166.2 N during the treatment and further increased to 174.1 N immediately after the treatment (Tab. 2). These increases in PFGF represented approximate mean increases of 37.0% and 47.5%, respectively (calculated on a per individual basis). The change in placebo and control was negligible both during and after their application. The ANOVA showed that there was a condition × time interaction effect for PFGF (Tab. 1, Fig. 2). *Post hoc* pair-wise comparisons with the Tukey HSD test revealed that PFGF increased during and after the application of the MWM treatment technique, but not during or following the placebo or control (Tab. 2).

Pressure pain threshold. Pressure pain threshold changed from 281.4 kPa to 300.8 kPa following the

[§§] SPSS Inc, 233 S Wacker Dr, Chicago, IL 60606.

Table 1.
Results of the Within-Subjects Analysis of Variance (Interaction Effect Between Treatment Conditions and Time) for All Outcome Measures

Outcome Measures[a]	Treatment						Placebo						Control						P^b
	Before		During		After		Before		During		After		Before		During		After		
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	
Pain-related measures																			
Pain-free grip force	127.1	55.9	166.2	56.7	174.1	53.1	146.8	74.3	145.0	73.7	144.9	70.9	150.4	73.4	146.5	69.1	143.9	65.6	.001
Pressure pain threshold	281.4	142.6			300.8	115.2	280.8	123.0			280.3	133.7	305.5	135.3			279.9	125.7	.01
Thermal pain threshold	43.8	3.6			44.1	3.8	44.4	3.5			43.9	3.6	44.5	3.2			42.7	3.4	.01
SNS-related measures																			
Heart rate	66.3	7.6			69.0	8.2	66.8	9.4			65.8	8.8	65.8	9.4			65.2	9.2	.001
Systolic blood pressure	117.9	10.0			122.1	12.7	118.8	10.6			119.0	11.1	120.5	11.5			119.7	12.2	.001
Diastolic blood pressure	77.6	6.6			80.1	8.0	77.5	8.3			77.7	7.6	77.5	8.2			76.7	7.9	.01
Hand skin temperature	31.6	1.4	31.2	1.4			31.3	1.8	31.3	1.8			30.5	1.8	30.7	1.7			.001
Elbow skin temperature	32.4	0.8	33.2	0.8			32.4	0.9	32.8	0.8			32.6	1.9	32.8	1.8			.001
Skin conductance	1.9	1.0	3.0	1.5			2.2	2.1	2.7	2.6			1.8	1.2	2.3	1.7			.002
Hand blood flux	227.9	125.8	58.0	62.8			165.9	117.0	78.5	59.1			164.8	89.7	78.8	47.0			.001
Elbow blood flux	49.9	35.6	108.1	52.4			49.5	53.0	75.4	52.0			57.0	43.3	77.1	43.6			.001

[a] Pain-free grip force (in newtons), pressure pain threshold (in kilopascals), thermal pain threshold (in degrees Celsius), heart rate (in beats per minute), blood pressure (in millimeters of mercury), skin temperature (in degrees Celsius), blood flux (in flux units per minute), skin conductance (in microsiemens).
[b] Degrees of freedom = 2,46, except for pain-free grip force (df = 4,92).

treatment application, whereas PPT did not change in the placebo condition and decreased in the control condition (Tab. 3). The ANOVA showed a condition (ie, treatment, placebo, and control) × time (ie, before and after treatment) interaction effect for PPT (Tab. 1, Fig. 2). There was no mean percentage increase in PPT (calculated on a per individual basis) following the MWM treatment compared with the placebo and control conditions.

Thermal pain threshold. Thermal pain threshold did not change following the treatment application or in the placebo condition; however, there was a reduction in TPT in the control condition (Tabs. 1 and 3). There was a mean percentage reduction of 4.1% for the control condition as compared with an increase of 0.8% and a reduction of 1.1% for the treatment and placebo conditions, respectively.

Sympathetic Nervous System-Related Measures

Heart rate and blood pressure. The treatment technique produced an increase in heart rate from 66.3 bpm to 69.0 bpm, as well increases in systolic blood pressure from 117.9 mm Hg to 122.1 mm Hg and in diastolic blood pressure from 77.6 mm Hg to 80.1 mm Hg (Tab. 4). These mean increases were approximately 4.1% for heart rate, 3.5% for systolic blood pressure, and 3.1% for diastolic blood pressure. There were no placebo- or control-induced changes (Tabs. 1 and 4, Fig. 3).

Skin conductance, cutaneous blood flux, and temperature. On the affected side, the cutaneous SNS functions (ie, skin temperature, cutaneous blood flux, and skin conductance) were all activated (sympathoexcitation) in the treatment condition, but not in the placebo or control condition (Tabs. 1 and 5, Figs. 4 and 5). The treatment technique induced reductions in hand skin temperature (−1.1%) and hand blood flux (−72.4%) and a increases in skin conductance (55.0%), elbow skin temperature (2.1%), and elbow blood flux (123.7%).

Discussion and Conclusions

Our study showed that MWM for chronic lateral epicondylalgia is capable of producing concurrent hypoalgesic effects during and following its application, as well as altering SNS function. These findings are consistent with those of previous studies of spinal manipulation,[6,7] which implies to us that there is a multisystem response to manipulation regardless whether the spine or the elbow is manipulated.

In contrast to the apparent similarity in multisystem response produced by manipulation applied to the spine and the elbow, the MWM-induced response profile in the pain system appears different from that shown in previous studies of manipulation of the cervical spine for

Table 2.
Pain-free Grip Force (in Newtons) for Each Condition (N=24)

Condition	Before Treatment[a,b,c]		During Treatment		After Treatment	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Treatment	127.1	55.9	166.2	56.7[d]	174.1	53.1[d]
Placebo	146.8	74.3	145.0	73.7	144.9	70.9
Control	150.4	73.4	146.5	69.1	143.9	65.6

[a] No differences at baseline among the 3 conditions ($P>.05$).
[b] Unaffected side values ($\bar{X}\pm$SD) for pain-free grip force=246.2±71.0 N.
[c] No differences at baseline among the days (day effect), $P>.05$.
[d] Differences when compared with before treatment ($P<.05$, *post hoc* Tukey HSD test).

Table 3.
Pressure Pain Threshold (in Kilopascals) and Thermal Pain Threshold (in Degrees Celsius) for Each Condition (N=24)

Condition	Pressure Pain Threshold				Thermal Pain Threshold			
	Before Treatment[a,b,c]		After Treatment		Before Treatment[a,b,c]		After Treatment	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Treatment	281.4	142.6	300.8	115.2	43.8	3.6	44.1	3.8
Placebo	280.8	123.0	280.3	133.7	44.4	3.5	43.9	3.6
Control	305.5	135.3	279.9	125.7	44.5	3.2	42.7	3.4[d]

[a] No differences at baseline among the 3 conditions ($P>.05$).
[b] Unaffected side values ($\bar{X}\pm$SD) for pressure pain threshold=390.2±127.4 kPa and thermal pain threshold=45.5°±3.4°C.
[c] No differences at baseline among the days (day effect), $P>.05$.
[d] Differences when compared with before treatment ($P<.017$, *post hoc* paired *t* tests with Bonferroni correction).

Table 4.
Pretreatment and Posttreatment Values for Heart Rate (in Beats per Minute) and Blood Pressure (in Millimeters of Mercury) Responses for Each Treatment Condition (N=24)

Condition	Heart Rate				Systolic Blood Pressure				Diastolic Blood Pressure			
	Before Treatment[a,b]		After Treatment		Before Treatment[a,b]		After Treatment		Before Treatment[a,b]		After Treatment	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Treatment	66.3	7.6	69.0	8.2[c]	117.9	10.0	122.1	12.7[c]	77.6	6.6	80.1	8.0[c]
Placebo	66.8	9.4	65.8	8.8	118.8	10.6	119.0	11.1	77.5	8.3	77.7	7.6
Control	65.8	9.4	65.2	9.2	120.5	11.5	119.7	12.2	77.5	8.2	76.7	7.9

[a] No differences at baseline among the 3 conditions ($P>.05$).
[b] No differences at baseline among the days (day effect), $P>.05$.
[c] Differences when compared with before treatment ($P<.017$, *post hoc* paired *t* tests with Bonferroni correction).

lateral epicondylalgia.[7,15] The MWM produced an improvement in pain-free grip force of 47.5% and in PPT (15.4%), in contrast to studies of spinal manipulation that demonstrated increases in pain-free grip force in the order of 12% to 30% and an improvement in PPT of approximately 25% to 30%.[7,15] Differences in responses may be dependent, in part, on the body part being manipulated[28,29] and the frequency with which the treatment is used.[11,30]

Pressure pain threshold, but not TPT, was relatively improved with treatment in our study. This finding is consistent with the results of other studies of manipulation for lateral epicondylalgia (ie, spine and elbow treatment) that showed that joint manipulation appears to selectively influence PPT, but not TPT.[7,14]

Accompanying the pain-relieving effect of the MWM was an excitatory effect in the SNS functions. On the whole, as was the case for the initial hypoalgesic effect, the treatment effect was superior to the placebo and control conditions. Our findings are similar to those shown during manipulation of the cervical spine and corroborate the multisystem response profile of manipula-

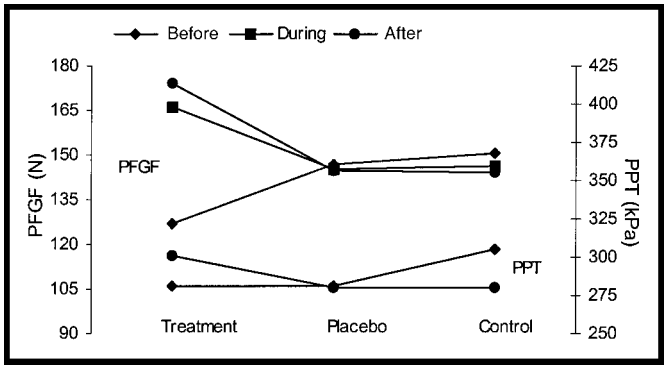

Figure 2.
Plot of interaction between the treatment condition (treatment, placebo, control) and time for pain-free grip force (PFGF) (in newtons) over 3 measurement times (before, during, and after treatment) and for pressure pain threshold (PPT) (in kilopascals) from before treatment to after treatment.

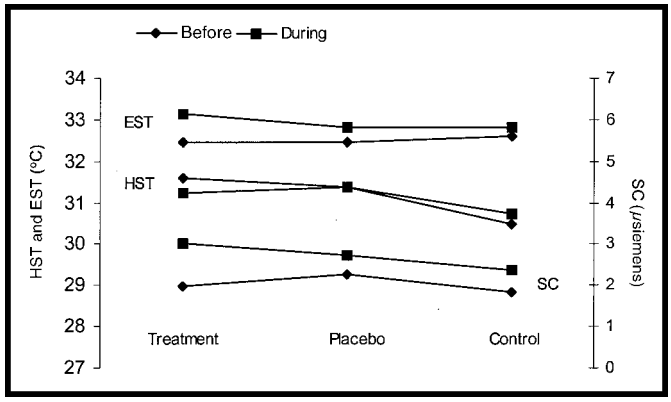

Figure 4.
Plot of interaction between the treatment condition (treatment, placebo, control) and time (before and during application of the experimental conditions) for skin conductance (SC) (in microsiemens) and for hand and elbow skin temperature (HST and EST) (in degrees Celsius).

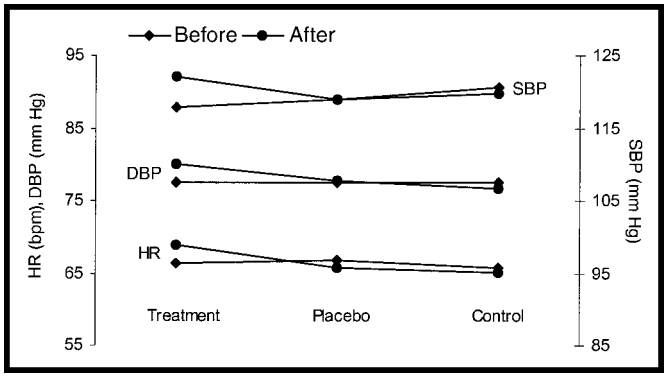

Figure 3.
Plot of interaction between the treatment condition (treatment, placebo, control) and time (before and after application of the experimental conditions) for heart rate (HR) (in beats per minute) and for systolic and diastolic blood pressure (SBP and DBP) (in millimeters of mercury).

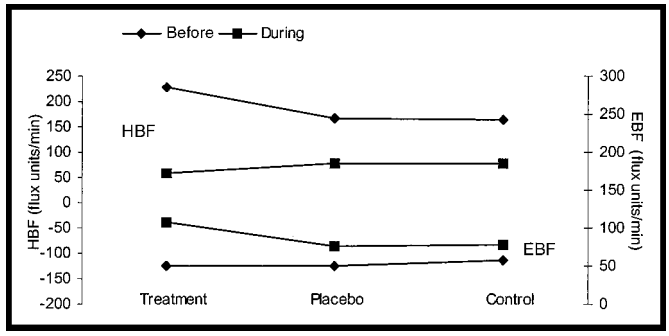

Figure 5.
Plot of interaction between the treatment condition (treatment, placebo, control) and time (before and during application of the experimental conditions) for hand and elbow blood flux (HBF and EBF) (in flux units per minute).

Table 5.
Hand and Elbow Skin Temperature (in Degrees Celsius), Hand and Elbow Blood Flux (in Flux Units per Minute), and Skin Conductance (in Microsiemens) on the Affected (Treated) Side for Treatment Condition (N=24)

	Before Treatment		During Treatment[a]	
Outcome Measures	$\bar{X}$	**SD**	$\bar{X}$	**SD**
Hand skin temperature	31.6	1.4	31.2	1.4
Elbow skin temperature	32.4	0.8	33.2	0.8
Skin conductance	1.9	1.0	3.0	1.5
Hand blood flux	227.9	125.8	58.0	62.8
Elbow blood flux	49.9	35.6	108.1	52.4

[a] Differences when compared with before treatment ($P<.0083$, *post hoc* paired *t* tests with Bonferroni correction).

tion.[6,7,15] Sato et al[31] studied cats and showed that sustained end-range positions of the knee (eg, rotation) altered heart rate and blood pressure and that decortication attenuates this stimulation-induced sympathoexcitatory effect. The manipulation of the cat knee in that study, we contend, is somewhat similar to the MWM because both involved application of a manually induced sustained pressure across a joint. On the basis of the pattern of response in the SNS in our study and evidence from animal studies about the control mechanisms of these SNS functions, it appears likely that, as a part of its response, the MWM may activate some centers in the neuraxis.

An important finding of our study is that the effects on experimentally induced pain and the SNS were produced by the MWM treatment technique, but not by the placebo or control conditions. This finding, in our view, confirms that any treatment effects cannot easily be explained as placebo effects or the natural history of a condition. The purpose of our study was to examine whether physiological effects similar to those seen with spinal manipulation occurred with MWM, and they did occur. We were not attempting to determine whether MWM provided a beneficial clinical outcome as a treatment (eg, improved function, permanently reduced disability or impairments).

The magnitude of changes of some sympathetic nervous system-related measures was relatively small. For example, heart rate, blood pressure, and cutaneous skin temperatures were induced changes of less than 5%; therefore, caution must be exercised when interpreting these findings as to the clinical significance.

We did not address the possible involvement of local effects at the elbow as a possible explanation of the mechanism of action of the MWM technique being evaluated. Local effects, such as possible changes in the relationships of bones and soft tissues about the joint and possible changes in local neural receptors in soft tissues at the time of treatment, may account for the changes we measured.[4,5]

In considering the mechanism of action we measured for MWM, the reader should consider that our data show that there was a change in pain and SNS function during the application of the treatment technique and that there were changes in blood pressure, heart rate, vasomotor function, and sudomotor function. These changes cannot be fully explained by local mechanical effects.

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Hypoalgesic and Sympathoexcitatory Effects of Mobilization With Movement for Lateral Epicondylalgia

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