JAOA
ORIGINAL CONTRIBUTION

Manipulative Treatment of Carpal Tunnel Syndrome: Biomechanical and Osteopathic Intervention to Increase the Length of the Transverse Carpal Ligament: Part 2. Effect of Sex Differences and Manipulative "Priming"

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As a theoretical basis for treatment of carpal tunnel syndrome (CTS) and expanding upon part 1 of this study, the authors investigated the effects of static loading (weights) and dynamic loading (osteopathic manipulation [OM]) on 20 cadaver limbs (10 male, 10 female). This larger study group allowed for comparative analysis of results by sex and reversal of sequencing for testing protocols. In static loading, 10-newton loads were applied to metal pins inserted into carpal bones. In dynamic loading, the OM maneuvers used were those currently used in clinical settings to treat patients with CTS. Transverse carpal ligament (TCL) response was observed by measuring changes in the width of the transverse carpal arch (TCA) with three-dimensional video analysis and precision calipers. Results demonstrated maximal TCL elongation of 13% (3.7 mm) with a residual elongation after recovery of 9% (2.6 mm) from weight loads in the female cadaver limbs, compared to less than 1 mm as noted in part 1, which used lower weight loads and combined results from both sexes. Favorable responses to all interventions were more significant among female cadaver limbs. Higher weight loads also caused more linear translatory motion through the metal pins, resulting in TCA widening equal to 63% of the increases occurring at skin level, compared to only 38% with lower loads. When OM was performed first, it led to greater widening of the TCA and lengthening of the TCL during the weight loading that followed. Both methods hold promise to favorably impact the course of management of CTS, particularly in women.

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Clinical management of carpal tunnel syndrome (CTS) continues to be a challenge to physicians and their patients, both of whom are often left to struggle with a choice between pursuing limited conservative treatment or surgical intervention in the form of surgical release of the transverse carpal ligament (TCL).[1] However, osteopathic manipulative treatment (OMT) and stretching exercises have shown promising results when used in combination therapy as a potential treatment modality for CTS, demonstrating an increase in the width of the transverse carpal arch (TCA) as confirmed with nerve conduction improvements and findings from magnetic resonance imaging.[2–6]

In the first part of this study,[7] we measured actual TCL elongation under direct clinical observation during sustained static loading (weights). The width of the TCA was also measured before and after osteopathic manipulation (OM).[7] Both methods confirmed the potential benefit of these non-surgical approaches to enlarge the carpal tunnel and alleviate symptoms of CTS. In addition, these conservative treatment methods produced changes in the TCA that approached those seen after surgical release of the TCL.[8,9]

In part 1,[7] we used lighter weight loads than were used in the present study. Additionally, part 1 was conducted with a smaller subject group (ie, seven cadaver limbs), minimizing any inherent difference in results by sex. Observations from the use of varying weight loads in the original study also led us to anticipate that higher weight loading could further increase the TCL elongation effect. Observations from part 1 also indicated that our methods and results could easily be duplicated in a clinical setting without damaging the skin and subcutaneous tissues from increased pressure.

Therefore, in the present study, we opted to use higher applied loads and identified equal numbers of male and female cadaver limbs so that we might assess results for any differences by sex. In addition, the sequencing of static versus dynamic weight loading was varied (weights first or OM first) to observe for any alterations in outcome.

Finally, because two OM maneuvers used on cadaver limbs in part 1 of the study appeared to have minimal effect,

Figure 1. *Radiographic image of a male cadaver limb showing placement of surgical pins in the scaphoid and pisiform on the proximal end of the carpal tunnel and in the trapezium and hamate on the distal end of the carpal tunnel (saggital view).*

Figure 2. *Radiographic image of a male cadaver limb showing placement of surgical pins in the scaphoid and pisiform on the proximal end of the carpal tunnel and in the trapezium and hamate on the distal end of the carpal tunnel (anteroposterior view).*

Figure 3. *Experimental set-up demonstrates cadaver limb mounted and secured on plywood boards with pins in place and wires attached, as detailed in part 1 of this study.*[7]

Figure 4. *Primary investigator (B.M.S.) performing manipulation maneuver 4: Guy-wire and distal row transverse extension combined (ie, manipulation maneuver 1 and manipulation maneuver 2).*

we chose to eliminate them from the protocol for the present study to simplify the procedures.

Methods

Preparation and Static Loading (Weights)

Twenty human cadaver limbs (10 male, 10 female), sectioned at the midhumerus level, were used in the evaluation. The mean age at death in our study population was 65 years (63 years for males and 67 years for females), and there was no known injury or disease involving the upper extremities. No other information was available on the premorbid condition of the cadavers.

Of the 20 limbs evaluated, 11 were right and 9 were left. All arrived frozen and were maintained in that condition until the day of testing, at which time they were warmed to room temperature. Freezing has been shown to have no significant effect on the biomechanical properties of ligaments.[10,11]

Prior to testing, investigators used a drill to place surgical pins (1.6 mm in diameter, approximately 50 mm in length) into each of the four carpal bones that would serve as attachment sites for the TCL: the scaphoid and pisiform on the proximal end of the carpal tunnel, and the trapezium and hamate on the distal end (*Figure 1* and *Figure 2*). The pins were definitive markers above the surface of the skin, allowing investigators to measure the width of the TCA accurately, also providing data regarding the TCL length. Pin placement was verified by fluoroscopy. Additionally, three 4-mm diameter white balls were placed at precisely measured locations on each pin to delineate its long axis above skin level (*Figure 3*).

Two 60 Hz video cameras were mounted to the ceiling of the testing lab looking diagonally down on the limb from the left and right. The camera-to-limb distances were approximately 2 m. Coordinates of the markers, as documented in the two-dimensional images captured on these cameras, were used to calculate the three-dimensional (3D) positions of the markers on each pin during application of, and recovery from, tensile loading using the direct linear transformation method.[12] Three-dimensional positions were calculated at set intervals throughout the two testing sequences. Details of the 3D methodology are forthcoming (R.N.H., B.M.S., R.L.W., et al, unpublished data, 2005).

Wires were attached to each pin with weights suspended over pulleys to provide horizontal distraction forces across the TCL, as previously described.[7] In part 1,[7] we used weight loads of 2 newtons (N), 4 N, and 8 N in static loading procedures. In response to results from part 1, however, we chose to increase all static loads in the present study to 10 N per pin.

Precision calipers were used to measure pin-to-pin distances just above skin level at certain elapsed-time intervals (measured in minutes) after the loads were applied: 0.5, 1, 3, 7, 15, 30, 60, 120, and 180. Caliper measurements were used to determine the time at which no further lengthening was achieved and equilibrium was assumed. For this reason, it was also sometimes necessary to measure pin-to-pin distances at 240 minutes. Typically, static loads were applied for 3 hours with maximal widening of the TCA obtained after 2 hours (ie, the measurement at 3 hours was the same as at 2 hours).

Once maximal elongation was achieved, static loads were removed and similar caliper measurements were taken during the recovery period. A typical recovery period lasted 2 hours. Following the recovery period, static loads were reapplied and then once again removed when equilibrium was reached using the aforementioned criteria. Equilibrium required approximately 2 hours to achieve in all cases with verification taking place at 3 hours.

The duration of the entire static loading sequence (ie, 2 cycles of static loading and unloading) was approximately 6 hours for each human cadaver limb.

Dynamic Loading (Osteopathic Manipulation)

Dynamic loads were applied by the primary investigator (B.M.S.) using OM . The four manipulations used in this study are a subset of the six used in part 1 (ie, 2, 3, 4, and 6 applied in sequence).[6] Osteopathic manipulations were repeated after a 15-minute recovery period. The two least effective manipulations from part 1 (ie, 1 and 5) were not used in the present study.

However, for continuity between the two parts of this study, all six manipulation maneuvers performed in part 1 are listed here:

1. Guy wire indirect transverse extension (not used in the present study),
2. Distal row transverse extension,
3. Proximal row transverse extension,
4. Guy-wire and distal row transverse extension combined (ie, manipulation maneuver 1 and manipulation maneuver 2) (*Figure 4*),
5. Thenar extension/abduction and lateral axial rotation (not used in the present study), and
6. Guy-wire and thenar extension/abduction and lateral axial rotation combined (ie, manipulation maneuver 1 and manipulation maneuver 5).[7]

Transverse carpal extension maneuvers have been described previously[2] and involve a 3-point bending by the osteopathic physician who hooks his thumbs on the inner ventral edge of the carpal bones (trapezium and hamate distally, scaphoid and pisiform proximally) while his fingers wrap around dorsally to converge on the center of the wrist to provide a counterforce. This manipulation maneuver allows a powerful leverage for the osteopathic physician's thumbs to apply distraction forces transversely across the carpal canal and separate or widen the TCA as the TCL is stretched.

The guy-wire maneuver, described in part 1,[7] requires the osteopathic physician to apply maximal abduction with extension to the thumb and little finger. This position vigorously stretches the tendons of the flexor pollicis longus and flexor digitorum profundus of the fifth digit, both of which deviate around the inside edge of the distal carpal bones (trapezium and hamate, respectively), and create a fulcrum effect with force vectors at the deflection contact points of those bones which tend to pull the TCA apart.

Finally, in the extension/abduction and lateral axial rotation, also previously described,[2,4] the osteopathic physician uses the thumb as a lever to apply direct traction forces on the TCL. This OM maneuver has been shown to be highly effective clinically[4] because the abductor pollicis brevis and opponens pollicis muscles are directly attached to the TCL, so that securing the medial aspect of the wrist and hand provides an "anchor" that allows for effective traction by applying vigorous counterforce with extension/abduction of the thumb. At the same time, the osteopathic physician can move the thumb in the reverse direction of opposition (lateral axial rotation) to further stretch and elongate the TCL.

Experimental Groups and Loading Sequence

Half of the cadaver limbs of each sex (ie, 5) received static loading (weights) first followed by dynamic loading (OM) on subsequent days. The other half of cadaver limbs of each sex underwent OM first followed by weights on subsequent days.

This protocol created four separate study groups: (1) males, weights first; (2) females, weights first; (3) males, OM first; and (4) females, OM first. The total experiment lasted approximately 36 hours for each cadaver limb. Overnight between testing days, each limb was returned to the refrigerator but not refrozen.

Data Collection and Analysis

Although pin-to-pin distances were recorded at skin level using precision calipers, as in part 1 of this study,[7] we also used 3D video analysis in the present study to compute actual TCL elongations from the 3D motion of the white balls placed

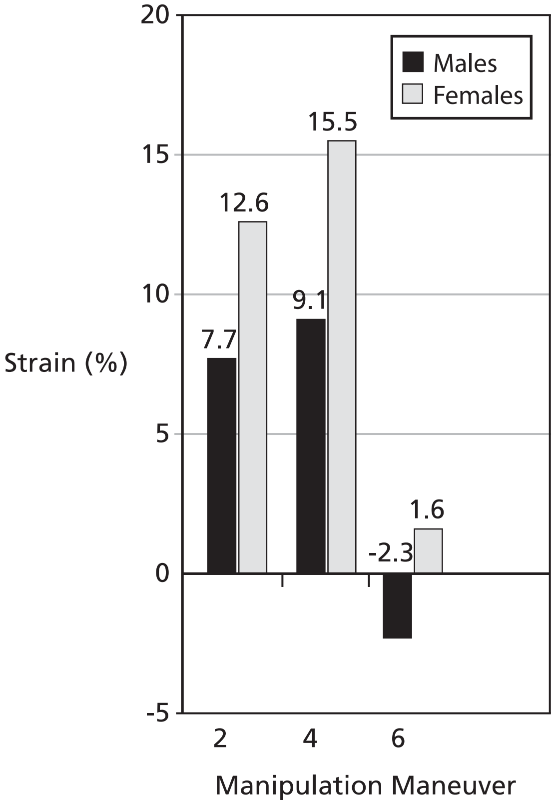

Figure 5. *Manipulation set 1: dynamic loading. Results of dynamic loading (osteopathic manipulation) alone on the transverse carpal ligament in males (n=5) vs females (n=5) on the first day of testing. Static loading was performed after the manipulation sequence was completed. Manipulation maneuver 2 (distal row transverse extension), manipulation maneuver 4 (guy-wire and distal row transverse extension combined), and manipulation maneuver 6 (guy-wire and thenar extension/abduction and lateral axial rotation combined)[7] were used. The results of manipulation maneuver 3 (proximal row transverse extension) are not presented here because this manipulation maneuver is intended to stretch the proximal portion of the TCL and has little effect on the distal portion of the TCL.*

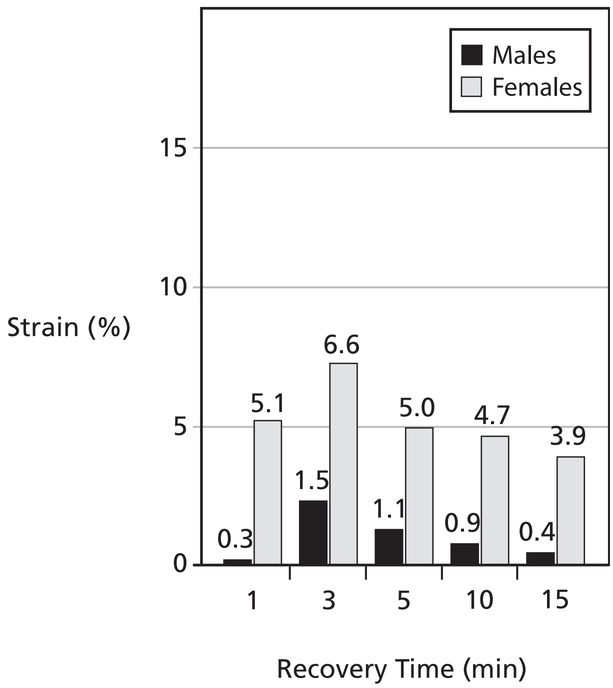

Figure 6. *Manipulation set 1: 15-minute recovery period after dynamic loading. Results of dynamic loading (osteopathic manipulation) alone on the transverse carpal ligament in males (n=5) vs females (n=5).*

on the bone pins. The details of this method are forthcoming (R.N.H., B.M.S., R.L.W., et al, unpublished data, 2005) and are summarized below.

By knowing the 3D coordinates of the three balls on each pin, the 3D coordinates of the point where each pin intersected the TCL could be calculated by extrapolating along each pin below the skin a certain distance. Once testing was complete, investigators dissected down to the TCL and measured below-skin distances using precision calipers.

Calculating changes in the 3D coordinates of ligament-pin intersection points during loading and unloading allowed us to calculate TCL elongations. This method was acceptably accurate with a mean error of 0.41 mm $\pm$ 0.25 mm. When normalized to the mean starting TCL length of 32.9 mm, the error was 1.25% (R.N.H., B.M.S., R.L.W., et al, unpublished data, 2005).

As in part 1,[7] the primary area of interest in the TCL was the distal ("thick") portion spanning between the trapezium and hamate bones. Data analysis for the present study required that we obtain data by: (1) plotting the data derived from caliper measurements of pin movement above skin level, and (2) plotting the data derived from 3D videography of points on the pins to predict actual TCL length changes. Elongations were normalized by dividing the change in length by the original length, and are expressed as a percentage of strain.

This new analytical model is in contrast with that presented in part 1,[7] where all elongation measurements were noted in millimeters only. Normalizing elongation data makes it easier to combine results from limbs with different initial (pretest) TCL lengths. However, we took the mean strain

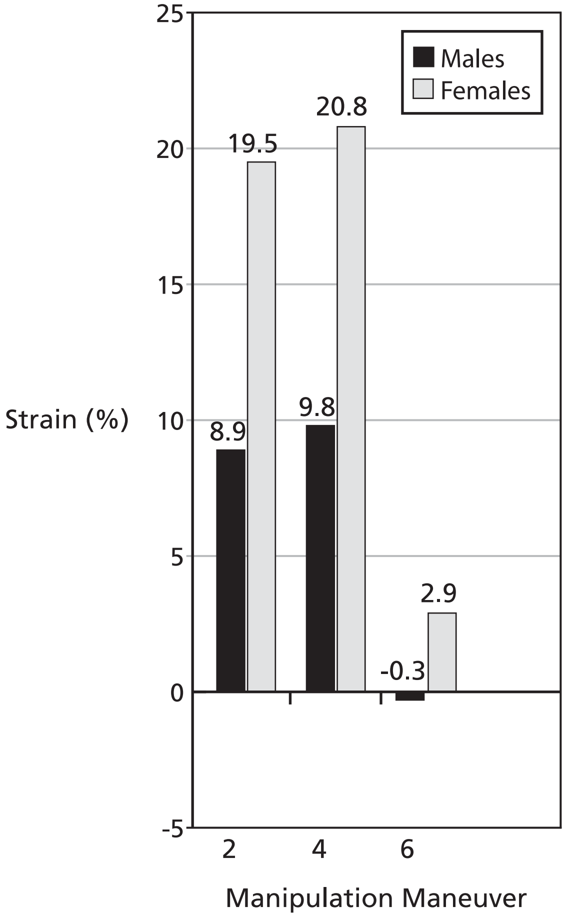

Figure 7. *Manipulation set 2: dynamic loading (procedure repeated). Results of dynamic loading (osteopathic manipulation) alone on the transverse carpal ligament in males (n=5) vs females (n=5) on the first day of testing. Static loading was performed after the manipulation sequence was completed. Manipulation maneuver 2 (distal row transverse extension), manipulation maneuver 4 (guy-wire and distal row transverse extension combined), and manipulation maneuver 6 (guy-wire and thenar extension/abduction and lateral axial rotation combined)[7] were used. The results of manipulation maneuver 3 (proximal row transverse extension) are not presented here because this manipulation maneuver is intended to stretch the proximal portion of the TCL and has little effect on the distal portion of the TCL.*

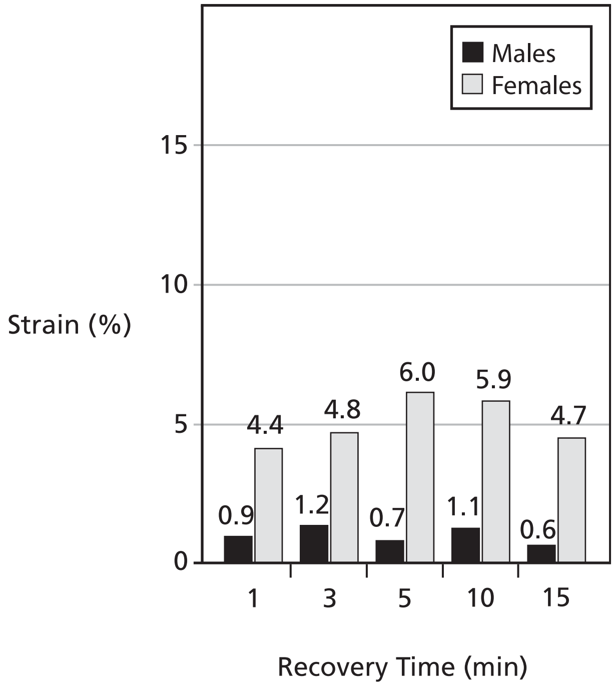

Figure 8. *Manipulation set 2: 15-minute recovery period after dynamic loading (procedure repeated). Results of dynamic loading (osteopathic manipulation) alone on the transverse carpal ligament in males (n=5) vs females (n=5).*

values, as measured in percentages, and multiplied that number by the mean initial TCL length for each sex (28.7 mm for females and 36.6 mm for males) to provide an equivalent elongation in millimeters that could then be compared with the results of other studies.

In order to determine significant differences between means, a two-way repeated-measures analysis of variance was performed using SAS software (version 8.2 for Windows, SAS Institute Inc, Cary, NC). The dependent variable was residual TCL elongation at the end of the recovery period.

Independent variables were sex (male vs female) and order of loading sequence (static [weights] followed by dynamic [OM] or vice versa). When appropriate, pairwise planned contrasts were performed to investigate simple effects. The α level of significance was set to .05 for all tests.

Results

The dynamic loading results demonstrate that OM alone was able to elongate the TCL more significantly in females than in males (P=.006), with substantially greater peak TCL elongation and less recoil during recovery (manipulation set 1: *Figure 5* and *Figure 6*; manipulation set 2: *Figure 7* and *Figure 8*).

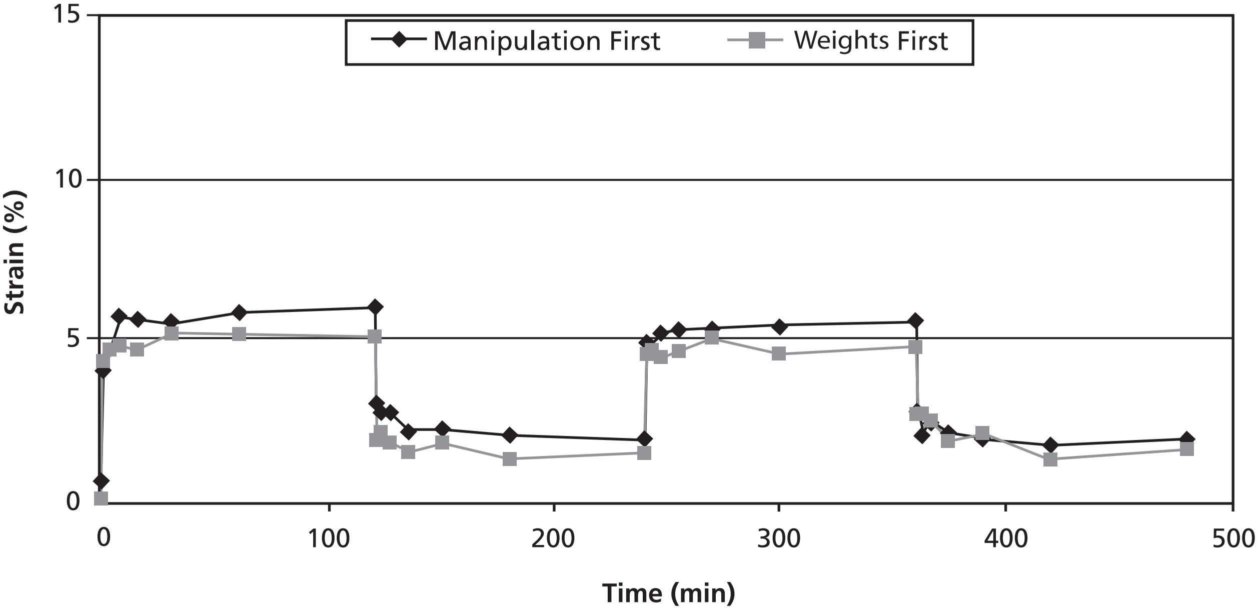

Figure 9. *Results of static loading (weights) first and dynamic loading (osteopathic manipulation) first trials for male cadaver limbs. Loading sequence had little effect on the results for male cadaver limbs. Elongations were normalized by dividing the change in length by the original length, and are expressed as a percentage of strain.*

The results of manipulation maneuver 3 (proximal row transverse extension) are not included in *Figure 5* and *Figure 7* because this manipulation is intended to stretch the proximal portion of the TCL and we found it to have little effect on the distal portion of the TCL. As discussed in part 1,[7] we consider the distal portion of the TCL to be the "limiting factor" in TCL stretches and the site where most of the pathology/compression in CTS occurs.

Male TCLs recoiled almost back to baseline following OM, whereas female TCLs maintained some (approximately 5%) residual elongation (*Figure 8*). Peak elongations in the distal band of the TCL occurred with manipulation maneuvers 2 and 4. There was a slightly higher peak strain by adding the guy-wire technique to the transverse extension (manipulation maneuver 4), similar to the results observed in part 1.[7] In both manipulation sets, the thenar and guy-wire technique (manipulation maneuver 6) was not effective in stretching the TCL (*Figure 5* and *Figure 7*).

Static loading results (weights) demonstrate a typical "creep" response, with the distal portion of the TCL elongating between 5% and 7% (1.6 mm to 2.3 mm) over a 2-hour period, then returning close to baseline measures when the weights were removed (*Figure 6*). The second application of weights generally stretched the TCL more than the initial application of weights did, and the final resting position reflects an overall increase in TCL length of approximately 2% (0.6 mm) for most of the cadaver limbs (*Figure 8*).

The one group that differed from the other three was the female group that received OM first (*Figure 9* and *Figure 10*). In this group, dynamic loading (OM) allowed the static loading (weights) to stretch the TCL significantly further than in males (9% [2.6 mm] vs 2% [0.7 mm], P=.0006). The reverse was not found to be true, however; that is, OM was not significantly more effective when preceded by weights for either sex (P=.213).

The overall mean change (± standard deviation [SD]) in TCL length (determined by 3D video analysis) was found to be 63% ± 36% SD of the change in pin separation at skin level (as measured using precision calipers). The relatively large standard deviation reflects differences between limbs as well as differences between the loaded and unloaded states of TCLs. Generally, the values were smaller during the loading of the TCLs and larger during the recovery periods after elongations.

Comment

After analyzing results of the present study, several key points are apparent in relation to the results from part 1,[7] especially when comparing male to female TCL responses at higher weight loads and in alternate loading sequences.

The TCL elongation produced in the present study was substantially greater than estimated in part 1.[7] Further, the ratio of TCL lengthening relative to the separation of the pins

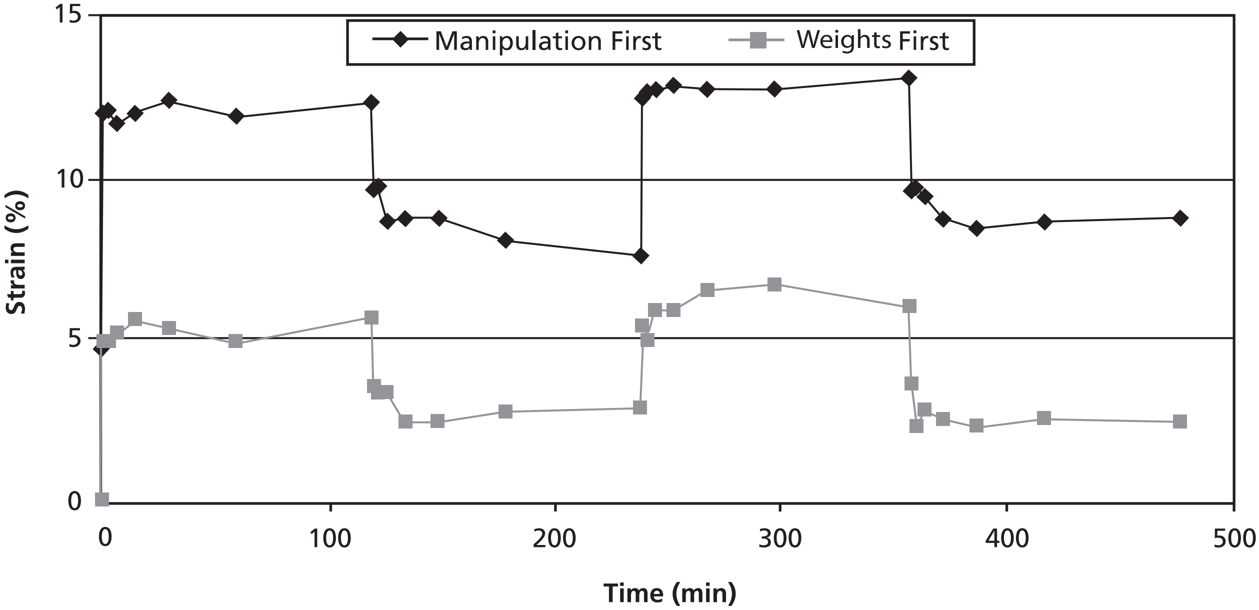

Figure 10. *Results of static loading (weights) first and dynamic loading (osteopathic manipulation [OM]) first trials for female cadaver limbs. Prior application of dynamic loading (OM) had a large and significant effect for female cadaver limbs. In particular, note the shift in baseline for the trial using OM first, indicating residual elongation carried over from OM maneuvers used on the previous day. Elongations were normalized by dividing the change in length by the original length, and are expressed as a percentage of strain.*

at skin level was also greater. All interventions produced greater effects on female TCLs, and performing OM prior to weight loading produced an enhanced effect that was not observed when reversing the sequence of the two testing procedures.

Finally, the most effective manipulative maneuver was shown to be the same one as was used in the initial study that added the guy-wire maneuver to the distal row transverse extension (manipulation maneuver 4, *Figure 4*).[7]

In part 1 of this study,[7] we used lighter weight loads (2 N, 4 N, and 8 N) for longer periods of time (8-12 hours) and did not produce the degree of TCL elongation achieved in the present study with 10 N applied for 2 to 3 hours.

In addition, part 1 focused on maximal TCL elongations that occurred during the application of loads, whereas the present study focused on residual TCL elongations once loads were removed, because this effect would be the more clinically significant and desirable result from any intervention used to treat patients with CTS.

We have now also demonstrated that the actual changes in TCL length (measured by video) were approximately 63% of the changes in pin separation (measured by precision calipers). In other words, for every millimeter that the pins moved further apart above the skin, the TCL actually elongated 0.63 mm. This new result contrasts sharply with the results of part 1 in which we estimated this value to be only 38%.[7]

In part 1,[7] we used caliper measurements for both above-skin and at-ligament–level measures in two cadaver limbs dissected prior to applying static loads. In those two limbs, we dissected down to the TCL first, applied loads to the pins, and took direct measurements at both sites as the pins moved apart from each other. We directly observed (in the dissected state) that the measurements at ligament level were only about 38% of those taken above the skin. Based upon these observations in part 1,[7] mean residual TCL elongation was calculated to be less than 1 mm, compared to 2.6 mm for the female TCLs in the present study.

It now appears to have been inaccurate to apply the 38% value to the other five cadaver limbs that were tested intact in part 1,[7] when the loads were applied to the pins prior to dissection. In the present study, it has become obvious that the TCL elongates in a different fashion when loaded after dissection compared to when it is loaded before dissection. Evidently, the surrounding tissue affects the manner in which the pins (and hence the bones and TCL) move during loading. There is more of a side-to-side parallel translation of the pins during loading when the surrounding tissue is left intact (*Figure 11*).

In contrast, when this tissue is removed, there is increased

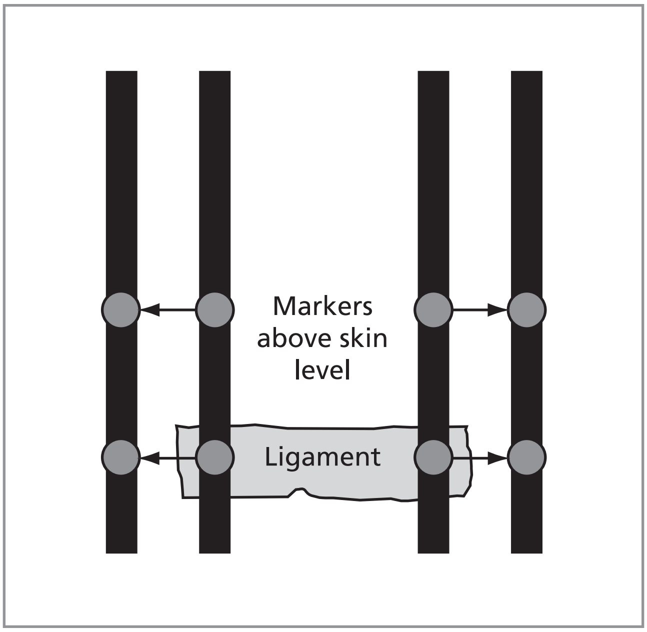

Figure 11. *Above-skin vs below-skin transverse carpal ligament measurements (TCL): pure translation of pins (an unlikely outcome). Above-skin measurements reflect TCL elongation directly.*

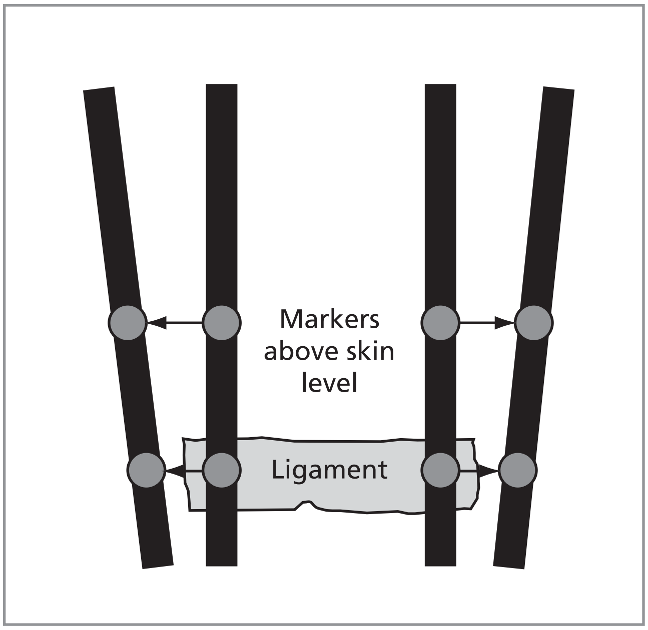

Figure 12. *Above-skin vs below-skin transverse carpal ligament measurements (TCL): combined translation and rotation of pins (a more likely outcome). The distance pins separate above the skin is greater than actual TCL elongation.*

rotation of the pins that results in greater movement above the skin level (*Figure 12*), but relatively less widening of the TCA, with less bone separation and less TCL elongation. In any event, residual TCA widening obtained in part 1 was substantially less than that achieved in the present study among the female cadaver limbs.

Another significant finding in the present study were sex differences in static and dynamic loading results. The difference in response by sex suggests a need for osteopathic researchers to quantify the elastic properties of ligaments in males and females so that we might establish reference ranges for the purposes of comparison.

The primary investigator (B.M.S.) observed that male cadaver wrists were more resistant to OM. In general, the male wrists were noted to be larger, making it cumbersome and more difficult technically to apply OM optimally while working around the surgical pins. This technical challenge inherent to the study was particularly problematic when the primary investigator attempted to apply manipulation maneuver 4 to male wrists (*Figure 4*).

In fact, we believe this difficulty partially explains the greater TCL strain (elongation) with OM in females. Because male TCLs were observed to be "thicker" in comparison to that of the females,[7] and were less extensible according to the strain data, it is reasonable to presume that a 10 N load would have less effect on lengthening male TCLs than it could on a thinner and more extensible female TCL, thereby explaining the difference in response to static loading.

Perhaps an even more significant finding that was exclusive to females was that the effect of applying OM on day 1 of testing was apparent in day 2 when static loading was applied. When OM was applied first, it appears to have enhanced the effect of subsequent static loading, an effect which we call "priming." Interestingly, when the sequence was reversed, there was no evidence of any priming effect from applying weights before OM. This effect logically suggests that in a clinical situation, the "preferred" sequence of therapy would be osteopathic manipulative treatment (OMT) first, followed by static stretching (ie, a regimen of stretching exercises for the patient to follow at home after a physician provides OMT in the office).

Previous clinical trials[2–6] demonstrated successful treatment of CTS using combinations of various treatment modalities, with OMT and vigorous stretching exercises as the mainstay. However, no controlled study was undertaken regarding the most effective sequencing of a combined OMT and exercise treatment protocol. These two approaches were often randomly applied because patient compliance and accessibility to physician's offices varied. It now appears that a recommended protocol beginning with OMT is justified.

It is noteworthy that female TCLs responded significantly better to OM and static loading than male TCLs. Because substantially more women suffer from CTS than men,[13] it is convenient that women could more readily benefit from treatment with OMT for this condition than men.

However, it is likely that male TCL elongation would approach levels observed in the females by applying greater static loads—or by using more vigorous OM techniques in combination with more vigorous stretching exercises in this patient population.

It is encouraging that residual TCL elongation in female limbs was greater than estimated in part 1.[7] This result further supports the greater potential of OMT to alleviate symptoms of CTS because the resulting increase in TCA dimensions more closely approaches changes observed postoperatively, after transection of the TCL.[8,9]

Future studies will investigate additional OM techniques, such as two-person manipulations that could be more effective on the larger and more challenging male subjects. Such an approach might facilitate manipulation maneuver 4, the use of which was limited in the present study, as noted elsewhere.

In live subjects (actual patients), the primary investigator (B.M.S.) has noted anecdotally that OMT is clinically very effective in men when more vigorous (higher force) techniques are used and when a second osteopathic physician is available to assist (oral communication, June 2004). The observed thicker TCLs on male cadaver limbs, which were more resistant to elongation using static weight loading compared with TCLs in female cadaver limbs, supports the requirement for the use of higher forces in males.

The results of the present study are being used as parameters to design a dynamic orthotic device that would apply low static loads to patient's TCLs over several hours. Clinical trials will be required to assess the efficacy of this type of treatment for patients with CTS, however. As noted, we expect to observe in clinical trials that the findings on cadaver studies will compare with living tissue because, as noted, it has been previously demonstrated that postmortem storage has little or no effect on the biomechanical properties of ligaments.[10,11]

Conclusion

Elongation of the TCL was underestimated in part 1 of this study.[7] Widening of the TCA provides a much greater percentage of pin separation at skin level than prior calculations predicted. Thus, intervention with OMT, stretching exercises, and the use of dynamic orthosis should be more effective than previously concluded[7] based upon the results of the present study. These interventions may prove to have greater effects on women than men. Technical limitations inherent in the study protocol may have reduced the clinical efficacy of proposed treatment effects on male wrists. However, these specific limitations would not exist in the clinical setting.

Because OM appears to prime the TCL, potentially making it more responsive to subsequent stretching or exercise, it appears that there is a preferred sequence for these combined treatment protocols when used to treat patients with CTS. This finding has the potential to impact and dramatically alter clinical outcomes. Knowledge and application of this preferred sequence of OMT followed by stretching should be used to increase patient motivation and compliance.

Finally, this study adds further objective evidence that the OM technique which adds the guy-wire maneuver to the distal carpal row transverse extension[7] is the most effective osteopathic approach in the management of CTS.

Acknowledgment

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