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# The examination of soft tissue compliance in the thoracic region for the development of a spinal manipulation training mannequin

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Purpose: *To determine if the soft tissue compliance of the thoracic paraspinal musculature differs based on gender and body type to help create a foam human analogue mannequin to assist in the training of spinal manipulative therapy.*

Methods: *54 volunteers were grouped based on their gender and body types. In the prone position, thoracic paraspinal soft tissue compliance was measured at T1, T3 T6, T9 and T12 vertebrae levels bilaterally using a tissue compliance meter.*

Results: *There was no significant difference in tissue compliance when comparing the genders except at T1 (p=0.026). When comparing body types, significantly higher tissue compliance was found between endomorphs and the other groups. No significant difference was found between ectomorphs and mesomorphs. The compliance for the participants in this study ranged from 0.122 mm/N to 0.420 mm/N.*

Objectif : *Déterminer si la compliance des tissus mous de la masse musculaire thoracique paradorsale diffère selon le sexe et le type corporel afin de créer un mannequin en mousse de forme humaine pour aider à la formation en traitement par manipulation dorsale.*

Méthodologie : *On a regroupé 54 volontaires en fonction de leur sexe et de leur type corporel. En position allongée, on a mesuré la compliance des tissus mous thoraciques paradorsaux au niveau des vertèbres T1, T3, T6, T9 et T12 bilatéralement à l'aide d'un dispositif de mesure de compliance.*

Résultats : *Il n'y a pas de grande différence sur le plan de la compliance des tissus lorsqu'on compare les sexes, sauf à la vertèbre T1 (p = 0,026). En comparant les types corporels, une compliance des tissus bien plus élevée a été remarquée chez les endomorphes par rapport aux autres groupes. Il n'y a pas de différence importante entre les ectomorphes et les endomorphes. La compliance pour les participants à cette étude allait de 0,122 mm/N à 0,420 mm/N.*

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This trial has been registered with the Canadian Memorial Chiropractic College Research Ethics Board (approval number: 112026)
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Conclusion: *There are significant differences in thoracic spine soft tissue compliance in healthy asymptomatic patients between genders in the upper thoracic spine, and between different body types throughout the thoracic spine. It may be beneficial to create multiple versions of practice mannequins to simulate variations amongst different patients.*

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KEY WORDS: compliance, thoracic spine, mannequins, somatotypes, chiropractic

Conclusion : *Il existe de grandes différences entre la compliance des tissus mous thoraciques dorsaux chez les patients en santé asymptomatiques entre les sexes dans la colonne thoracique supérieure et entre les différents types corporels dans toute la colonne thoracique. Il peut être bénéfique de créer plusieurs versions de mannequins de pratique pour simuler les variations chez les différents patients.*

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MOTS CLÉS : compliance, colonne thoracique, mannequins, somatotypes, chiropratique

## Introduction

The introduction of using force-sensing table technology in a chiropractic institution is providing increased opportunity for students to practice manipulative skills. Force-sensing table technology provides direct and immediate knowledge of results (KR).[1,2,3] The force-sensing table is a typical chiropractic table that has been modified and fit with a force-plate and the software required to provide immediate KR.[4,5] Knowledge of results is provided in terms of an immediate force-time profile, containing information about force, moments, and speed. Although the force-sensing table technology provides objective feedback, it is important to recognize that it cannot fully mimic a real clinical encounter, and a number of variables must be considered for its use. For example, to maintain a high level of safety, and to enhance manual manipulation skills, it would be ideal to have a simulated mannequin that can mimic the human body as closely as possible for students to practice. To maintain a reasonable level of fidelity, it is important to use a mannequin form that simulates real contours of a patient, and a compliant material similar to a human body. These foam human analogue mannequins would allow the students the opportunity to practice manual skills procedures while learning to modulate forces by receiving immediate KR using the force-sensing table. By learning more about tissue compliance and variability of the compliance of paraspinal musculature, it may be possible to create a human adult analogue mannequin with a high level of fidelity to accurately practice manual manipulation techniques.

Soft tissue compliance has been defined as the amount of displacement of the tissue with a fixed amount of force, as measured by a tissue compliance pressure meter (TCM).[6] It has been shown that measuring compliance is a valid method to evaluate the paraspinal soft tissue.[7,8,9,10] Previous research indicates there is a difference in compliance between genders, and by region in which the measurements were taken, but no significant differences exist for age or between symptomatic versus asymptomatic subjects.[11,12] The purpose of this study is to evaluate whether body type (ectomorph, endomorph, or mesomorph)[13] and gender impacts thoracic paraspinal soft tissue compliance as measured by TCM. Successful identification of any differences will aid in the development of a foam human analogue mannequin for manual skills training.

## Methods

### *Sample Population*

This study was approved by the CMCC Institutional Research Ethics Board. A convenience sample of healthy, asymptomatic, male and female subjects was used. Volunteer participants were screened by Investigator 1 using a questionnaire and Adam's forward bending test.[14] Particpants were excluded if they reported; thoracic back pain at the time of the interview; known history of scoliosis, fused vertebrae, Scheuermann's disease or Ankylosing Spondylitis; or had a visible rib hump during Adam's forward bending test.

The participants were divided into groups based on body type: ectomorphs, endomorphs, and mesomorphs.[13] Investigator 1 assigned participants to the appropriate group based on visual approximation using the definitions of mesomorph, endomorph and ectomorph.[13]

### Instrument

A TCM was used to measure the compliance of the thoracic region. The tool used in this study consists of a force gauge and a metal measuring rod with a $1cm^2$ probe that is pressed into tissue, resulting in a surface deformation (Figure 1 and 2).[15] Kawchuk et al. further explains

> "A collar surrounding the probe contacts the tissue and is believed to remain at the original surface level as the probe is moved downward. A marker on the collar measures how far the probe has passed into the tissue via a ruler-type scale. The amount of force that is used to push the instrument into the tissue is recorded by an analog gauge that is similar to a bathroom scale in mechanism. The overall result is a measurement of compliance that is expressed in millimeters per Newton (mm/N)."[15]

The TCM was used for all measurements in this study. Current literature supports the use of the TCM in measuring soft tissue compliance with low level variability for intra-examiner measurements.[8] To maintain consistency, Investigator 2 collected all TCM data.

### Experimental Maneuver

Investigator 1 grouped the participants according to body type, and then placed the participants in a prone position with their thoracic spine exposed. Investigator 2 was responsible for landmarkering and measuring all tissue compliance sites. Using palpation skills and procedures from the text "A Manual Therapist's Guide to Surface Anatomy and Palpation Skills" Investigator 2 located and marked with a washable marker the T1, T3, T6, T9 and T12 spinous processes.[16] These measurements were taken two centimetres lateral to the spinous processes, bilaterally, to maintain consistency. The TCM was used to measure the displacement of tissues at these identified levels with a four kilogram (4 kg) force applied following a standard protocol.[6,9,17] Investigator 2 recorded the displacement in millimeters at each of the chosen levels bilaterally. The compliance measurements were repeated a second time to test for consistency between the readings. An average of the two readings was recorded and used for statistical purposes.

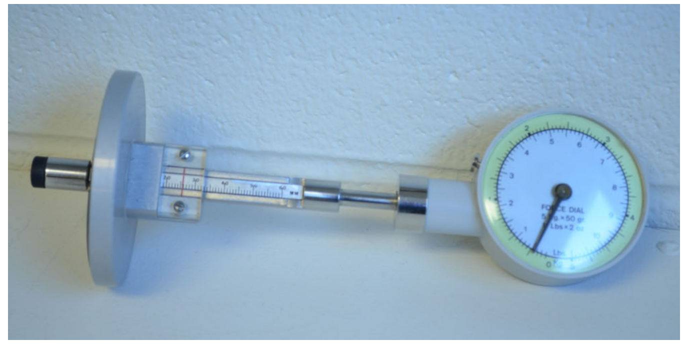

Figure 1:
*Picture of the Tissue compliance meter.*

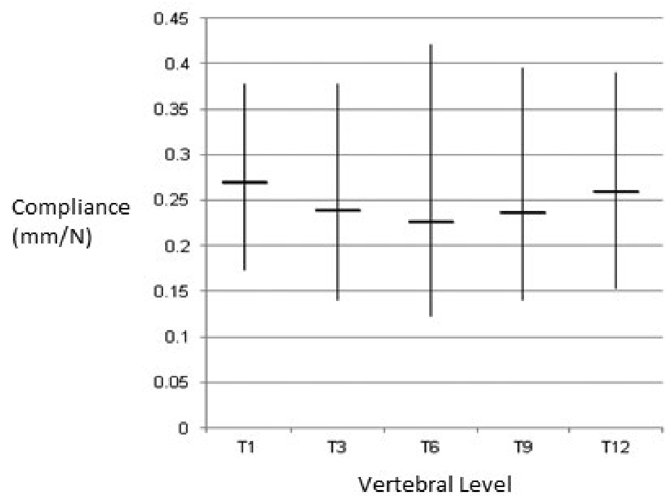


Figure 2:
*The mean and standard deviation of thoracic soft tissue compliance in asymptomatic males and female subjects (n=54).*

### Data Analysis

The data were converted to millimetres per Newton (mm/N) and divided into two different sets. The first set compared tissue compliance differences by gender, while the second compared tissue compliance differences by

Table 1:
*Mean and standard deviation tissue compliance of males and females and body types at all vertebral levels in the thoracic spine (mm/N).*

| | Ectomorph | Endomorph | Mesomorph |
|---|---|---|---|
| **Male** | n=10<br>Mean; Standard Deviation<br>T1: 0.271; 0.044<br>T3: 0.236; 0.071<br>T6: 0.218; 0.073<br>T9: 0.233; 0.080<br>T12: 0.260; 0.070 | n=7<br>Mean; Standard Deviation<br>T1: 0.320; 0.041<br>T3: 0.305; 0.046<br>T6: 0.287; 0.070<br>T9: 0.286; 0.043<br>T12: 0.307; 0.037 | n=9<br>Mean; Standard Deviation<br>T1: 0.273; 0.033<br>T3: 0.233; 0.054<br>T6: 0.215; 0.053<br>T9: 0.227; 0.035<br>T12: 0.261; 0.033 |
| **Female** | n=9<br>Mean; Standard Deviation<br>T1: 0.246; 0.580<br>T3: 0.209; 0.034<br>T6: 0.198; 0.037<br>T9: 0.208; 0.036<br>T12: 0.231; 0.055 | n=7<br>Mean; Standard Deviation<br>T1: 0.301; 0.040<br>T3: 0.277; 0.037<br>T6: 0.265; 0.049<br>T9: 0.277; 0.062<br>T12: 0.278; 0.038 | n=11<br>Mean; Standard Deviation<br>T1: 0.236; 0; 031<br>T3: 0.208; 0.036<br>T6: 0.206; 0.058<br>T9: 0.221; 0.050<br>T12: 0.242; 0.043 |

body types. The data were analysed using two-way analysis of variance (ANOVA) testing to compare potential differences between gender and body type at T1, T3, T6, T9 and T12 landmarks. Statistical significance was set at $p<0.050$. Post hoc analysis using Tukey honestly significant differences (HSD) method[18] with family confidence coefficient equal to 0.900 was completed if the two-way ANOVA demonstrated any interaction between body types.

## Results

At baseline, 54 participants aged 23 to 58 met all the inclusion criteria. One participant dropped out of the study during testing due to discomfort with the procedure leaving a total of 53 participants; 27 female and 26 male. When divided into body types there were 19 ectomorphs, twenty 20 mesomorphs, and 14 endomorphs. The mean tissue compliance data are displayed in Table 1.

### *General Pattern*

Upon visual inspection and descriptive statistical analysis, the general pattern of soft tissue compliance, regardless of body type or gender, showed greater compliance in the upper and lower thoracic regions when compared to mid (Table 1) (Figure 2). The data suggest the soft tissue

Table 2:
*Two-way ANOVA results for all vertebral levels comparing body type and gender.*

| | | F | p-value |
|---|---|---|---|
| T1 | Interaction gender x body type | 0.214 | 0.808 |
| | Gender | 5.254 | 0.026* |
| | Body type | 8.526 | 0.0006* |
| T3 | Interaction gender x body type | 0.004 | 0.996 |
| | Gender | 3.880 | 0.055* |
| | Body type | 10.546 | 0.0002* |
| T6 | Interaction gender x body type | 0.071 | 0.931 |
| | Gender | 1.104 | 0.299 |
| | Body type | 6.708 | 0.003* |
| T9 | Interaction gender x body type | 0.165 | 0.849 |
| | Gender | 0.840 | 0.364 |
| | Body type | 6.229 | 0.004* |
| T12 | Interaction gender x body type | 0.062 | 0.940 |
| | Gender | 3.649 | 0.062 |
| | Body type | 4.330 | 0.019* |

Table 3:
*Tukey HSD confidence intervals comparing body types with family confidence coefficient equal to 0.900.*

| Outcome | Endo – Ecto | Endo – Meso | Ecto – Meso |
|---|---|---|---|
| T1 | (0.021; 0.083) | (0.025; 0.086) | (-0.025; 0.032) |
| T3 | (0.038; 0.100) | (0.040; 0.102) | (-0.026; 0.030) |
| T6 | (0.037; 0.099) | (0.035; 0.096) | (-0.031; 0.026) |
| T9 | (0.030; 0.092) | (0.027; 0.088) | (-0.032; 0.025) |
| T12 | (0.016; 0.078) | (0.011; 0.072) | (-0.034; 0.022) |

Endo = Endomorph; Ecto = Ectomorph; Meso = Mesophorph

paraspinal compliance for the participants in this study range from a minimum of 0.122 mm/N to a maximum of 0.420 mm/N.

### *Male versus Female*

The descriptive statistics are displayed in Table 1 and the two-way ANOVA results are displayed in Table 2. There was no significant difference found between male participants and female participants at any site except at T1 (p=0.026) and borderline significance at T3 (p=0.055).

### *Body Types*

The descriptive statistics are displayed in Table 1 and the post hoc results are displayed in Table 3. The two-way ANOVA tests (Table 2) demonstrated that there was a significant difference between the three body types at all sites. Post hoc testing as displayed in Table 3 showed that endomorphs were significantly different than both the mesomorphs and ectomorphs, while there was no significant difference observed between the ectomorph and mesomorph groups. These groups had very similar values throughout the thoracic spine as confirmed by their descriptive statistics (Table 1). Conversely, the endomorphs were significantly different from both the ectomorphs and the mesomorphs (Table 3).

## Discussion

The data suggests that there may be no significant differences in soft tissue compliance in the thoracic spine between males and females. Previous research has indicated that there is a significant difference between genders regarding soft tissue compliance, however, differences were found at C6, L3, and L5[12], while the current study examined only the thoracic spine. The only areas found to have a statistically significant difference in this study were at T1 (p=0.026) and borderline significance at T3 (p=0.055), with males having more compliance than females. With no statistically significant differences at T5, T7, T9 or T12, the findings of this study are mostly consistent with previous research.[12] The data appeared to be consistent with the previous studies showing that there is less compliance in the mid thoracic spine compared to cervico-thoracic and thoraco-lumbar junctions. These are transitional regions, which may require more extensive study of the spinal musculature as a whole in the future.

Of the three body types investigated, the mesomorphs and ectomorphs were found to be very similar, while the endomorphs were significantly more compliant from the other groups. This may be caused by the amount of adipose tissue in the area or differences in musculature of the ectomorphs and mesomorphs compared to endomorphs.

To effectively create a practice mannequin that has high fidelity to human patients, the results of this study inform that the soft tissue compliance of the thoracic spine could range from 0.122 mm/N to 0.420 mm/N with increased compliance in the cervico-thoracic junction (T1) which decreases towards the mid t-spine (T6) and starts to increase again at thoracic/lumbar junction (T12). (Figure 2)

The limitations in the research include the population investigated, the limited area inspected, and the method used to determine body type and the reliability of the TCM. There is disagreement in the literature about reliability of TCM. In 1995, Kawchuk and Herzog found poor reliability which they acknowledge may be a result of instrument design or application.[15] However recently Wernicke et al. have validated TCM with low levels of intra-rater variability ($r>0.940$, $p<0.000$).[8]

The reliability and accuracy of spinal landmarking may also be a limitation in this study. Although a single researcher conducted all of the landmarking tasks to reduce inter-observer variability research has suggested that similar methods of palpation can been inaccurate in overweight and obese patients.[19]

The healthy adult sample used in this study also limits the application of results to different populations. Since the purpose of the research was to help design a human adult analogue mannequin, future research should investigate if there are any differences between age groups, and if there is a necessity to create mannequins based on age as well as body type. As well, there should be consideration of a symptomatic population, and the potential need for mannequins to reflect them. The focus on the thoracic spine allowed for a preliminary investigation. In the future, using compliance to match clinical populations throughout the full spine when constructing mannequins could improve the fidelity for training spinal manipulation. Further research should also attempt to determine body type by utilizing a more objective measurement system with higher reproducibility instead of using visual approximation.

## Conclusion

With respect to the development of a foam human analogue mannequin for manual skills training, it is important to respect that some body types have differing soft tissue compliance in the thoracic spine paraspinal musculature. Endomorph body types, regardless of gender, have significantly higher compliance when compared to both ectomorph and mesomorph body types. Based on our sample population, the soft tissue compliance should range from 0.122-0.420 mm/N, and trends suggest it is highest in the upper and lower thoracic spine and stiffest mid-thoracic spine. When designing a mannequin it is important to replicate these values, and possibly make different mannequins to accommodate each body type to maintain a high level of fidelity. Upon future research, other accommodations may include tissue compliance variations to replicate different age groups, symptomatic subjects, cervical spine or lumbar spine regions. This may lead to higher fidelity mannequin training for spinal manipulation, while reducing the need to train on human participants.

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