ORIGINAL RESEARCH
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Tactile Perception of Pressure and Volitional Thrust Intensity Modulate Spinal Manipulation Dose Characteristics

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ABSTRACT

Objective: The purpose of this study was to examine clinicians' ability to modulate spinal manipulation (SM) thrust characteristics based on their tactile perception of pressure and volitional intensity.

Methods: In a cross-sectional, within-participants design, 13 doctors of chiropractic delivered SM thrusts of perceived least, appropriate, or greatest intensity of their perceived safe output level for an SM thrust on low-fidelity thoracic spine models of 4 different pressure levels. The participants performed SM over the course of 96 trials in a randomized order on combinations of thrust intensity and pressure. Dependent variables included normalized preload force, thrust force, thrust duration, peak acceleration, time to peak acceleration, and displacement. For all dependent measures, 2-factor within-participants analysis of variance models with repeated measures on both factors were performed.

Results: Preload force increased with intensity ($F_{2,24}$ = 9.72; $P < .001$) and model pressure ($F_{3,36}$ = 4.27; $P = .011$). Participants modulated thrust force and displacement as each also increased with intensity escalation ($F_{2,24}$ = 22.53, $P < .001$; $F_{2,18}$ = 45.20, $P < .001$). The highest accelerations were observed during the greatest intensity. Increased thrust force was delivered at higher model pressures ($F_{3,36}$ = 6.43; $P < .001$). A significant interaction demonstrated that as volitional thrust intensity increased, greater displacement was attained, particularly on low pressure models ($F_{6,54}$ = 11.06; $P < .001$). Thrust duration and time to peak acceleration yielded no significant differences.

Conclusion: Spinal manipulation thrust dosage was modulated by the chiropractors' tactile perception of pressure and volitional intensity. (J Manipulative Physiol Ther 2019;42:335-342)

Key Indexing Terms: *Manipulation, Spinal; Touch Perception; Chiropractic; Intention; Palpation*

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INTRODUCTION

Clinicians, including chiropractors, osteopaths, and physical therapists, often incorporate spinal manipulation as a component of their therapeutic interventions.[1] Spinal manipulation is targeted toward spinal joints with intersegmental joint dysfunction or hypomobility.[2-4] Previous studies of spinal manipulation "dose" or "dose response" have largely considered frequency of care. The studies are important for documenting the number of treatment visits that reveal changes in pathologic conditions, including chronic low back pain[5] and cervicogenic headache,[6] but tell us little about the nature of the spinal manipulation delivered to a patient and whether the clinician modulated the "dose" of the manipulative thrust within a treatment session based on unique characteristics of the patient. A study conducted by Descarreaux et al[7] considered the dose of spinal manipulation as the preload and thrust forces and their relative timing, upon which this article builds.

Spinal manipulation consists of a mechanical thrust event with a relatively brief duration, approximately 150 ms in the thoracic spine.[8,9] The temporal nature of the intervention requires that the magnitude of the thrust be predetermined with no ability to make online corrections during the thrust itself. A number of factors contribute to the clinician's decision regarding the appropriate magnitude of thrust, including assessment of the spine and palpation of intervertebral joints.[10] Spinal joint palpation is the active tactile exploration and manual assessment of surface tissues at or near the spine. Although spinal joint palpation is a common technique used by manual therapists, little is known regarding how or whether feedback from tactile assessment modulates decision making related to the output delivered by the clinician. Other potential factors that can contribute to the predetermination of thrust dose include visual observation, patient history, and current clinical status. Whether any of these factors contribute to the selection of thrust magnitude, and the extent to which they may modulate spinal manipulation thrust, has not been determined.

The acquisition of complex information by the touch system is limited by tactile attention.[11] For the purpose of this proposal, we will focus on endogenous tactile attention.[11] Endogenous attention is considered a "top-down" phenomenon in which an individual voluntarily deploys their attention to a specific sensory modality. Endogenous attention can be directed by cognition and used to capture specific tactile features or attributes of stimuli or their location. Making the choice to focus attention on the feeling of a watch on one's wrist is an example of a shift in endogenous attention. The study of cognitive attention for tactile information has been identified as an area for future research.[12] Tactile perception can be modified by cognitive or contextual factors.[13]

The study of active touch is thought to be multimodal as a result of the perceptual and proprioceptive processing involved with effector movements.[14] Active touch is the conscious effort to move an effector across the surface of the stimuli to be detected.[15] An example of this would be a chiropractic clinician palpating a spinal region to assess paraspinal tissue tone, texture, and stiffness.

The objective of this study was to explore how perceptual factors, specifically how tactile feedback, influences the delivery of a dose of spinal manipulation. Our primary objective was to determine the consistency of the ability of a clinician to deliver a spinal manipulative thrust based on feedback detected from different tactile contexts. Our secondary objective was to examine the conscious ability to modulate manipulative thrust delivery based on the clinician's cognitively intended level of intensity for the thrust.

Methods

Using a clinician population, we measured force-time and kinematic information on spinal manipulative thrusts delivered to low-fidelity thoracic spine models.

Participants

Licensed chiropractic clinicians with more than 5 years of clinical experience (n = 13) were recruited for the study through the Manitoba Chiropractors Association membership email list. All participants underwent informed consent, and all procedures were approved by the Health Research Ethics Board at the University of Manitoba. Upon arrival, participants were provided with an informed consent document for their review. As compensation for their time, they were provided with parking reimbursement and a $5 refreshment gift card.

To determine minimal sample size, an a priori power calculation was performed using acceleration values from a comparable set of published data that included participants performing upper limb movements in response to tactile perceptual stimuli.[16] For a statistical power level of 0.8 and $\alpha < 0.05$, a minimum of 10 persons was required to attain appropriate power. Additional participants were recruited to allow for dropout or technical issues.

Inclusion Criteria. To be included in the study participants met the following criteria: (1) licensed with the Manitoba Chiropractors Association; (2) minimum of 5 years of clinical experience; (3) must be familiar with a covered thumb-push technique done on the angle of the rib just lateral to the transverse process. This movement is indicated when there is costotransverse joint dysfunction.[17]

Exclusion Criteria. Participants were excluded for any of the following reasons: (1) did not currently hold a valid chiropractic license; (2) not engaged in clinical practice in the past year; (3) not familiar with the covered thumb-push technique.

Apparatus

Custom experimental protocols to manage all aspects of participant timing and equipment triggering were developed using E-Prime software and hardware (E-prime, version 2.0; Psychology Software Tools, Sharpsburg, Pennsylvania). Force-time curves associated with the manipulative thrusts were recorded using a low-profile load cell (TAS606; HT Sensor Technology, China; 300 Hz sampling rate) positioned under the chiropractor's thrusting hand on the low-fidelity models. Acceleration data were collected using a wired triaxial accelerometer (ADXL335; Analog Devices, Norwood, Massachusetts) at a sampling rate of 300 Hz. The accelerometer was mounted on the distal aspect of the ulna, on the eminence on the dorsolateral aspect of the wrist proximal to the ulnar styloid.

To measure displacement, an infrared emitting diode (Northern Digital Instruments, Waterloo, Canada) that is detected with a 3-dimensional motion analysis system (3D Investigator; Northern Digital Instruments) was affixed to the accelerometer on the distal wrist over the ulnar styloid using an adhesive tape. Kinematic data was recorded using the 3-dimensional motion analysis system at a collection

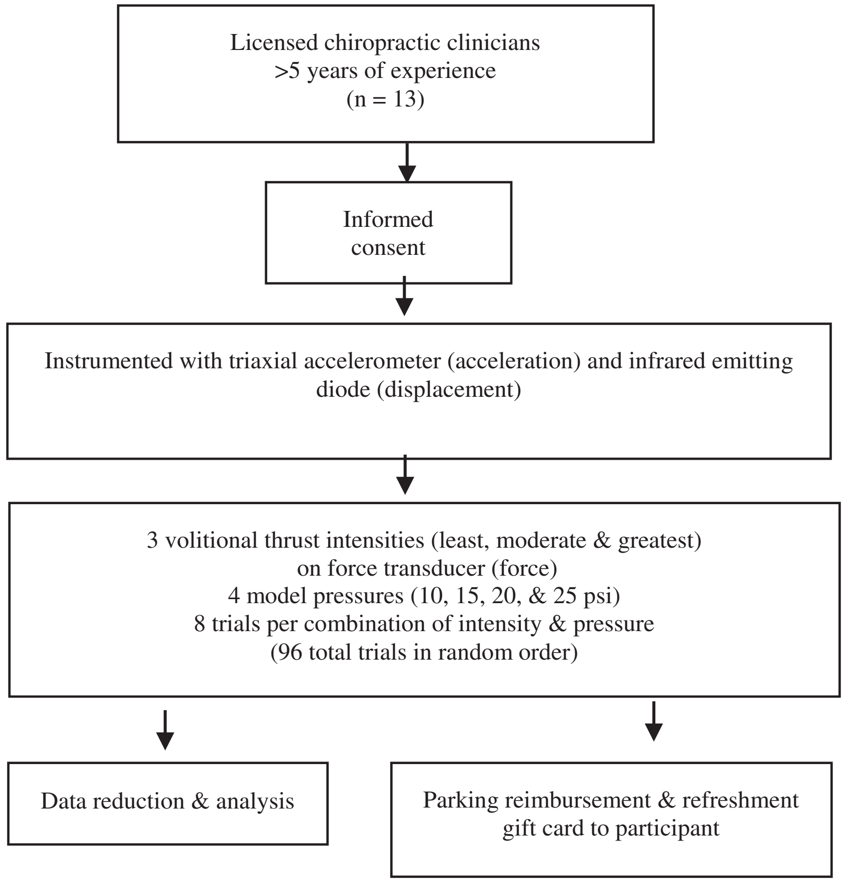

Fig. 1. *Flow diagram of the participants and their activities through the experiment.*

rate of 300 Hz, which has been reported to be sufficient for kinematic analysis.[18]

The low-fidelity thoracic spine model used varying air pressures to simulate differences in compliance of the human spine. A smooth-surfaced bicycle tire was used to provide the desired tactile stimulus approximating modifiable ranges of spinal stiffness and mounted in a custom stand. Four separate tires with pressures ranging from 10 to 25 psi in 5-psi increments were used as spinal models. Participants moved between models in a predetermined, randomized sequence.

Procedure

For each trial and for each spinal model, participants were asked to assess the stiffness of the model and to determine an appropriate magnitude of manipulation thrust. Once determined, the participant was then asked to deliver 1 of 3 thrusts; the perceived appropriate magnitude of thrust, a lower but still effective magnitude of thrust, or a higher but safe magnitude of thrust. The thrust was applied using a covered thumb-push technique,[17] which consists of the clinician using the palmar surface of the distal thumb pad of one hand over the contact point on the model, and the pisiform of their second hand is placed on the thumbnail of the contact hand for reinforcement. The fingers of the second hand are wrapped around the wrist of the contact hand, adding further reinforcement. A posterior-to-anterior thrust is administered as the clinician delivers a straight-arm body-drop using their body weight. The 3 levels of desired thrust magnitude were to be derived independently for each spinal model and were described to the participants as the following: (1) at low intensity, participants thrusted at a level perceived to be of just sufficient intensity for a successful spinal manipulative (SM) thrust; (2) at medium intensity, participants were told to thrust at what they perceive to be an appropriate level for a successful SM thrust; and (3) at highest intensity, participants were told to thrust at the maximal end of their perceived safe output level for a SM thrust. In this way, a participant's ability to incorporate tactile input into the clinical decision process of determining thrust magnitude, and to vary thrust consistently based on the tactile stimulus, was assessed. Four different model pressures and 3 different thrust intensities with 8 trials at each combination resulted in a total of 96 trials. Trials were presented in a random order in a list

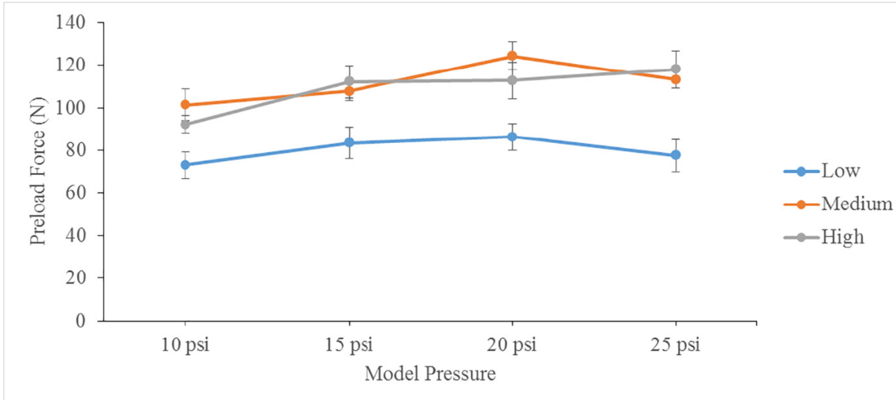

Fig. 2. *Mean preload force of the clinicians' hands at each model pressure and intensity. Error bars represent the standard error of the mean for each data point.*

generated by the E-Prime software, and participants were allowed to rest as needed (Fig 1).

Dependent Variables

Force-time Measures. Total force, peak force, and time to peak force of both the preload and the manipulative thrusts delivered to the low-fidelity thoracic spine model were recorded using a load cell (TAS606 load cell; HT Sensor Technology, Xi'an, China) connected to an I/O system (CED 1401; Cambridge Electronic Design, Cambridge, United Kingdom) using Signal Software (Version 5.04; Cambridge Electronic Design). Force data were collected at a sampling frequency of 300 Hz.

Kinematic Measures. The total displacement, peak acceleration, time to peak displacement, and time to peak acceleration of the hand delivering the thrusts were recorded. Displacement was measured directly by an active marker motion analysis system at a sampling frequency of 300Hz (3D Investigator; Northern Digital Instruments). Acceleration was measured using a triaxial accelerometer, and velocity was integrated from the acceleration recordings at a sampling rate of 300 Hz (ADXL335; Analog Devices, Norwood, Massachusetts).

Statistical Analysis

All data were normalized before analysis. Normalizing was done by calculating the overall mean for all trials within a participant and then expressing each individual trial as a percentage of this grand mean. Dependent variables included normalized preload force, thrust force, thrust duration, peak acceleration, time-to-peak acceleration, and displacement. Mean values of the 8 trials in each condition for each participant were compared for all dependent variables.

Performance differences for all kinematic and force-time dependent variables were assessed using within-participant 3 volitional thrust intensity (low, medium, high) multiplied by 4 low-fidelity thoracic model pressures (10, 15, 20, and 25 psi) repeated measures analysis of variance models. Significant effects involving more than 2 means were further analyzed using Bonferroni pairwise comparisons as post hoc tests. All statistical analyses (including post hoc tests) were conducted using SPSS Statistics (Version 24.0) (IBM Corp, Armonk, New York).

Results

Force-time Measures

Preload Force. Separate significant main effects for preload force revealed that it increased with intensity ($F_{2,24}$ = 9.72; $P < .001$; $\eta^2 = 0.448$) and model pressure ($F_{3,36}$ = 4.27; $P = .011$; $\eta^2 = 0.262$). Pairwise comparisons revealed that preload force was the least at the lowest intended thrust intensity compared with the other 2 volitional intensities. Likewise, the preload force increased as the model pressure increases, specifically from 10 to 20 psi (Fig 2). However, no significant interaction was found for intensity × model pressure, ($F_{6,72}$ = 1.24; $P = .296$; $\eta^2 = 0.094$).

Thrust Force. Participants modulated their thrust force through increases with intensity escalation as revealed by a significant main effect ($F_{2,24}$ = 22.53; $P < .001$; η^2 = 0.652). Pairwise comparison revealed that forces at each intensity level were significantly different than all other intensities (least intensity–lightest force, moderate intensity–intermediate force, greatest intensity–highest force). Similarly, a main effect of model pressure revealed that increased thrust force was delivered at higher model pressures ($F_{3,36}$ = 6.43; $P < .001$; $\eta^2 = 0.349$; Fig 3). Specifically, planned comparisons revealed that at the lightest model pressure, differences were seen from the highest 2 model pressures (more force at higher pressures). However, no significant interaction was found for intensity × model pressure ($F_{6,72}$ = 1.25; $P = .292$; $\eta^2 = 0.094$).

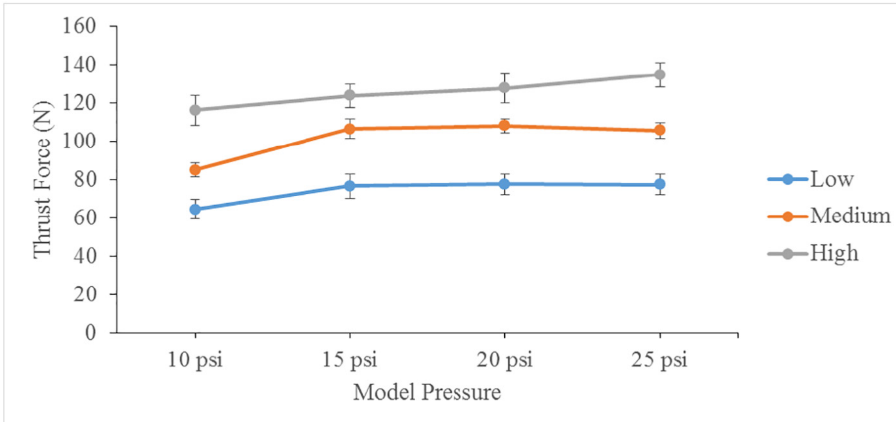

Fig. 3. *Mean peak thrust force of the clinicians' hands at each model pressure and intensity. Error bars represent the standard error of the mean for each data point.*

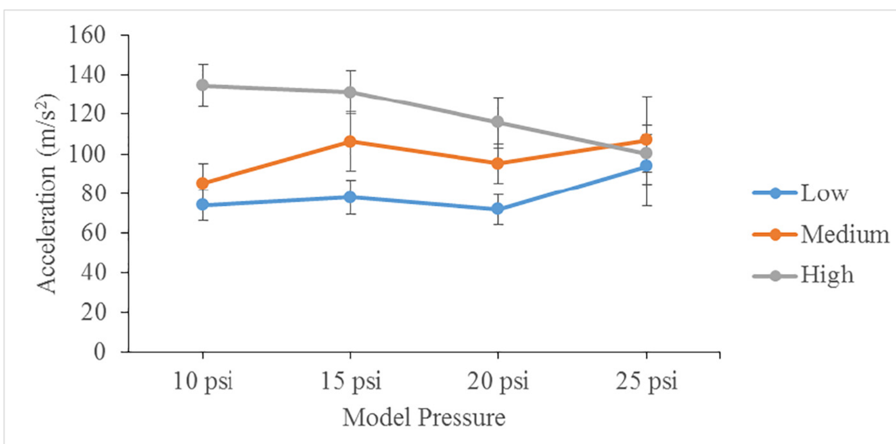

Fig. 4. *Mean resultant peak acceleration of the clinicians' hands at each model pressure and intensity. Error bars represent standard error of the mean for each data point.*

Thrust Force Duration. No significant main effects for intensity ($F_{2,24}$ = 2.797; P = .081; η^2 = 0.189) or model pressure ($F_{3,36}$ = 1.359; P = .271; η^2 = 0.102) were found for thrust force duration. Likewise, there was no significant intensity × model pressure interaction for thrust force duration ($F_{6,72}$ = 0.463; P = .834; η^2 = 0.037). Timing of the thrust force was consistent across conditions. Resultant peak force duration was consistent regardless of model pressure and the intended intensity of the SM thrust delivery.

Kinematic Measures

Acceleration. A significant main effect revealed that the highest accelerations were observed during the greatest volitional thrust intensity ($F_{2,24}$ = 10.745; P < .001; η^2 = 0.472; Fig 4). There was no significant main effect for model pressure ($F_{3,36}$ = 0.382; P = .766; η^2 = 0.031) and no significant intensity × model pressure interaction ($F_{6,72}$ = 1.596; P = .161; η^2 = 0.117). Pairwise comparison revealed that resultant peak acceleration of the thrust hand demonstrated the highest peak accelerations at the greatest intended intensity compared with the lighter 2 volitional intensities.

Time to Peak Acceleration. Analysis of time to peak acceleration data yielded no significant main effects for intensity ($F_{2,24}$ = 0.250; P = .781; η^2 = 0.020) or model pressure ($F_{3,36}$ = 0.1.165; P = .337; η^2 = 0.088). Likewise, there was no significant intensity × model pressure interaction ($F_{6,72}$ = 0.536; P = .779; η^2 = 0.043). The temporal aspects of the acceleration component of kinematic performance were consistent across all model pressures and intended thrust intensities.

Displacement. Displacement analysis was performed on 10 participants because motion analysis data were lost for 3 participants, possibly because of infrared diode occlusion. A significant interaction demonstrated that as volitional thrust intensity increased, greater displacement was attained, particularly on low-pressure models ($F_{6,54}$ = 11.063;

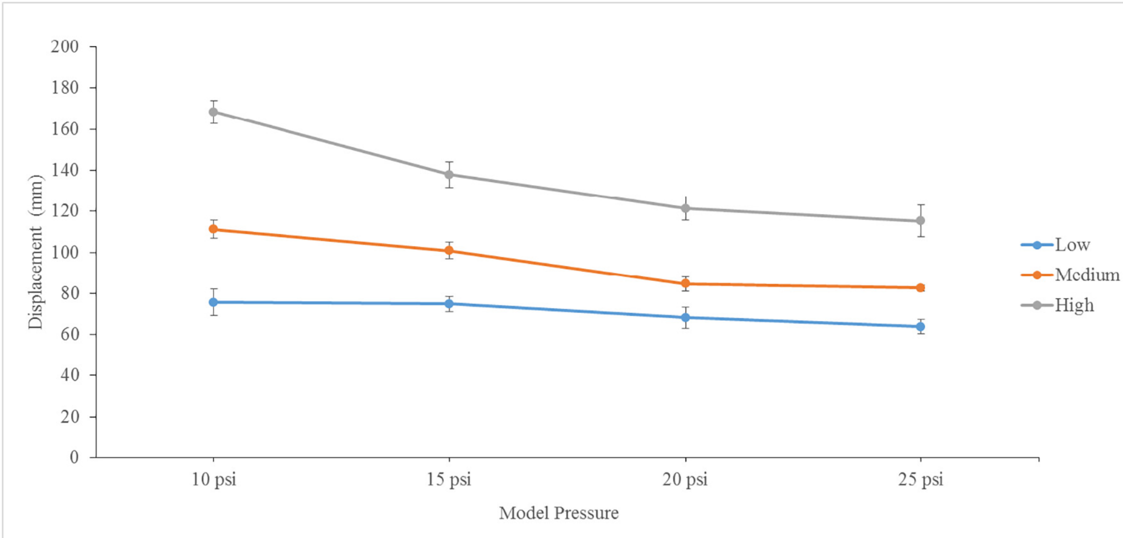

Fig. 5. *Mean peak displacement for the Intensity by Model Pressure interaction. Error bars represent the standard error of the mean for each data point.*

$P < .001$; $\eta^2 = 0.551$). Significant main effects for both intensity ($F_{2,18} = 45.198$; $P < .001$; $\eta^2 = 0.834$) and model pressure were found ($F_{3,27} = 29.759$; $P < .001$; $\eta^2 = 0.768$). Planned comparison revealed that each intensity was significantly different from all other intensities. As volitional thrust intensity increases, we see greater displacement, which is more pronounced on the lower model pressures (Fig 5).

Discussion

This study evaluated whether chiropractors could modulate the thrust characteristics of spinal manipulation based on the tactile perception of pressure and volitional thrust intensity. Tactile exploration of low-fidelity thoracic models led to a change in how clinicians interacted with the model. As the pressure of the thoracic spine models increased, the clinicians increased their preload and thrust forces. Clinicians were also able to modulate their force dependent on their intended thrust intensities (ie, least intensity–lightest force, moderate intensity–intermediate force, and greatest intensity–highest force). As the chiropractor's intended thrust intensity increased, we observed greater hand displacement, which was more pronounced on the models of lower pressures. This observation is consistent with a study that demonstrated that chiropractic students could modulate their manipulative thrusts to create varying levels of force input.[19]

The design of the low-fidelity model used in this study was selected to be a tactile proxy of patient thoracic spines commonly encountered in chiropractic clinical practice. The preload and thrust forces generated by the clinicians in this study ranged from 30.57 N to 191.54 N and 25.77 N to 191.77 N, respectively. Herzog[8] reports a mean thoracic preload force of 139 N; however, his reported mean thrust force of 399 N for thoracic SM is substantially greater than the maximum thrust force of 191.77 N observed in this study.

The differences in preload force and thrust force from this study, as compared with previous studies,[8] could be attributed to data collected during the use of simulated thoracic SM performed on low-fidelity models versus data from thoracic SM performed on human participants.

The mean thrust time of 150 ms, reported by Herzog for thoracic SM, closely approximates the maximum thrust time of 149.27 ms observed in this study. The latency data of the acceleration from this study is supported by Gelley et al,[9] who also reported that the acceleration of the chiropractors' hand is delivered over a relatively constant time base.[9] The temporal components of the spinal manipulative thrust are robust and consistent between studies for thrust force and time to peak acceleration.

Regarding acceleration, the results of this study provide evidence that chiropractor hand accelerations during simulated thoracic manipulation are volitionally modulated by the intensity that the chiropractor determines. In the present study, these accelerations ranged from 29.48 to 326.28 m/s^2.

The data from this study are supportive of chiropractors being able to modulate their thrust force and acceleration in the delivery of spinal manipulation. Furthermore, a dose of SM is delivered independently of the constant rate of the thrust and the resulting hand displacement, which is in accordance with our primary objective in determining the consistency of the chiropractors' ability to deliver a SM thrust based on the differing tactile contexts of the low-fidelity models. In response to our secondary objective, SM thrust dose is modulated by the clinician's tactile perception of model pressure and volitional intensity. Modulation of HVLA dose has less to do with timing, because temporal parameters are constant, and more to do with volitional changes in intensity and the clinician's perception of the pressure of the model.

The results of this study could be applied practically in the training of future clinicians. Deliberately directing a student's cognitive attention to the tactile characteristics of a model or patient can assist their decision making as they are contemplating the thrust intensity they wish to deliver. Experienced clinicians can apply the information from this study to better identify in self-reflection, or in communication to patients, how they determine the appropriate dose of SM to deliver.

Limitations

Use of low-fidelity thoracic spine models could limit the ability to generalize the results of the current study to a clinical population. However, simulated models are frequently used in training environments across clinical disciplines wherein low-fidelity models have been shown to demonstrate adequate transfer of some clinical skills.[20] Moreover, the use of instrumented mannequins has demonstrated that the SM force-time profiles of experienced chiropractors are comparable to the force-time parameters performed on actual clinical patients.[21-24] An additional limitation is that these results might not transfer to other spine or extremity regions based on the biomechanical postures required for manual thrust delivery.

We believe the use of a low-fidelity model in this study facilitated repeated thrusts in the same area, allowed for the clinician to deliver a high intensity thrust confidently, and isolated the variability measured to that of the clinician, as opposed to the clinical milieu in which the variabilities of the clinician and the patient would both be factors to consider. Future research on the unimodal or multimodal nature of perceptual information used by clinicians in the preparation and delivery of spinal manipulative thrust dosage is warranted to better understand clinical decision making.

Conclusion

Spinal manipulation thrust dose was modulated by the clinician's tactile perception of pressure and the volitional thrust intensity they select. By modifying the contextual factor of model pressure, tactile decision making was altered. These factors appeared to contribute to the chiropractors' decision of how much thrust force, acceleration, and displacement that was to be delivered. Our findings suggest that the dose of SM appears to be independent of the duration at which the thrust must be applied and the resulting clinician's hand displacement.

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Contributorship Information

Concept development (provided idea for the research): S.R.P., G.M.G., B.J.M.
Design (planned the methods to generate the results): S.R.P., G.M.G., B.J.M.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): S.R.P., B.J.M.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): G.M.G., Q.M.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): S.R.P., G.M.G., B.J.M.
Literature search (performed the literature search): S.R.P., G.M.G., B.J.M.
Writing (responsible for writing a substantive part of the manuscript): S.R.P., G.M.G., B.J.M.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): S.R.P., G.M.G., Q.M., B.J.M.

Practical Applications

- This study found that spinal manipulation dose was modulated by both tactile feedback and volitional intensity.
- Chiropractors modulate a dose of spinal manipulation through changes in the force, acceleration, and displacement of their thrust.
- Consistent with previous findings, time characteristics of a thoracic region targeted spinal manipulative thrust on a low-fidelity model were relatively invariant.

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