
ORIGINAL ARTICLE

A pilot study to determine the consistency of peak forces during cervical spine manipulation utilizing mannequins

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Objective: Cervical spine manipulation is a complex motor skill used to treat musculoskeletal ailments such as neck pain. There is evidence demonstrating the effectiveness of objective feedback and mannequins for the teaching of spinal manipulation (SM) in the thoracic and lumbar spine. This paper examines the effectiveness of an educational intervention combining both mannequins and force-sensing technology for teaching cervical SM.

Methods: Fourth-year chiropractic interns were separated into 2 groups: an intervention group and a group trained with the standard curriculum. The intervention included a 60-minute educational session focused on targeting 100 N total peak force cervical manipulations on mannequins, with objective feedback through force-sensing table technology. Pre- and post-CMs were recorded on both a mannequin and a paired student partner, with an attempt to have a target total peak force of 100 N.

Results: Ninety students were recruited. The intervention group ($n = 46$) scored significantly better at the outcome compared to the control group ($n = 44$) when manipulating the mannequin ($p = .003$). These improvements did not carry over when manipulating a paired human partner ($p = .067$).

Conclusion: Following a 1-hour cervical SM educational intervention utilizing thrusting on mannequins and force-sensing table technology, students demonstrated improved peak force control for SM delivered on the mannequin. However, this improvement was not carried over to SM delivered on human subjects.

Key Indexing Terms: Spinal Manipulation; Mannequin; Chiropractic; Education

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INTRODUCTION

Spinal manipulation (SM) is a treatment used for a variety of musculoskeletal complaints.^{1,2} It is performed by healthcare practitioners such as chiropractors, physical therapists, and osteopaths. Cervical SM is focused on the C1-7 vertebrae and is beneficial in treating complaints such as neck pain and headaches.²

SM is defined as taking a joint to the end of its clinical range of motion and using a controlled impulse to move it just beyond its clinical range.³ This impulse is defined as a high-velocity low-amplitude force.⁴ The person performing the manipulation is required to control the impulse velocity, force, and directionality to deliver a skilled SM. A cervical SM is a complex motor skill that requires the doctor and patient to be positioned in asymmetrical postures. Appropriate bimanual control allows for a skilled transfer of force from the doctor to the patient.⁵

Research is available on effective strategies to enhance teaching and learning of SM.⁶ These strategies have included changing the learning structure; utilizing im-

mediate feedback tools, such as force plates or specially designed tools; or utilizing mannequins for practice.⁶ Recently, there has been work done examining the effect of utilizing a mannequin for cervical SM practice, which demonstrated positive effects in students' subjective scoring of cervical SM skills.^{7,8} However, this did not include any examination of effects on a learners' objective outcome measures.^{7,8}

Therefore, the goal of this study was to examine the effectiveness of a 2-hour instructional strategy utilizing Force Sensing Table Technology (FSTT; Canadian Memorial Chiropractic College, Toronto, Ontario) and Human Analogue Mannequins (HAM; Canadian Memorial Chiropractic College, Toronto, Ontario) on the ability of students to achieve a targeted peak force in cervical SM.

METHODS

Participants

Fourth-year students with prior experience using FSTT and HAM for thoracic spine and lumbar spine training in



Figure 1 - Cervical spine adjustment setup on the mannequin.

their clinical internship were recruited for this study. The inclusion criteria comprised students within the 4th year of their chiropractic college training who were comfortable with delivering cervical SM. Exclusion criteria comprised students who had medical conditions that prevented them from either delivering or receiving cervical SM or prior experience using FSTT and HAM for cervical SM. This project was approved by the Canadian Memorial Chiropractic College research ethics board (#142018).

Sample Size

A target of 40 students was required for both the control group and the intervention group. The sample size was calculated from sizes of the effects of quantitative feedback on the speed of delivering cervical SM.⁹ Using that information, Cohen's *d* was used to determine a final sample size of 40 students within the intervention group.

Apparatus

All data were captured using FSTT instrumented with a force plate (Advanced Mechanical Technology Inc, Watertown, MA) providing quantification of force-time profiles transmitted through the torso support section. Data collected were processed using MATLAB (MathWorks, Natick, MA). A custom foam HAM with anthropometrically consistent soft tissue compliance,¹⁰ anatomical landmarks, and a movable cervical spine served as a stand-in for live subjects during the intervention. The HAM was securely strapped to the force-sensing table with built-in seat belts, and an antislip mat was positioned between the mannequin and table. During the procedures on the mannequin, the head was lifted off the table to avoid any load sharing with the headrest portion of the table (Fig. 1).

Cervical Manipulation Procedure

The students were asked to complete lateral cervical SM with a target impulse peak force of 100 N. In this study, 100 N was selected as the target force for the lateral cervical SM, which was previously described to have a peak force of 102.2 N.¹¹ The lateral cervical SM was performed as described by Thomas Bergmann and David Peterson¹² with the adjustment titled index/pillar push.

The student placed the ventrolateral surface of the index finger of the hand corresponding to the side of segmental contact onto the articular pillar of the superior vertebrae. The other hand supported the contralateral occiput and upper cervical spine.¹² The head was rotated slightly away from the contact side while laterally flexing toward the side of contact with the thumb of the thrusting hand resting on the patient's cheek.¹²

Students were required to lift the patient's head off the table and make the appropriate contact. The student then applied a force laterally into the cervical spine until they reported having found the patient's preload point of tension. The preload was defined as the point where the student felt they had reached maximal displacement of the segmental contact using the least amount of force possible to reach that limit. At this point, the student was instructed to hold the preload until they heard a "beep," at which point they thrust laterally, attempting to reach the target force of 100 N. This procedure was utilized for human and mannequin trials.

Experimental Maneuver

Students attended the lab with their patient management team during a 2-hour scheduled learning time. The patient management teams consisted of 8–10 students who worked together for their final 6 months of training. These groups were assigned to either a control group or experimental group by availability of the instructors.

At the beginning of the lab, students were all asked to complete 4 lateral cervical SMs with a target force of 100 N. It consisted of 2 mannequin manipulations, one for each hand, and 2 patient manipulations, one for each hand. The experimental group then participated in a 1-hour lab focusing on lateral cervical SM exclusively on the mannequins. In the session, the manipulation was broken down into separate parts, such as contact, finding preload, and the thrust. The session was structured so that the students would rotate their practice attempts to ensure each student had a similar number of practice manipulations. The instantaneous objective feedback allowed students to understand if they were near the target force of 100 N and subsequently given strategies to refine their ability to deliver the appropriate force. After the lab was concluded, the students were asked to deliver the same 4 thrusts from the start of the lab with a target goal of 100 N.

Control Group

The control group participants were asked to deliver the same 4 manipulations blinded to the knowledge of performance. However, instead of participating in a lab receiving feedback, they were instructed to return to their regular learning. Regular learning consisted of a technique practice session with only observational feedback from the tutor available, without the use of force-sensing technology. Ninety-minutes later they were asked to return and complete the same 4 manipulations.

Data Analysis

The raw data collected from the FSTT was digitized with MATLAB. Every recorded thrust was manually

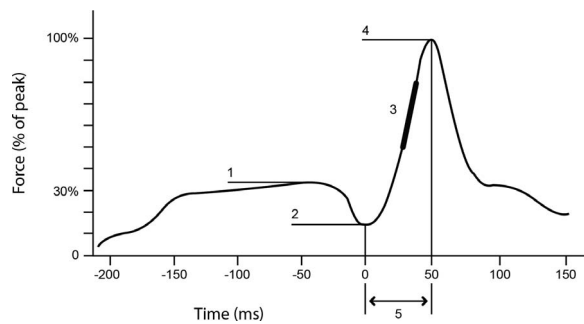


Figure 2 - Graph of a SM force profile. 1 = preload, 2 = dip in preload, 3 = rate of rise, 4 = peak force.

cursed by a single investigator. The points selected included preload levels, dip in preload, peak force, and return to rest. These points then gave the values for preload, peak force, and rate of rise (Fig. 2). The outcome measure utilized to assess distance from target force was the absolute value of the constant error, which gives the distance from the target regardless of the direction, which was previously done in SM education research.^{13,14} The data were analyzed using analysis of covariance to assess any differences between the groups.

RESULTS

Ninety students were initially recruited for the study (44 in the control group and 46 in the intervention group). There was 1 dropout from each group due to time constraints and an inability to complete the lab. Twelve samples were corrupted in the process of data collection (5 in the intervention group and 7 in the control group). In the end, there were 40 sets of complete pre-post data in the intervention group and 36 sets in the control group that were analyzed (Fig. 3). There was no difference found in the baseline values for preload force, time to peak, or peak force for the control and intervention groups (Table 1).

The results for the manipulations completed on a mannequin subject are displayed in Figure 4 and for the human thrusts in Figure 5. The manipulations performed on the mannequins demonstrated a significant difference ($p = .003$), with the intervention group -22.7 N closer to the target force compared to the control. The control group had a nonsignificant difference ($p = .67$), with the postsession manipulations ending farther from the target force by 6.7 N. These results are displayed in Figure 4. The manipulations completed on the human subjects did not display a significant difference between the intervention

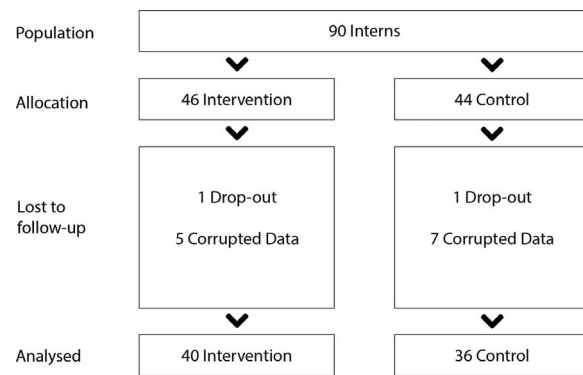


Figure 3 - Recruitment and allocation of participants.

group and control group with regard to mean error away from target force. These results are displayed in Figure 5.

DISCUSSION

This study demonstrated that it is possible to utilize immediate feedback to help students control their peak forces with lateral cervical SM. This is similar to previous research for improved outcomes associated with using Dynadjust tools (LaBarge Inc, St. Louis, MO) for cervical manipulation as well as force-sensing technology for thoracic manipulation.^{8,15,16} This study is unique in that the improvements in peak force control on the mannequin thrusts did not carry over to the human SM. Previous studies had differing methods on how to improve SM. The only study that investigated the effectiveness of force-sensing technology on cervical SM utilized a Dynadjust for its practice.⁸ This needed neither a force table nor a mannequin and instead used a tool that indicates if the student was successful in achieving the targeted force. Their outcomes were measured on the same tool. The other research focused on thoracic spine manipulations and FSTT. It has methods similar to this study; however, it used mannequin manipulations for outcome measures.

There are several possible explanations for why this improvement did not carry over to manipulations on human participants. These reasons include that the mannequins may transmit forces to the force plates differently than does a human, the testing environment may have added additional stress, the students may not have felt confident to thrust at the practiced level, or this intervention did not improve participants' skills for manipulating human patients.

When looking at the raw data of all participants, there was a trend that each individual's force of a manipulation on a human was approximately 50% that applied to a

Table 1 - Baseline Values for Preload and Peak Force

Outcome	Control Group (SD)	Intervention Group (SD)	p Value
Preload on human, N	10.4 (9.8)	12.7 (10.1)	.32
Preload on mannequin, N	22.9 (26.4)	18.8 (18.3)	.43
Peak force on human, N	46.9 (27.5)	48.5 (23.4)	.78
Peak force on mannequin, N	123 (51.1)	125.9 (54.2)	.81

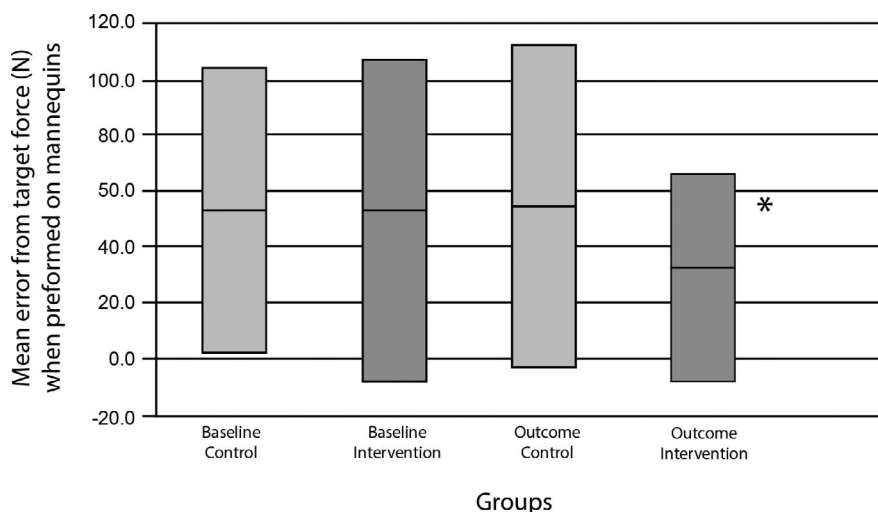


Figure 4 - Peak force error for SM delivered to mannequins.

mannequin. This issue has previously been seen in pediatric mannequins that have forces underreported by factors of 2–3.5.¹⁷ This led the investigators to hypothesize that there may be a force transmission difference when thrusting on the human or the mannequin. Since the lab allowed the participants to practice only on the mannequin, the force recorded on the human thrusts would not improve.

The second possible explanation for the difference in peak forces from mannequins to humans is the participants' reluctance to thrust on a human subject. These participants were selected due to their previous experience with utilizing SM on patients. This was to lower the chances of a participants' reluctance to use the appropriate amount of force on a human subject. This may not be the case with the consistent lower forces found in the human thrusts. Future directions with the research could focus on the addition of a qualitative component to cervical SM. This could examine the learners' view on delivering SM at the suggested force as well as any apprehension that they may be feeling.

The third possible explanation for the difference in peak force is that the system used in this study measured transmitted forces through the neck and not those that were applied to the neck. It is possible that the applied forces could have been consistent on both mannequins and human subjects, but the forces measured by our system (transmitted forces) were different because of a difference in the forces retained by the mannequins and human subjects. Forces most likely do not transfer to the table in the same way through the mannequin as they do for humans. Future research should investigate the differences in applied versus transmitted loads.

The final explanation includes that this intervention does not carry over from practice to manipulation on a human patient. Other research in learning SM has demonstrated a positive effect of mannequin practice and real-time feedback, individually, on cervical SM. The utilization of a practice mannequin demonstrated that there is no negative effect on subjective marking of cervical SM.^{8,18} However, it did not evaluate the biomechanical

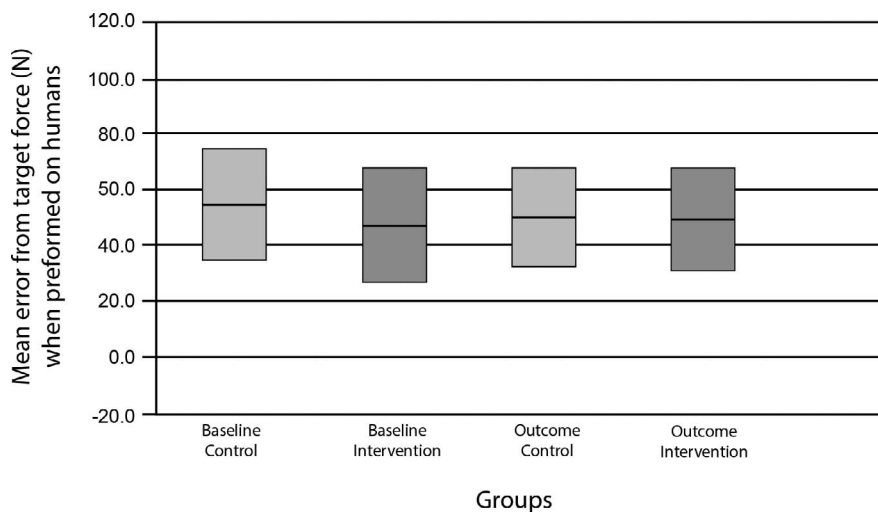


Figure 5 - Peak force error for SM delivered to humans.

parameters of the thrust itself, while the utilization of real-time feedback from inertial sensors demonstrated a decrease in thrust angular velocity.¹⁹ Therefore, there needs to be additional research in the disparity of this paper and other research.

Future research should include exploring the consistent difference in mannequin and human SM peak force transmitted through the thoracic spine. This could include the addition of a direct measure of force at the cervical spine as well as the assessment of student feedback or confidence with the manipulation. Finally, this investigation explored only the short-term effects of the intervention. Longer term follow-up will be needed to assess if the intervention makes a sustained change in the learners' SM skill.

This study has limitations. First, there was a lack of an independent measure of input forces during data collection as the study relied on the transmission of force from the cervical spine to the thoracic spine. Second, this was a novel experience for the tutors involved in the study as this study was a modification of a previously successful education intervention that focused on the thoracic spine utilizing practice to develop student SM skill. Finally, during the 60-minute intervention, the control group returned to their regular learning of technique practice without the use of force-sensing technology. Future studies can specify regular technique practice focusing only on the manipulation being examined in the study to exclude any variable changes that might arise simply due to the learned psychomotor response.

CONCLUSION

Following a 1-hour cervical SM educational intervention utilizing thrusting on mannequins and FSTT, students demonstrated improved peak force control for SM delivered on the mannequin. However, this improvement was not carried over to SM delivered on human subjects. Further research is needed to assess the reason for the lack of change for human thrusts.

FUNDING SOURCES AND CONFLICTS OF INTEREST

Dominic Giuliano and David Starmer have a patent for the Manipulative Treatment Training System and Method and Mannequin Therefor, which are licensed and issued to Canadian Memorial Chiropractic College. Dominic Giuliano and David Starmer are listed as inventors of intellectual property (FSTT and HAM) used in this study. All rights of patents and intellectual property are assigned to CMCC, and they share no financial interest in the revenues generated from sales.

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Author Contributions

Concept development: SAD, DAG, DJS. Design: SAD, DAG, DJS. Supervision: DAG, DJS. Data collection/processing: DAG, DJS. Analysis/interpretation: SAD. Literature search: SAD. Writing: SAD, JBP. Critical review: SAD, DAG, DJS, JBP.

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