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The evolution of teaching chiropractic manual skills: part 2 – a narrative review and discussion of the impact of research evidence authored by faculty of the Canadian Memorial Chiropractic College

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The objectives of this article, Part 2 of a two part series, are twofold: (i) To provide a narrative review of the research evidence authored by faculty of the Canadian Memorial Chiropractic College (CMCC) and; (ii) discussion of the impact this research evidence had on teaching chiropractic manual skills at CMCC and – theoretically - to the broader chiropractic educational community. Research evidence discussed are in the areas of: Experimental studies linked to biomechanics; Measuring Force – Integration of Force Sensing Table Technology (FSTT®) into technique labs; Characteristics of injuries sustained by chiropractic students during technique labs; Finding

L'évolution de l'enseignement des compétences manuelles en chiropratique: la deuxième partie - examen narratif et une discussion de l'impact des données probantes de recherche rédigées par le corps professoral du Canadian Memorial Chiropractic College

Les objectifs de cet article, la deuxième partie d'une série en deux parties, sont doubles : (i) fournir un examen narratif des données probantes de la recherche rédigées par le corps professoral du Canadian Memorial Chiropractic College (CMCC) et; (ii) discuter de l'impact de ces données probantes de la recherche sur l'enseignement des compétences manuelles en chiropratique au CMCC et - théoriquement - sur la communauté éducative en chiropratique plus large. Les preuves de recherche qui ont fait l'objet de discussions portent sur les domaines suivants : Les études expérimentales liées à la biomécanique; la mesure de la force - L'intégration de la Technologie de la table de détection de force (FSTT®) dans les laboratoires de techniques; les caractéristiques des blessures subies par les étudiants en chiropratique pendant les laboratoires de techniques; trouver la cible clinique pour l'intervention thérapeutique et; les recommandations

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the clinical target for therapeutic intervention and; Recommendations toward a model technique curriculum. The intent of this article is for faculty at current and future accredited educational programs to incorporate this research evidence into their technique curricula and to potentially strengthen the pedagogical approach used to teach chiropractic manual skills.

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KEY WORDS: chiropractic manual skills, biomechanics, student injuries, site of care, Force Sensing Technique Tables ®

pour un programme de technique modèle. L'objectif de cet article est que les professeurs des programmes d'enseignement accrédités actuels et futurs intègrent ces données de recherche dans leurs programmes d'études techniques et renforcent potentiellement l'approche pédagogique utilisée pour enseigner les compétences manuelles en chiropratique.

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MOTS CLÉS : compétences manuelles en chiropratique, biomécanique, blessures des élèves, site de soins, la Technologie de la table de détection de force ®

Introduction

Starting from the early 19th century, four factors influenced the development of the chiropractic profession: the bonesetters of Europe (which gave chiropractic its method), magnetic healing (which gave chiropractic its original theory), popular health reform and orthodox science.[1] Starting in the late 1890s, these factors would influence the curriculum at the Palmer School of Chiropractic (PSC) and be further undergirded by the theories developed by its founder, Daniel David (DD) Palmer and later by his son Bartlett Joshua (BJ) Palmer who assumed ownership of PSC in 1906.[2] Over the next 50 years, new theories, often based on research evidence, would emerge, leading to curricular changes not only at PSC but also at the myriad of other chiropractic educational programs that opened – some still in existence today - each with their own ideological view and distinctive cultural approach to chiropractic.[3]

Founded in 1945, the Canadian Memorial Chiropractic College (CMCC) has undergone several ideological and cultural changes, reflected in changes in its curricula over the decades.[4] Starting in either the late 1970s or mid 1980s, the authors of this study witnessed many curricular changes first-hand as students and later as CMCC technique faculty. During their collective 120 years as faculty in the 'technique trenches' at CMCC they and many other faculty members published research evidence that directly led to curricular changes as to how chiropractic manual skills were taught to students.

Part 1 of this two Part 2 series provided a narrative review of the evolution of teaching and evaluating chiropractic manual skills as chronicled by the same authors as this study.[5] The objectives of this study - Part 2 of the two part series - are to: (i) provide a narrative review of the research evidence authored by faculty at CMCC germane to teaching and evaluating chiropractic manual skills and (ii) discuss the impact of this research evidence had, continues to have and may theoretically have on teaching manual chiropractic skills at CMCC and, theoretically, at the broader chiropractic educational community.

To achieve these objectives, topics discussed in this article are: *Experimental Studies Linked to Biomechanics*; Measuring *Force – Integration of Force Sensing Table Technology®* into *technique labs; Characteristics of injuries sustained by chiropractic students during technique labs; Finding the Clinical Target – The Site of Care Study* and; *Recommendation Toward a Standardized Chiropractic Technique Curriculum.*

Methods

For this narrative review, articles had to meet the following inclusion criteria:

> (i) Research evidence published by authors while faculty at CMCC; (ii) research evidence published in indexed, peer-reviewed journals or presented at national or international conferences and (iii) research evidence that directly impacted teaching chiropractic manual skills at CMCC or that may

theoretically impact teaching chiropractic manual skills to the broader chiropractic educational community. Since no human subjects were involved in this review, ethics approval was not required.

Results

(i) Experimental studies linked to biomechanists

In the late 1990s Kim Ross, then chair of the technique department at CMCC and CMCC faculty member David Bereznick began a PhD program in biomechanics under the supervision of esteemed biomechanist Dr. Stuart McGill from the University of Waterloo. They sought to apply the laws of biomechanics to established chiropractic ideological hegemony, focusing on: the validity of motion palpation to identify dysfunctional vertebral segments requiring manual therapy; the necessity to optimally apply manipulative forces in a particular direction (line of drive) based on the location of a targeted vertebral segment and; the ability of a practitioner to target a specific vertebral segment during high velocity, low amplitude spinal manipulative therapy (HVLA-SMT).

Facet asymmetry

There are many diagnostic procedures chiropractors use to select the clinical target (synonyms include subluxation, joint dysfunction, manipulable lesion and many others[6]) for clinical intervention. Among these methods motion palpation (MP) is one of the most commonly used. MP is predicated on the assumption that the bony architecture on the left side of a joint is sufficiently symmetric to the right, such that the same force would be needed to move one segment relative to the other. If the examiner perceived the forces needed were different to move a vertebral joint from one side to the other, they would conclude that segment required a manual procedure (e.g., mobilization or spinal manipulation) to re-establish optimal joint motion.

It has been well established that motion palpation lacks reliability, calling into question it's clinical usefulness.[7] What has been investigated to a much lesser degree is the validity of motion palpation with respect to identifying vertebra requiring manipulation to restore normal motion. The assumption is that any perceived restrictions in joint motion would be amenable to HVLA-SMT; however, if facets are indeed asymmetrical, then the anatomical asymmetry would contribute to apparent restrictions in motion during palpation, negating the need for therapeutic intervention.

Furthermore, it had been well established that facet asymmetry at C1-C2 was the rule rather than the exception, but it was unknown if that asymmetry was sufficient to affect the forces needed to move one segment on the other. Ross, Bereznick and McGill theorized they would. To test this underlying theory, they examined six cadaver specimens to determine if the asymmetry would result in an asymmetry of forces required to move C1 laterally on C2.[8]

As they theorized, the facet with the steeper angle resisted lateral translation more so than a shallow angle. As an example, the right facet would resist the C1 from translating to the left if the angle was relatively steeper and the left facet would offer less resistance to right lateral translation if the angle was relatively more shallow. Hence, they concluded, when a clinician is challenging vertebrae to the left and the right *in vivo*, any differences felt may in fact be due to different facet angles rather than the presence of a reversible fixation reducible through manipulation. Furthermore, the facet angles vary greatly from individual to individual.[8] This meant a clinician could not know if resistance to MP is caused by anatomy or by joint fixation.

Line of drive

For many years it was traditional to instruct CMCC students and, based on the authors' experience with the Technique Consortium, students at other chiropractic programs[5] to thrust along the joint planes (angulation) while performing prone thoracic HVLA-SMT. For the upper thoracic region students were instructed to thrust straight down (posterior to anterior) and for the lower thoracic region they were instructed to thrust headward at a 45° angle.

Using specialized equipment to test if this was the most effective way to adjust a person's thoracic spine ('most effective' in terms of maximizing the force transmitted from the doctor to the patient) the researchers reported that the skin-fascia interface over the thoracic spine exhibited negligible friction, meaning the only forces transmitted to the targeted vertebrae are those applied perpendicular to the surface.[9] From a clinical perceptive, this meant it would be ineffective to thrust in any direction other than perpendicular to the surface. If a chiropractor thrusted cephalad as they had been taught to do, it merely tugged the skin which would, in turn, move the entire body and give the illusion that forces had been translated to the patient. That being said, a slight cephalad force was required to remove the skin slack - otherwise it was difficult to maintain a static contact during the thrust because the doctor's hand and patient's skin could slide as a unit to the point where the doctor would no longer be over the intended target (Ross- personal communication).

A frictionless skin-fascia interface also meant that the ability to 'hook' a thoracic transverse or spinous process in the superior-inferior direction during HVLA-SMT may be greatly over-rated. In practical terms, this meant students ought to be instructed to only thrust perpendicular to the surface during prone thoracic adjustments to optimally transmit the forces they generated.[9] The research emphasized that if the doctor thrusts perpendicular to the surface of the skin, the vertebrae would not travel cephalad, since it would follow the facet surfaces, not unlike a train on its tracks. (Ross – personal communication)

Target specificity

A third study authored by Ross, Bereznick and McGill investigated the ability of doctors to specifically cavitate a contacted vertebral segment during thoracic HVLA-SMT and during side posture lumbopelvic manipulation (SPLM).[10]

Sixty-four asymptomatic participants received HLVA-SMT delivered by 28 different chiropractors (including many CMCC technique tutors). Based on data collected by accelerometers secured to the participant's skin that calculated the distance between the source of vibration from the cavitation site to the target location, the researchers' reported cavitation was at least one segment away from the target during thoracic HVLA-SMT or SPLM, with a range of 0 to 14cm. The site of cavitation during thoracic HVLA-SMT was also found to be distant from the point of contact with the doctor accurately hitting their target slightly more than half the time.[10]

How then to increase the likelihood of cavitating the targeted joint? Simply put, the biomechanists recommended the more joints that cavitate the greater the probability that the targeted joint would cavitate as well.[10] Looked at another way, if it is important to cavitate the targeted joint, the best strategy is to cavitate multiple joints since the targeted joint would cavitate by default.

It would appear that manipulating the targeted joint may not matter with respect to patient outcome. A systematic review by Sorensen *et al*.[11] concluded: "Targeting a specific vertebral level when administering SMT for patients with nonspecific low back pain did not result in improved outcomes on pain intensity and patient-reported disability compared to a nontargeted approach."[11p39] The caveat to this conclusion is it is unknown that, even if a particular vertebra were targeted, it experienced the forces delivered. To do so, a study would require the technology developed by Gregory Cramer, Dean of the Department of Research at National University of Health Sciences to determine which joints gapped (discussed below).

Refractory period following cavitation

Bereznick, Ross and CMCC technique tutor Gary Pecora investigated other presumptions related to HVLA-SMT. They investigated the '20 minute refractory period cavitation rule', which stated a joint could only 're-cavitate' after a 20 minute pause.[12] Put succinctly, they discovered that the refractory period was quite variable but was subject specific.

Quantifying joint gap during SPLM

Using magnetic resonance imaging (MRI), Cramer, Ross and their colleagues sought to quantify the amount of joint gap during SPLM.[13] They discovered that the joints on the upside were the ones that gapped the most and using accelerometer technology developed by Ross, they determined that these joints were the ones that cavitated.[13]

One may ask: Why all the focus on cavitation? In the authors' experience, it is because technique tutors and students alike consider cavitation to be the hallmark of manipulation success. This of course is a contentious issue. As mentioned above, a recent systematic review concluded that the audible pop (cavitation) does not appear to be related to successful manipulation if success is considered to be a reduction in pain.[14]

(ii) Measuring force – force sensing table technology®

Despite the best efforts of technique faculty, they are unable to accurately judge the force a student generated during HVLA-SMT by observation, a key subskill graded during technique testing.[5] A method was therefore needed to (i) augment a students' ability to consistently generate sufficient force for HVLA-SMT (ii) instruct students how to modify forces generated during HVLA-SMT as clinical circumstances dictated and (iii) provide a valid method for faculty to grade forces students generated during technique testing.

Various types of transducers, used to measure force, had been used in research studies for many years, and entrepreneurs had attempted to harness this technology for teaching purposes. One early entrée was the Dyna-Adjust, a 12-inch cylindrical metal device containing instrumentation that could measure the users' force and speed produced by OrthoNeuro Technologies.[15] The data could be coded such that an individual user could access their performance.

Jay Triano, then Dean of Graduate Education and Research at CMCC, Ross and CMCC technique tutor Brian Gleberzon (who became chair of the technique department after Ross) were involved in research studies investigating the potential teaching benefits of using the Dyna-Adjust in technique class, which also included creating a revised version of the CMCC technique manual (discussed in Part 1[5]) using the device.

Unfortunately, the results from the in-class studies indicated students did not improve their manual skills using the device. A significant confounding factor was the way the study was designed since it used an early version of a force sensing table that compromised students' ability to perform HVLA-SMT. As an example, students could not contact the patient's upper torso during SPLM as is customary; instead, they had to contact a metal arm of the table. The data was also compromised if the student bumped into the table, requiring the student to step away from the table when performing HVLA-SMT.

According to the study protocols, students only used the device twice - once at baseline and once after several weeks of practicing; however, students did not practice using the force sensing table, meaning they were not able to become comfortable with the limitations in performing SMT required. The study's results, along with concerns about the cost of the device and accompanying software, led to project being abandoned, at least at CMCC.

In 2009, the Higher Education Quality Council of Ontario (HEQCO) issued a request for proposals that focused on innovative technology and its use in classroom setting.[16] The goal was to provide academic institutions with an opportunity to evaluate the effectiveness of pedagogical approaches that aim to enhance the quality of student learning through the introduction and integration of new technologies. Through the auspices of the Knowledge Infrastructure Program (KIP) of Industry Canada, as overseen by the Ministry of Industry and in consultation with the Minister of State (Science and Technology), CMCC received a grand that established its simulation ('sim') laboratory. There were two components to the 'Sim lab'; one was the use of computerized and interactive mannequins that could be used in various real-life scenarios (i.e., patient emergencies such as heart attack or diabetic comas) and the other was the use of mannequins for Force Sensing Tables (FSTT®).[16]

Developed by Triano, FSTT® are standard chiropractic tables that are specially equipped with force plates that record force-time profiles which are projected onto a computerized screen immediately after the delivery of each procedure, providing objective and quantifiable real time feedback (Figure 1). Rather than thrust on the table or on each other, students perform HVLA-SMT on specially designed mannequins that are positioned on the FSTT®. Students received instructional training using the FSTT® during lab sessions outside of regular technique laboratory times. The intent of implementing FSTT® into the curriculum was to provide students with an opportunity to rehearse the application of manual skills on mannequins prior to (or in addition to) progressing to volunteer subjects (i.e., other students), especially since there a number of studies that have demonstrated chiropractic student are commonly injured during undergraduate technique training, as discussed below.

With respect to quantitative outcomes, on average, the cohort of students using the FSTT® achieved statistically significant gains in force amplitude and speed by the end of a two-hour session. In addition, learners who did not obtain notable changes during FSTT® labs were self-motivated to voluntarily participate in unscheduled lab sessions and, upon re-evaluation, were found to achieve gains in performance compared to their peers. Most importantly, these gains in performance were sustained through a seven-month (for Year II students) and five-month (for Year III students) interval between FSTT® sessions, as determined by formative assessment.[16] Lastly, FSTT® users were found, on average, to be able to achieve statistically significant modulations of forces on demand.[16]

With respect to qualitative outcomes, students' ratings of their confidence and competence in performance increased during the final year of training.[16] A similar study

Figure 1.
Force Sensing Table Technology ®

involving students in all three technique classes found they perceived themselves to be more competent to deliver the cross bilateral adjustment after FSTT® sessions, with more senior students reporting the highest level of self- perceived competence.[17]

A companion study sought to determine what method of teaching FSTT® would result in the most optimal classroom experience for students.[18] For this study, 'structured FSTT®' classes, during which students were assigned designed times and tasks to use the FSTT® was compared to an 'unstructured FSTT®' class system, during which students could use the FSTT® at will. All students receiving 'structured FSTT®' training during technique labs perceived class time to be the most efficient. This effect was most pronounced among Year I students.[18]

A slew of studies has been published investigating the FSTT® on topics as diverse as clinical outcomes, education, biomechanics and basic sciences.[19] Examples include: the ability of first year CMCC students to retain the ability to modulate forces generated SMT using FSTT® after a 12 week detraining period[20]; the ability of experienced clinicians to be taught to recalibrate the peak forces generated for children using mannequin simulators[21] and; improved peak-force control demonstrated by students on mannequins following a one hour training session using FSTT®.[22] Although beyond the scope of this study, the authors encourage academics, researchers and other subject matter experts undertake a narrative review of the research evidence pertaining to FSTT® to share with the broader healthcare educational community.

Lastly, since the mid 2010s, CMCC has marketed FSTT® to other programs that teach psychomotor skills. To date, 21 educational programs have purchased FSTT® throughout North America as well as the United Kingdom, France and Australia.[23]

(iii) Characteristics of injuries sustained by chiropractic students during technique labs

It was widely acknowledged that students were injured during technique class. This was not surprising since novice students were repeatedly applying several hundred Newtons of force to essentially healthy (e.g., fully functional) joints during technique labs. But the characteristics of these injuries (e.g., frequency, location, duration, sequelae) were unknown.

To investigate whether students were injured during technique class and, if they were, what were the characteristics of these injuries, Gleberzon spearheaded a cross-sectional retrospective cohort study that administered a unique survey to undergraduate CMCC students during class time.[24] The survey was unique in the sense that a review of the literature revealed this would be the first research project of its kind.[24]

The study was approved by CMCC's Ethics Review Board. Students were assured their responses would be anonymous. In addition to gathering basic demographic data (age, gender) students were asked to indicate if they had been injured during technique class. If the answer was 'yes', they were asked where they were injured (e.g., what region of their body), the symptoms they experienced (e.g., sharp pain, dull or achy pain, numbing, tingling), how severe it was (e.g., mild, moderate, severe), how long it lasted and what treatment, if any, they sought out. They were also asked to indicate which year of study they were in when they were injured.[24]

Overall, 55% of students reported being injured during technique class, the same frequency patients report being injured after their first chiropractic treatment.[25,26] The majority of injuries (62.6%) were described as light to moderate in intensity, lasting less than 72 hours (66.5%). The most common anatomic location of injury was the low back (35.0%) followed by the cervical spine (27.5%). Most students (59.0%) reported being injured during their second year of study – not surprising since that is when they were first introduced to cervical and lumbopelvic manipulation. 55% of student did not seek any care for the injury.[24]

Gleberzon approached colleagues at other chiropractic programs to administer the same survey to their students. His colleagues informed him they were not permitted to do so because administrators feared the potential political fallout if the results at their programs were the same as at CMCC. Even so, representatives at four chiropractic programs were willing to participate in the project. The data from those chiropractic programs were very similar to the data we collected at CMCC.[27]

Over the next few years, a number of other studies characterizing student injuries at other chiropractic programs were conducted and published[28-31] with results mirroring those from CMCC. Some of those studies addressed an oversight in our original study and asked respondents if they were the 'doctor' or the 'patient' when they were injured. Most commonly the person injured was the 'doctor', most commonly delivering a SPLM.

Finding the clinical target – the site of care study

In 2006 Triano and Brian Budgell, the Director of Life Sciences Laboratories at CMCC, were asked to lead a study that sought to assess the evidence investigating the validity of the various methods manual therapies such as chiropractors use to determine the clinical target for therapeutic intervention, such as HVLA-SMT.[32] Research participants ranked the quality of evidence using the QUADAS (Quality Assessment of Diagnostic Accuracy Studies) checklist for validity and the QAREL (Quality Appraisal of Reliability Studies) checklist for reliability, as appropriate. Once the data was extracted and synthesized, the studies that met the inclusion criteria were evaluated in terms of their 'strength of evidence' and the degree to which the method under investigation was favoured for clinical use.[32]

The researchers agreed the quality of evidence was high for pain provocation, postural asymmetry, range of motion, certain specialized tests, thermography of lower limbs in confirming frank sciatica and the recommendation was favorable for all of them, meaning they was deemed a valid method of finding a clinical target.[32]

Conversely, many of procedures such as leg length analysis and manual muscle testing had mixed results, whereas x-ray line marking had a high level of evidence that concluded it was not a valid method to find a clinical target.[32] As one might imagine, this did not go over well with a substantial segment of the profession, especially those who use Gonstead, Upper Cervical or Chiropractic Biophysics/ Clinical Biomechanics of Posture protocols.[6]

Recommendation toward a standardized chiropractic technique curriculum

Starting in 2014, Cooperstein, Christopher Good, Christopher Roecker, Charles Blum – all technique faculty at American chiropractic programs - and Gleberzon convened four facilitated workshops at ACC-RAC with the objective of developing a standardized chiropractic technique curriculum[33] using a modified Nominal Group Technique protocol.[34,35]

Based on the best available evidence, including the 'site of care' study[32] they sought consensus opinion from workshop participants as to which diagnostic and therapeutic procedures ought to be included in a standardized chiropractic technique curriculum. Where evidence was lacking, participants agreed a procedure must have, at a minimum, face validity and biological plausibility for it to be included in a technique program.[33]

With respect to diagnostic procedures, workshop participants reached consensus that chiropractic students should be taught to use postural assessment, gait analysis, palpation (static, motion and joint play analysis), global ranges of motion, and evidence-based orthopedic/neurological tests. No consensus could be reached with respect to the use of x-ray line marking (spinographs) for the purpose of identifying a clinical target (especially serial or repeated x-rays), although there was agreement a baseline x-ray during patient intake was reasonable to screen for various pathologies.[33]

For therapeutic procedures, all participants agreed the following should be taught soft tissue therapy (both manual and instrument assisted); mobilizations and HVLA manipulation of the spine and peripheral joints; handheld instrument-assisted adjusting (i.e., Activator); pelvic blocking and; use of drop piece and flexion-distraction tables.[33]

Discussion

The studies included in this narrative review have had either a direct or theoretical impact on teaching chiropractic manual skills within CMCC and in the broader chiropractic educational community.

Curricular revisions at CMCC

Prior to 2000, courses that taught students 'biomechanics' principally focused on the functional anatomy of joints of the spine and peripheral joints. When Ross and Bereznick completed their PhDs and returned to the faculty at CMCC around 2000, these courses were revised to include instruction on what they characterized as 'hard core biomechanics', teaching concepts such as moment arms and resultant force vectors, concepts that had hitherto never been taught. Over the years, instruction in these courses were transferred to then-CMCC faculty Steven Lester and, more recently, to CMCC faculty member Simon Wang.

The five principles of achieving cavitation

As is often the case in science, the findings from the research evidence linked to biomechanists led to other discoveries that culminated in the 'five principles to successfully produce cavitation during SMT', developed by Ross (Figure 2).

Principle 1. Shorten moment arm on doctor.

It was found that it was the magnitude of the moment applied to the patient, rather than the magnitude of the force, that resulted in cavitation (see text box below). Thus, students were recommended to increase the moment arm on the patient to increase the moment. However, the moment arm on the doctor needed to be shortened to reduce the deleterious effects of the moment on the doctor's shoulders. Hence students were recommended to mimic a 'T Rex' posture when learning SPLM. A collateral benefit was, by keeping the arms as close to the body as possible, it was postulated the doctor was less likely to injury the shoulder of the thrusting arm.

Text box:
Moment of force is a measure of its tendency to cause a body to rotate about a specific point or axis.

Principle 2. Lengthen moment arms on patient

Using slow motion video-analysis of the tutors as they performed SPLM, it was discovered they all impacted the patient's upside buttock or thigh with their own hip or

1. **Shorten moment arms on doctor** (T-Rex) – keep the body directly behind the contact hand/impact region of the doctor and keep the arms close to the body, like a T-Rex. This reduces the counter moment seen by the doctor's joints. This in turn increases energy efficiency and protects the doctor.
2. **Lengthen moment arms on patient** (Use thigh, knee) – utilize long moment arms of the patient when attempting to create a moment/torque. Impact the doctor's body along the thigh/knee during side posture lumbar manipulation to produce the required moment, thereby decreasing the force needed (increasing patient comfort).
3. **Use momentum of doctor and patient** (Drop, don't stop) – when the doctor starts to move, momentum is built up. Transfer this momentum to the patient, to produce the required force. If the doctor hesitates during the maneuver, he/she loses their momentum.
4. **Use impact whenever possible** (Drop and impact) – if the doctor's body collides against the patient's body, then maximum energy can be transferred. This produces the required force for the manipulation without relying on large amounts of muscle force. This in turn can reduce the doctor's muscle fatigue and injury risk.
5. **Minimize energy leaks through doctors' joints** (Tighten core and say "BAM" or "POW"). As momentum is built up by the doctor and impact is made onto the patient, the momentum needs to be transferred. If the doctor does not contract their core and shoulder muscles, the built-up momentum will be transferred to the doctor's upper body instead of the patient. Energy (momentum) is then not transferred to the patient and is essentially lost/leaked.

Figure 2.
Five principles to successfully produce cavitation during SMT

thigh. The impact is analogous to what happens when one billiard ball hits another billiard ball, where the impacted ball almost instantly accelerates to the velocity of the impacting ball, in accordance with Newton's First Law of Mechanics. Hence, it is easier to overcome the inertia of the patient's body weight if the doctor generates momentum and transferred it to the patient by impact, rather than the doctor essentially standing still and trying to deliver HVLA-SMT to the patient relying only on upper body strength. Ross and his colleagues investigated this principle and concluded that force ought to be generated by the doctor impacting the patient rather than by using the doctor's hand alone. They found that cavitation would *not* occur if more than 25% of force was solely generated by the doctor's hand. Or, looked at another way, cavitation *only* occurred when less than 25% of force was delivered directly to the vertebra itself by hand. (Ross- personal communication)

Principle 3 - Use of momentum of doctor and Principle 4 - Patient and use of impact whenever possible

Another strategy to improve the likelihood of cavitation is to use momentum of the doctor/patient unit. To accomplish this, the doctor starts by initiating the movement of the patient, and then applies the actual thrust when joint slack has been reached. The thrust would primarily be generated by the aforementioned impact. It must be emphasized, however, that these two principles are neither necessary nor recommended in situations where the patient is much smaller (such as a child or infant) than the doctor.

Principle 5. Minimize energy leaks through doctors' joints

In circumstances where impacting the patient during SPLM was deemed optimal, it is critical to 'stiffen' the trunk of the doctor so that the impact does not result in deformation of the doctor. This can be achieved by tightening the doctor's core muscles. This stiffening removed what were termed 'energy leaks' – the loss of generated force or energy - allowing for the force generated by the doctor to be optimally transferred to the patient, increasing the likelihood of cavitation.

Inclusion of Force Sensing Table Technology® into the undergraduate curriculum

Part 1 of this series described the evolution of teaching and testing manual skills at CMCC over the years.[5] As the data emerged demonstrating students accrued technique skills faster with the use of the FSTT® than without it, and that these skills were retained even after a period of no instruction, the FSTT® was included during technique classes and during technique testing. Currently, students are provided 6 lab experiences that focus on prone thoracic, supine thoracic, side posture, cervical-thoracic, lower cervical and upper cervical procedures.[36]

Bearing in mind FSTT ® has now been included in 21 other accredited chiropractic educational programs, it is reasonable to theorize its use has had a significantly positive impact on teaching technique at those programs as well.

Student injuries during technique class

Recognizing the frequency of injuries among students during technique class, and based on the experience Gleberzon had while visiting another chiropractic programs as chronicled in Part 1 of this series[5], CMCC student were required to read and sign an 'acknowledgment of risk' form prior to beginning technique classes in the undergraduate program, starting in 2018. This form was quickly expanded to include other courses with instructional laboratories that could potentially result in student injuries, namely orthopedics, clinical diagnosis and anatomy.

A study protocol for a randomised clinical trial (RCT) investigating if a strength and conditioning program can prevent the injuries chiropractic students commonly experience during technique training has recently been published.[37] At the time of this writing, no further information on the status of this RCT is available.

Diagnostic procedures

Since CMCC did not teach leg length checking, x-ray line marking to either identify subluxation or to calculate a uniquely appropriate line of drive to correct it, or procedures favoured by specific chiropractic technique systems, the results of the site of care study pertaining to those diagnostic procedures were inapplicable.[32] It is unknown if the site of care study had any impact on those chiropractic educational programs that do teach those diagnostic procedures.

Combing the results of the 'facet asymmetry'[8] and 'site of care'[32] studies CMCC students were taught that selecting a clinical target should not only rely on where the spine feels most restricted; rather, students should rely on both joint restrictions and pain on palpation (tenderness), especially bearing in mind the spine should not be overly tender.

Furthermore, If the site of contact of the doctor's hand was too tender for the patient, students were instructed it was rational to move the contact to a less tender region because the vertebra under the contact was no more likely to cavitate than those somewhat remote from the site. Finally, the students were taught to thrust perpendicular to the surface of the patient's spine when appropriate.

The authors of this study observed these instructions often resulted in friction between some technique faculty. Based on their clinical experience, some technique faculty found the use of motion palpation in the absence of pain provocation to be a good indicator of where to direct therapy and taught students in their technique groups accordingly.

Therapeutic procedures

With respect to therapeutic procedures, CMCC had already included manual and, to a lesser extent, instrumented soft tissue therapy in the core technique curriculum. Mobilizations as well as HVLA and drop piece manipulations of the spine and peripheral joints have also been taught for many years. However, at the time of this writing (winter, 2024) CMCC does not teach instrumented adjusting, use of traction tables and provides no more than one or two lab session on the use of pelvic blocking, contrary to the 'recommendation toward a standardized technique curriculum' study.[33]

By way of contrast, the Australian Chiropractic College, located in Adelaide, Australia, better aligns with the recommendations toward a standardized technique curriculum by including the following chiropractic technique systems[6] in its core curriculum: Diversified, Gonstead (both of which use HVLA-SMT), Thompson Terminal Point, Toggle Upper Cervical, Activator, Advanced Bio Structural Correction (ABC™), and Sacro-Occipital Techniques (Chanelle Vaughan, Stream Coordinator – Technique: Personal communication).

Knowledge translation at the grassroot level

It is widely recognized there is a knowledge-to-action (KTA) gap between the time of publication of research evidence and its uptake and utilization by healthcare professionals in clinical practice.[38] Using various strategies, some success has been achieved with respect to closing the KTA gap pertaining to performing manual skills in Ontario, Canada. The research evidence from the biomechanical[8-10], student injury[24,27] and site of care[32] studies has been shared with chiropractors on a grassroots level in the form of presentations at professional conferences[39,40], continuing educational programs[41,42] and in-person, hands-on technique workshops[43,44].

Limitations

There are several limitations to this study. Similar to Part 1 of this series,[5] a different group of authors may have selected a different group of studies to review. Since only a brief synopsis of each study was provided in this narrative review, some important details of each study may have been missed. With very few exceptions, the authors purposefully avoided discussing articles that were related to this topic but outside of this study's inclusion criteria. We encourage interested parties undertake either a broader narrative review or a systematic review to capture other studies germane to chiropractic manual skills.

Summary

This article provided a narrative review of the research evidence authored by faculty at CMCC as well as a discussion of the impact this research has had on teaching chiropractic manual skill within the college and, theoretically, to the broader chiropractic educational community. It is the authors' hope faculty and curricular planners at current and future accredited educational programs may potentially incorporate this research evidence to strengthen the pedagogical approach to how they teach chiropractic manual skills.

References

1. Kaptchuk TJ, Eisenberg DM. Chiropractic. Origins, controversies and contributions. Arch Intern Med. 1998;158: 2215-2224.
2. Keating JC Jr. Several pathways in the evolution of chiropractic manipulation. J Manipulative Physio Ther. 2003;26(5): 300-321.

3. Montgomery PD, Nelson MJ. Evolution of chiropractic theories of practice and spinal adjustment, 1900-1950. Chiro Hist. 1985;5: 71-77.
4. Keating JC Jr. Chronology of the Early History of the Canadian Memorial Chiropractic College. Source unknown.
5. Gleberzon BJ, Ross JK, Kinsinger FS, Szaraz Z. The evolution of teaching chiropractic skills: Part 1 – a narrative review of lessons learned during the 120 collective years of four tutors in the technique trenches at the Canadian Memorial Chiropractic College. J Can Chirop Assoc. 2024.
6. Cooperstein R, Gleberzon BJ. Towards a Taxonomy of Subluxation-Equivalents. Top Clin Chiropr. 2001;8(1): 49-58.
7. Nolet PS, Yu H, Cote P, Meyer A, *et al*. Reliability and validity of manual palpation for the assessment of patients with low back pain: a systematic and clinical review. Chiropr Man Therap. 2021;29:33.
8. Ross JK, Bereznick DE, McGill SM. Atlas-axis facet asymmetry. Implications in manual palpation. Spine. 1999;24(12):1203-1209.
9. Bereznick DE, Ross JK, McGill SM. The frictional properties at the thoracic skin-fascia interface: Implications in spinal manipulation. Clin Biomech. 2002;17(4):297-303.
10. Ross JK, Bereznick DE, McGill SM. Determining cavitation location during thoracic spinal manipulation: is spinal manipulation accurate and specific? Spine. 2004;29(13): 1452-1457.
11. Sorensen PW, Nim CG, Poulsen E, Juhl CB. Spinal manipulative therapy for nonspecific low back pain: does targeting a specific vertebral level make a difference?: A systematic review with meta-analysis. J Orthop Sports Phys Ther. 2023;53(9):529-539.
12. Bereznick D, Pecora CG, Ross JK *et al*. The refractory period of the audible 'crack' after lumbar manipulation: a preliminary study. J Manipulative Physio Ther. 2008;31(3):199-203.
13. Cramer GD, Ross K, Raju PK *et al*. Quantification of cavitation and gapping of lumbar zypapophyseal joints during spinal manipulative therapy. J Manipulative Physio Ther. 2012;35(8): 614-621.
14. Moorman AC, Newell D. Impact of audible pops associated with spinal manipulation on perceived pain: a systematic review. Chiropr Man Therap. 2022;30:42.
15. Leathers K. How and why you can utilize Dynadjust even before matriculation to grad school! https://www.youtube.com/watch?v=wesGIK3YyPA
16. Triano, J., Giuliano, D., McGregor, M., & Howard, L. (2014). Enhanced Learning of Manipulation Techniques using Force-Sensing Table Technology (FSTT). Toronto: Higher Education Quality Council of Ontario.
17. Azad A, Ellul N, Gleberzon BJ. Computerized Text Analysis of Emergent Themes from Responses to Curricular Change. Platform Presentation, Association of Chiropractic Colleges and Research Agenda Conferences, March 14, 2016
18. Ellul N, Azad A, Gleberzon BJ. Student perceptions of Force Sensing Table Technology integration in the classroom: A Controlled Cohort Study at CMCC. Platform Presentation, Association of Chiropractic Colleges and Research Agenda Conferences, March 14, 2016
19. CMCC- FSTT® Technology – Publications. https://www.cmcc.ca/research/fstt-publications
20. Starmer DJ, Guist BP, Taylor TT *et al*. Changes in manipulative peak force modulation and time to peak thrust among first-year chiropractic students following a 12-week detraining period. J Manipulative Physiol Ther. 2016;39(4):3111-3117.
21. Triano JJ, Lester S, Starmer D, Hewitt EG. Manipulation peak forces across spinal regions for children using mannequin simulators. J Manipulative Physiol Ther. 2017;40(3): 139-146.
22. Duquette SA, Starmer DJ, Plener JB *et al*. A pilot study to determine the consistency of peak forces during cervical spina manipulation utilizing mannequins. J Chirop Educ. 2021;35(1): 8-13.
23. CMCC: FSTT® Technology – Global Presence. https://www.cmcc.ca/research/fstt-technology
24. Macanuel K, Deconinck A, Sloma KC, LeDoux M, Gleberzon BJ. Characteristics of injuries sustained by chiropractic students during their undergraduate training in technique class at a chiropractic college: a pilot retrospective study. J Can Chiro Assoc. 2005;49(1):46-55.
25. Senstad, O, Lebeouf-Yde, C, Borchgrevink, C. Frequency and characteristics of side effects of spinal manipulative therapy. Spine 1997;22(4): 435-441.
26. Cagnie B., Vinck E, Beernaert A, *et al*. How common are side effects of spinal manipulation and can these side effects be predicted? Manual Ther. 2004;9(3):151-156.
27. Kuehnel E, Beatty A, Gleberzon BJ. An intercollegiate comparison of prevalence of injuries among students during technique class from five chiropractic colleges throughout the world: a preliminary retrospective study. J Can Chiro Assoc. 2008;52(3): 169-174.
28. Bisiacchi DW, Huber LL. Physical injury assessment of male versus female chiropractic students when learning and performing various adjustive techniques: a preliminary investigative study. Chiropractic Osteopath. 2006;14:17.
29. Ndetan HT, Rupert RL, Bae S *et al*. Epidemiology of musculoskeletal injuries among students entering a chiropractic college. J Manipulative Physio Ther. 2009;32: 134-139.
30. Kizhakkeveettil A, Sikorski D, Tobias G *et al*. Prevalence of adverse effects among students taking technique classes: a retrospective study. J Chiro Educ. 2014;28(2): 139-145.
31. Hodgetts CJ, Walker BF. Testing a strength and

conditioning program to prevent common manipulative technique training injuries in chiropractic students: a study protocol for a randomised controlled trial. Chiro Manual Ther. 2018;26: 23.
32. Triano JJ, Budgell B, Bagnulo A *et al*. Review of methods used by chiropractors to determine the site of applying manipulation. Chiropr Man Ther. 2013; 21:36.
33. Gleberzon BJ, Cooperstein R, Good C, Roecker C, Blum C. Developing a standard curriculum for teaching chiropractic technique: qualitative analysis of participants' opinions from 4 intercollegiate conference workshops. J Chiro Educ. 2021; 35(2): 249-257.
34. McMillan S, Kelly F, Sav A, *et al*. Using nominal group technique: how to analyze across multiple groups. Heal Serv Outcomes Res Methodol. 2014;14: 92-108.
35. McMillan S, King M, Tully MP. How to use the nominal group and Delphi techniques. Int J Clin Pharm. 2016;38(3): 655-662.
36. CMCC- FSTT® Curriculum. https://www.cmcc.ca/research/fstt-curriculum
37. Hodgetts CJ, Walker BF. Testing a strength training and conditioning program to prevent common manipulative technique training injuries in chiropractic students: A study protocol for a randomized clinical trial. Chiropr Man Therap. 2018;28: 26-33.
38. Graham ID, Logan J, Harrison MB *et al*. Lost in knowledge translation: time for a map? J Contin Edu Health Prof. 2006;26(1): 13-24.
39. Ellul N, Doucet C. Fine-Tuning Force: Modulation for Special Populations, from Pediatrics to Geriatrics. Canadian Chiropractic Association National Convention & Tradeshow (NCT). April 20, 2024
40. Kinsinger FS, Guist B (Moderators). Evolving chiropractic education and research. The Healthcare Evolution. Association of Chiropractic Colleges Educational Conference Research Agenda Conference (ACCRAC 2024).
41. Choi G. Force-Sensing Table Technology Lab. CMCC Continuing Education. May 4, 2024.
42. Wang S. The science of the pop. Exploring expectations, cavitations, and spine biomechanics. Parker Seminars – Invictus Las Vegas. February 22, 2024.
43. Azad A, Draper C, Ellul N, Gates R. Skills for exceptional patient care: An in-person interactive workshop. CCPA-CCA Workshop. Nov 21, 2023.
44. Gleberzon BJ. Hands on Technique Tune-Up. Eastern Ontario Chiropractic Society. April 13, 2024.