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REVIEW OF THE LITERATURE

Developing spinal manipulation psychomotor skills competency: A systematic review of teaching methods

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ABSTRACT

Objective: To update the state of the art regarding the acquisition of spinal high-velocity low-amplitude psychomotor skills competency among chiropractors and chiropractic students.
Methods: Available electronic articles from 5 databases, published between June 2015 and August 2020, were obtained. Eligible studies underwent methodological quality assessments using the Joanna Briggs Institute Critical Appraisal Checklists and Cochrane Collaboration's Risk of Bias Tools.
Results: Fourteen critically appraised studies were identified, including 10 cohort studies and 4 randomized controlled trials. There was no literature excluded due to high risk of bias. The type of augmented devices included a mannequin on a force platform, a computer-connected device, a human analogue mannequin, and a 3-dimensional electrogoniometer with an instrumented spatial linkage.
Conclusion: The use of augmented feedback devices such as human analogue mannequins with force-sensing table technology and computer-connected devices is potentially beneficial in the chiropractic curricula and may facilitate student learning and improvement of spinal manipulation. More studies are required to determine whether psychomotor skill aids translate directly into raised competency levels in novice clinicians.

Key Indexing Terms: Manipulation, Spinal; Chiropractic; Learning; Education

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INTRODUCTION

High-velocity, low-amplitude (HVLA) manipulations are complex psychomotor skills, recognized as the technical foundation of the chiropractic profession.[1] Despite the numerous criteria that describe the professional practice of chiropractors, HVLA spinal manipulation remains integral to chiropractic identity and practice. The literature on learning motor and bimanual coordination suggests that complex skills require rehearsal and experience,[1–4] which are essential for body coordination and controlling the amount of force applied during a manipulation.[5] However, a clear definition of what constitutes clinical competency of HVLA manipulation has not been established.

Traditionally, HVLA manipulations are taught by experienced clinicians demonstrating the technique and the chiropractic students replicating the complex skills to the best of their ability.[6] Spinal manipulation has proven to be challenging for chiropractic students to master due to the limited rehearsal time and insufficient reinforcement attributed to these skills.[1,2,7] This teaching method presents some challenges, such as a risk of injuries to the students who play the role of simulations if spinal manipulations are repeatedly performed,[2] and there is also the potential for overreliance on students mimicking experienced clinicians. Thus, innovative methods are required that support psychomotor skills competency.[3]

A recent synthesis of the literature aimed to review the effectiveness of various methods of teaching spinal manipulations to chiropractic students[8] with the methods being identified as effective in developing manipulation skills, transference of knowledge, and retention of tasks among students.[8] Training devices were identified that were used as teaching aids. These included the noninstrumented thrust in motion cervical manikin (Macquarie University Centre for Chiropractic, Sydney, Australia), an instrumented cardiopulmonary resuscitation manikin (model UL 400, Statham, Oxnard, CA, USA), an instrumented treatment table embedded with a force plate,

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Dynadjust instrument (LaBarge, Inc, St. Louis, MO, USA), and a load cell attached to a padded contact (Omega Engineering Inc, Stanford, CT, USA). The results indicated the benefits of augmented feedback devices in the chiropractic curriculum to facilitate the development of spinal manipulation skills.[8] All reported methods of teaching and learning were included; however, the study did not elaborate on which skills or competencies each innovation focuses on nor determine a superior teaching form or describe the psychomotor domain within Bloom's taxonomy for various levels of learning. This review provides information that has since been updated, because, with the continued development of technology, multiple studies have since emerged to add to the enhancement of learning spinal manipulation skills.

As part of prioritizing more nuanced educational practice, literature highlighting development must be constantly updated. According to the Cochrane Collaboration, a systemic review should be updated after 2 years or alternatively include a commentary stating why it has not been updated.[9] Better tools may have been designed, new outcomes measured, or modern interventions reported, and this approach ensures that the latest literature is used to facilitate the potential of new developments arising in the subject under review. The importance of this area to chiropractic education necessitates the need for this to remain updated, and a perusal of the literature suggests that several investigations have moved the discourse forward.

The most recent synthesis was conducted 6 years ago, and the purpose of this systematic review is therefore to update the state of the art with respect to best-practice approaches, to facilitate a discussion of HVLA thrust technical competency among chiropractors and chiropractic students.

METHODS

The study design was a systematic review (best-evidence literature synthesis) that targeted studies available on electronic databases. This research made use of only a single data extraction process, with an independent second reviewer verifying the literature. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was used for formatting the report.[9]

Eligibility Criteria

The review targeted studies that identified methods of teaching spinal manipulation skills to chiropractic students or chiropractors. Studies were excluded if they did not match the population reviewed or did not include learning spinal manipulation in the intervention. Studies were used that focused on methods of teaching and improving spinal manipulations other than the traditional methods of a demonstration by the instructor, rehearsal on peers, and verbal feedback. Studies that compared various methods of teaching spinal manipulations, traditional with modified teaching methods using augmented devices and participant's various levels of education and years of experience for performing a technique, were included. Qualitative or quantitative measurements were included as a requirement to ensure evidence-based methods were used to evaluate the spinal manipulation performance. Quantitative evaluation consisted of the parameters that quantified the HVLA as seen on a time velocity graph. The qualitative evaluation included verbal feedback from peers or educators as to the success of the performance analogues to an ideal spinal manipulation or surveys that referred to the effectiveness of the interventions or prevalence of injury obtained by patient simulators.

Study Characteristics

Studies were eligible for inclusion if they studied humans, were published in English between June 2015 and August 2020, and were clinical trials, randomized clinical trials, cohort studies, or systematic reviews. Studies that obtained qualitative or quantitative results of spinal manipulation performed by chiropractors or chiropractic students were included.

Studies were excluded if the Cochrane Collaboration's Risk of Bias Tool or The Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) assessment tool classed them as high risk. Other exclusion criteria included poor quality and unethical studies, not being relevant to the topic, relating to animal studies, failing to provide evidence of randomization, and being a duplicate.

Information Sources

Information sources were obtained by searching 5 electronic databases: HubMed, PubMed, MEDLINE, Index to Chiropractic Literature, and Google Scholar. The time frame for the literature search was between June 2015 and August 2020. Applicable search terms and settings were applied to include English randomized control trials or cohort studies that obtained qualitative or quantitative results of spinal manipulation performed by chiropractors or chiropractic. The Boolean formulation and Medical Subject Headings (MeSH) used for this review were spinal manipulation [Title/Abstract]) AND (learning [Title/Abstract]); (spinal manipulation [Title/Abstract]) AND (learning [Title/Abstract]) OR (augmented feedback); or (spinal manipulation [Title/Abstract]) AND (chiropractic) AND (training). Broadened search terms used included "Quantify spinal manipulations," "motor skills chiropractic," and "chiropractic adjustment forces."

Study Selection and Assessment

Retrieved titles and abstracts were initially evaluated in relation to the inclusion and exclusion criteria. The included literature from this process then underwent a methodological assessment, with the use of JBI Critical Appraisal Checklist for Randomised Controlled Trials and JBI Quasi-experimental Appraisal Tool. These checklists are composed of several questions and provided the reviewer with 1 of 3 options to check ("yes," "no," "unclear," or "not applicable"), which best describes the quality of the study. The checklists were used to ensure reliable and nonbiased studies were included in the review, by providing a method to assess the extent to which a study addressed the possibility of bias in the design, conduct, and analyses. The studies underwent an internal review by the researcher, and the decision to include, exclude, or gather more information was made.

The next phase involved the screening of qualifying studies to remove duplications (as agreed by 2 reviewers) and the utilization of Cochrane Collaboration's Risk of Bias Tool, JBI Critical Appraisal Checklist for Randomised Controlled Trials, or The Risk Of Bias In Non-randomized Studies – of Interventions (ROBINS-I) assessment tool. These tools categorize studies according to the risk of bias present, such as "high risk," "low risk," or "unclear." These assessment tools are based on the adequacy of sequence generation, allocation concealment, method of blinding, addressing incomplete outcome data, selective outcome, and other sources of bias. Studies that scored low or unclear on the risk assessment were included for the review.[3,10]

These guidelines were used to assist the reviewer in making an informed judgment on the internal validity of the studies by means of a qualitative review. This ensured that a low risk for selection bias and confounding of results was present. The results were reviewed by means of discussion with an independent second reviewer. Studies that had a low risk of bias and adequate internal validity were included in the systematic review, following which, the literature data were summarized, outlining the characteristics of each study and included the authors, year and title of publication, study design, aim, methodology, characteristics of participants and total number, interventions, outcomes, and risk of bias assessment that kept the risk of bias as low as possible. Findings from the included studies were extracted with accompanying illustrations and tables for each study. Categories were developed for findings of a similar nature, and the literature was discussed and a conclusion drawn using the modified JBI Checklists[11] as guidelines.

RESULTS

Study Selection

The search for diverse sources yielded a total of 786 studies and was conducted between July 10, 2020, and August 15, 2020. The literature was cross-checked for relevance based on the information provided in the abstract and title, and 706 studies that were not relevant were excluded. Eighty relevant full-text articles were recorded in a table format and screened for duplication, with 45 additional duplication exclusions. Thirty-five articles were assessed for eligibility and recorded in a log. The studies were screened during the phase 2 screening process according to the inclusion and exclusion criteria, and a total of 21 were excluded with a stated reason if they did not meet the inclusion criteria. Critically appraised studies included in the qualitative synthesis were assessed for methodological quality and were excluded if the studies were classified by the Cochrane Collaboration's Risk of Bias Tool research, ROBINS-I assessment tool, and with verification by the second reviewer as "high risk"; there was no literature excluded due to high risk of bias. Fourteen high-quality studies were included in the final review. A modified PRISMA flow diagram was used to illustrate the selection process (Figure 1).

Study Characteristics

A total of 14 admissible studies were identified: 4 were randomized control trials, and 10 were cohort studies. Of those, 2 studies evaluated cervical spinal manipulation using augmented devices, and 12 evaluated thoracic spine manipulation. The devices used as teaching aids varied between the studies. Three studies used a mannequin placed onto a force platform as an augmented device for assessing spinal manipulations, 5 studies used a computer-connected device with a strain gauge, 5 studies used human analogue mannequins (HAMs), and 1 study used a 3-dimensional (3D) electrogoniometer with an instrumented spatial linkage. The characteristics of the included studies are presented in Supplemental Table 1 (available online accompanying this article). The summarized table was used to synthesize a narrative review.

Risk of Bias Assessment Within Studies

After the risk of bias and methodological quality evaluation, a total of 14 studies qualified for the final review. A summary of the judgment made for each study is tabulated for comparison in Tables 1 and 2. Nine studies were classified as "low risk" of overall bias, and 4 studies were classified as "moderate risk" for overall bias, mostly relating to the small sample size used in the study.

Summary of Evidence

Mannequin and Force Platform

Three studies, each using a mannequin placed onto a force platform as an augmented device for assessing spinal manipulations, were conducted, and all 3 studies were classified as "moderate risk" of bias. Two studies[2,20] were found to be effective for improving spinal manipulation performance in novice chiropractic students, with the duration of both studies being similar, ranging between 8 and 10 weeks. The first of these studies[2] combined verbal feedback with the augmented device training, which resulted in a decrease in preload, increase in peak force, decrease in thrust rate, and a decreased variability for heavy and normal thrusts. The second study[20] combined augmented device training with a physical exercise program, which resulted in a decrease in preload and an increased thrust duration. However, the thrust duration was attributed to familiarity and not the physical exercise program. The physical program included push-ups, core stabilization, and speeder board exercises 3 times per week for 8 weeks. Owens et al[2] established minimum force and speed training targets for lumbar spinal manipulations but failed to determine normative values for student learning. Two of these studies[2,12] used a study sample of less than 20, which weakens the strength of evidence, with 1 study[17] having a study sample of more than 100. The studies occurred at different universities/institutions, 1 in the United States[2] and 1 in France,[17] indicating widespread usage of the device.

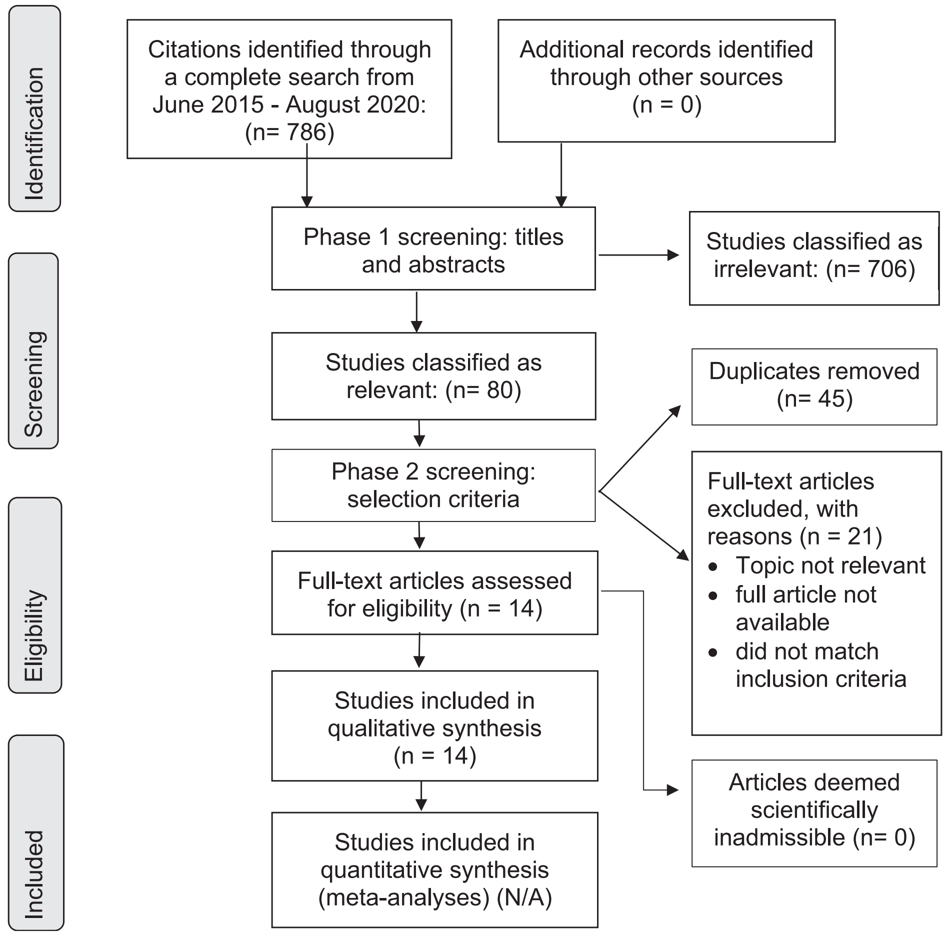

Figure 1 - Modified PRISMA flow diagram chart showing the methodology for this review.

Computer-Connected Device With a Strain Gauge

Five studies[1,7,15,19,21] used a computer-connected device with a strain gauge as a method to assess and improve spinal manipulations. One study[15] determined that feedback based on error detection, via the computer-connected device, was effective at improving spinal manipulation skills. Two studies[15,19] also indicated that the level of expertise plays a key role in the performance of spinal manipulations. Descarreaux et al[7] (classified as moderate risk of bias) used a computer connected combined with task difficulty and indicated an increase in the variability of spinal manipulation performance with increased task difficulty and that the thrust force is traded off for increased thrust duration to optimize performance during challenging tasks. Three of the studies[1,21,19] indicated that a short training period of 30 manipulations with feedback on the computer-connected device resulted in improved spinal manipulation performance. These studies varied in approach, from a short practice period of thrusts toward a target force,[19] a constant practice group targeting only 1 peak force, and a variable practice group targeting variable peak forces[1] and training on variable feedback to determine the effect of decency on feedback,[21] with all 3 studies indicating increased accuracy and consistency regardless of the practice type. The effects were still present at the retention period up to 1 week after the training period. The study samples varied from 16 senior students and qualified chiropractors,[7] which weakens the strength of evidence. Quebec (Université du Québec à Trois-Rivières) was the setting for 3 of these studies,[1,7,15] with the rest being at other institutions.[19,21]

HAMs

Five studies[13,14,16,17,22] used HAMs as an augmented device to assess and improve spinal manipulation performance. Starmer et al[13] indicated that novice chiropractic students did not show a decrease in spinal manipulation performance after a 12-week detraining period, but students still lack the speed and force of manipulations to imitate the force parameters of qualified chiropractors, while Triano et al[14] indicated that once-off short 2-hour interval training with experienced chiropractors, consisting of technology-assisted coaching with visual feedback using a HAM, resulted in a reduced error rate by 23% to 45%. A standardized 6-session training program for senior chiropractic students consisting of 30-minute sessions (60 to 100 thrusts) on the HAM resulted in more accurate delivery of

Table 1 - Summary of Risk of Bias in Individual Randomized Controlled Trials

Study	Confounding Bias	Baseline Confounding	Time-Varying Confounding	Selection Bias	Information Bias	Performance Bias	Attrition	Outcomes Bias	Reporting Bias	Overall Risk	Inclusion/ Exclusion
Owens et al (2017)[12]	L	L	L	M	L	L	U	L	L	M	I
Starmer et al (2016)[13]	L	L	L	L	L	L	L	L	L	L	I
Triano et al (2015)[14]	L	L	L	L	L	L	L	L	L	L	I
Loranger et al (2016)[15]	L	L	L	L	L	L	U	L	L	L	I
Owens et al (2016)[2]	L	L	L	M	L	L	M	L	L	M	I
Shannon et al (2019)[16]	L	L	L	M	L	L	U	L	L	M	I
Pasquier et al (2019)[17]	L	L	L	U	L	L	U	U	L	L	I
Descarreaux et al (2015)[7]	L	L	L	M	L	L	L	L	L	M	I
Van Geyt et al (2017)[18]	L	L	L	M	L	L	L	L	L	M	I
Pasquier et al (2017)[19]	L	L	L	L	L	L	L	L	L	L	I

L: low risk; U: unclear risk; M: moderate risk; I: included.

2 prescribed peak forces.[16] The study used a sample of only 16 participants, which weakens the strength of the results, and was therefore classified as a moderate risk of bias. One study[14] showed that sex and expertise differences affect spinal manipulation performance, with female participants showing lower time-to-peak force and rate of force and being more precise with less variability, which is similar to a previous finding within this review.[15,19] Duquette et al[22] indicated that a 1-hour force-sensing table technology (FSTT) and HAM training period is effective in improving cervical spinal manipulations performed by students. However, these improvements did not carry over when cervical manipulation was performed on human subjects. Three studies[14,13,22] were conducted at the Canadian Memorial Chiropractic College, where the HAM was developed, and subsequently used in Palmer College of Chiropractic in the United States[16] and the Institut Franco-Européen de Chiropraxie in France.[17]

3D Electrogoniometer With an Instrumented Spatial Linkage

One study[18] used a 3D electrogoniometer with an instrumented spatial linkage to better understand a patient's subjective experience when being manipulated by chiropractors. The results indicated that the motion parameters obtained during manipulation corresponded with cavitation occurrence and were variable between different chiropractors. This device was effective in assessing spinal manipulations in the cervical spine. The study sample was only 20 participants who served as patients and 5 chiropractors, which decreases the strength of evidence, and the study was classified as moderate risk for bias. This study was conducted at Université Libre de Bruxelles.

DISCUSSION

There is a strong body of evidence to suggest the use of augmented feedback devices in improving spinal manipulation performance. This literature review presents updated methods with the most recent information available. With the continued development of technology, there has been an increase in the number of devices available, which broadens the scope of training. It revises the usage of the devices to provide a better understanding of the force parameters during HVLA manipulations, the effect that training duration has, and what role experience plays in performing HVLA manipulations.

Most of the studies reviewed used a computer-connected device and an HAM with FSTT. Moderate evidence (due to small sample sizes) exists for the use of a mannequin with a Bertec force plate. There is some evidence to support the use of a 3D electrogoniometer with an instrumented spatial linkage as a spinal manipulation learning device; however, no other literature supports the use of this device.

These devices have already been incorporated into several chiropractic program curricula and have shown to be effective training aids.[1,7,13,23] Significant improvements in spinal manipulation performances were reported in the

Table 2 - Risk of Bias in Individual Cohort Studies

Study	Selection Bias	Performance Bias	Detection Bias	Attrition Bias	Reporting Bias	Other Bias	Overall Risk	Inclusion/ Exclusion
Lardon et al (2019)[20]	L	M	L	L	L	L	M	I
Marchand et al (2017)[1]	L	L	L	L	L	L	L	I
Lardon et al (2016)[21]	L	L	L	L	L	L	L	I
Duquette et al (2020)[22]	U	L	L	L	L	L	L	I

L: low risk; U: unclear risk; M: moderate risk; I: included.

literature, such as decreased preload force, increased peak force, decreased thrust rate (time to peak force), improved consistency,[1,12,16,20,22,24] and improved error detection skills.[21] It was also evident that several factors influence the learning of spinal manipulations and should be considered when assessing the performance of these skills. The level of expertise was a common variable addressed during the studies, Indicating that more experienced chiropractors performed better.[2,14,15,17,19] Therefore, it could be beneficial to incorporate training devices at an earlier stage of learning; however, more evidence on this topic is required.

Other factors, such as task difficulty[7] and sex differences,[17] also play a role in spinal manipulation learning, which suggests customized programs should be implemented concomitantly with the devices. The combination of training programs and augmented devices has indicated that even within a short training period of up to 2 hours, a significant improvement in the performance of spinal manipulations has been observed.[1,4,14,16,19,24] Similar effects were observed during more extended training periods.[12,13,20]

The effect of exercise programs combined with augmented feedback on the thrust duration of a manipulation has not yet been clearly defined,[24] and further research is necessary to make a conclusion regarding the normative values for optimal spinal manipulation in chiropractic students[13] and the translation of these improvements using the augmented devices into clinical outcome in patients.

The strengths of this study are attributed to the precision of the search strategy developed and clearly defined inclusion and exclusion criteria that were set to filter the relevant articles from the searched literature. Critical appraisal of the articles followed PRISMA, which is the preferred method for reporting systematic reviews and meta-analyses.[9] Bias was minimized by using Cochrane Collaboration's Risk of Bias Tool or the ROBINS-I assessment tool.

A potential limitation of this systematic review is that only full-text reports and electronically published studies were included. Also, a single data extraction and review process was followed with verification by an independent second reviewer with only English studies being considered, which may reduce the relevant articles available. However, previous reviews indicated that restricting reviewed articles to only the English language did not lead to a bias in reported results.[25] Contact with authors was made for full-text articles, but no responses were received. A limited number of high-quality studies were available for review, and scientific judgment was used for the critical review, which may differ between reviewers. The risk of bias was minimized by using a consensus process between reviewers regarding scientific admissibility. The review was limited to the chiropractic profession, which excludes other professions that also teach spinal manipulation. The studies were also limited to prone thoracic manipulations, and outcomes may not be transferable to lumbar and cervical spine manipulation.

Further research in augmented feedback device training is recommended and should investigate the long-term role of these teaching and learning devices for chiropractic students in the initial stages of the educational program and then extended to postgraduate training and how these skills transfer to clinical settings. A wider spectrum of spinal manipulation experience, from novice to expert, should be included in future research.

Quantification of normative values for optimal spinal manipulation in chiropractic students need to be developed,[13] and the inclusion of specific training programs, alternative training devices, plyometric and elastic tubing exercises, and their ability to improve outcomes should be evaluated.

A limitation is that only a minority of universities have implemented these training devices into their curricula, and they are limited to Europe, Canada, and the United States. An additional limiting factor is that mannequins have been designed to have a similar feel to real patients; however, they cannot reproduce pain responses or feedback, which are important considerations when performing spinal manipulation.

CONCLUSION

Current evidence supports the effectiveness of augmented feedback devices, which are seen as an asset for optimal skill development and teaching spinal manipulation to students. The devices appear to be useful to standardize the forces applied during spinal manipulation and could be used during assessments and further research. In addition, practicing on these devices has been shown to be valuable for skill retention and reduction in the risk of injury to patients. Although included studies indicate an improved outcome regardless of the augmented device used, no comparative studies of these devices have been conducted, and determining whether a psychomotor skill aid translates directly into improved competency levels in real patients in novice clinicians need to be considered.

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