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ORIGINAL ARTICLE

A pilot study of the effect of force feedback training on students learning flexion-distraction chiropractic technique*

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Objective: We compared traditional training alone and with the addition of force feedback training for learning flexion-distraction chiropractic technique.
Methods: Participants were randomly allocated to two groups (traditional or traditional plus force feedback training). Students' forces were measured before training and after force feedback training. Students rated the helpfulness of the training and the comfort of the force transducer.
Results: Thirty-one students were enrolled. Both groups delivered similar forces at baseline. Group 1 students' subsequent force measurements were higher after force feedback training. Group 2 students' forces were unchanged. Group 2 students were trained with force feedback for week 2 of the class, and forces were higher after feedback and similar to those in group 1. Students rated the training as very or somewhat helpful. Students also experienced discomfort as a patient and a student-doctor due to the force transducer that was used. Students who received force feedback training learned to deliver higher forces, which were closer to the forces delivered by experienced doctors of chiropractic. Students who did not receive force feedback continued to deliver lower forces.
Conclusion: Force feedback helped students deliver forces closer to the desired force level and to learn this delivery faster than students who were not trained with force feedback.

Key Indexing Terms: Spinal Manipulation; Chiropractic; Motor Skills; Education; Formative Feedback; Learning

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INTRODUCTION

Low back pain is a common complaint in the United States and costly to society.[1–10] Many patients choose to see doctors of chiropractic (DCs) for relief of low back pain. DCs treat these patients with several different methods, including different types of spinal manipulation therapy (SMT). Two commonly used methods of SMT include manual high velocity low amplitude (HVLA) and low velocity variable amplitude (LVVA) spinal manipulation. One form of LVVA SMT is known as the Flexion-Distraction (FD) or Cox Flexion-Distraction technique and is used by approximately 64% of chiropractors on at least some of their patients.[11] Patients receiving the FD technique are positioned prone on a treatment table that allows movement of the lower body, controlled by the clinician. At the same time, the clinician manually stabilizes (holds) a spinal segment by applying anterior-to-posterior and cephalad pressure to the spinous process. The distal portion of the table then is moved through the motions of flexion, lateral flexion, circumduction, and extension, which induces a traction force on the spine.

To learn SMT, chiropractic students participate in lectures, demonstrations, and practice sessions. In the chiropractic curriculum, the teacher will demonstrate the technique and then the students will attempt to replicate the procedure on other students. Learning a hands-on skill, such as SMT, can be time-intensive and frustrating. There is evidence that practicing a manipulation type of therapy with real-time feedback helps students learn to apply the appropriate forces.[12–15] Snodgrass et al. found that using real-time force measurement and providing students with feedback helped them to learn cervical spine mobilization.[13]

Another study demonstrated that novice chiropractors learned to apply forces more consistent with those applied by experienced chiropractors when performing chiroprac-

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tic LVVA SMT.[16] In that study, the investigators used a system designed to provide clinicians with real-time visual graphic feedback on the magnitude of forces applied to the participant's lumbar spine.[16] In the posterior to anterior (P to A) direction, mean and standard deviation (SD) preload force in Newtons (N) delivered by experienced chiropractors was 95 N (34). Mean (SD) P to A peak force was 140 N (43). Inferior to superior (I to S) mean (SD) preload force was 44 N (16), and mean (SD) I to S peak load was 65 N (10).[16] Inexperienced chiropractors delivered lower forces at first, but with training were able to more closely approximate the forces of the experienced chiropractors.

To date, to our knowledge no studies have tested different levels of force during FD treatments. Without clinical trials to test whether outcomes are better with higher or lower forces, we do not know what amount of force is optimal. Therefore, we proceeded under the assumption that the amount of force used by experienced chiropractors is appropriate. With that assumption, we hypothesized that the force measuring and feedback system could have a role in training chiropractors to deliver standardized forces in research studies or to train students in performing SMT.

This study was designed to advance the training of chiropractic students by using force feedback technology while delivering FD to the low back. Force feedback technology was used to train students and test their skills in duplicating the delivery of forces identified by the instructors. Two groups of students were compared. One group received traditional training and one received traditional training plus force feedback.

METHODS

The study was ruled exempt by the human subjects protections officer of Palmer College of Chiropractic (IRB Assurance #N2017-7-31-R).

Participants

The sample consisted of volunteers from students enrolled in the elective course on FD at the chiropractic college. Demographic information on participants was collected after signing the informed consent form.

Randomization

Students were allocated randomly to groups 1 or 2 by use of sequentially numbered opaque envelopes prepared by an independent person. Envelopes were opened following the baseline measurements on the first day of class.

Measurements

This crossover, two-group randomized study (Fig. 1) took place at a chiropractic college class room equipped with a FD table (Haven Medical, LLC, Grand Haven, MI) during a FD class. Initially, all students were given an introductory lecture and demonstration of the technique. Then, baseline force measurements were taken on all students as they applied LVVA SMT to the lumbar spines of other students.

Group 1 students were trained additionally with force feedback, while Group 2 students were trained without force feedback. A second measurement was taken with both groups following training of Group 1. One week later, force measurements were repeated for students in Group 1. Students in Group 2 then were allowed to crossover during week 2 of the class to be trained with force feedback technology, and their forces were measured after training and then again 1 week later.

Training consisted of practicing on fellow students approximately two to three times with five cycles in approximately <5 minutes. Simulated patients received the procedure two to three times for five cycles in approximately 20-second durations.

Forces were gathered with a three-dimensional (3D) force transducer (Model # Mini45, ATI Industrial Automation Inc, Apex, NC) placed between the student's hand and the patient's low back. The transducer gathered 3D forces in the x, y, and z planes. The force sensor was connected to a laptop computer. Custom developed software in the LabView (National Instruments, Austin, TX) environment was used to collect data on the 3D forces at a sampling rate of 100Hz. Data were stored in text format and read by custom written MATLAB software (Version 2011a, MathWorks, Inc, Natick, MA). MATLAB read the exported data and graphed the forces as a function of the duration of treatment. Data were extracted using a semiautomated custom written program on the preload and peak load forces in all three directions. Data on the preload and peak forces then were written to Microsoft Excel (Microsoft Corp, Redmond, WA) for ease of generating and reporting descriptive statistics (counts, percentages, means, and SDs).

At the end of the study, students completed a questionnaire about the usefulness of training and also the comfort of using the transducer. Students were asked to rate their opinion of how helpful the force feedback was when learning flexion-distraction technique, using a 5-point Likert scale with descriptors of 1, very helpful; 2, somewhat helpful; 3, neither helpful nor unhelpful; 4, somewhat unhelpful; and 5, very unhelpful.

Descriptive Statistics

The 3D force data obtained from graphs of student forces were summarized descriptively (means and SDs) corresponding to the preload and peak forces for each of the cycles.

RESULTS

A total of 31 students volunteered, gave consent, and were enrolled in the study. Demographics of the two groups are given in Table 1. There were five female students in each group. Group 1 had 11 male students and group 2 had 10. Mean age (SD) of the participants was similar in both groups (Group 1 = 25.5 [1.5] and Group 2 = 26.1 [2.0]).

The preload and peak force mean and SDs delivered by students in groups 1 and 2 delivered at baseline are reported in Table 2 (Measurement 1). The forces were

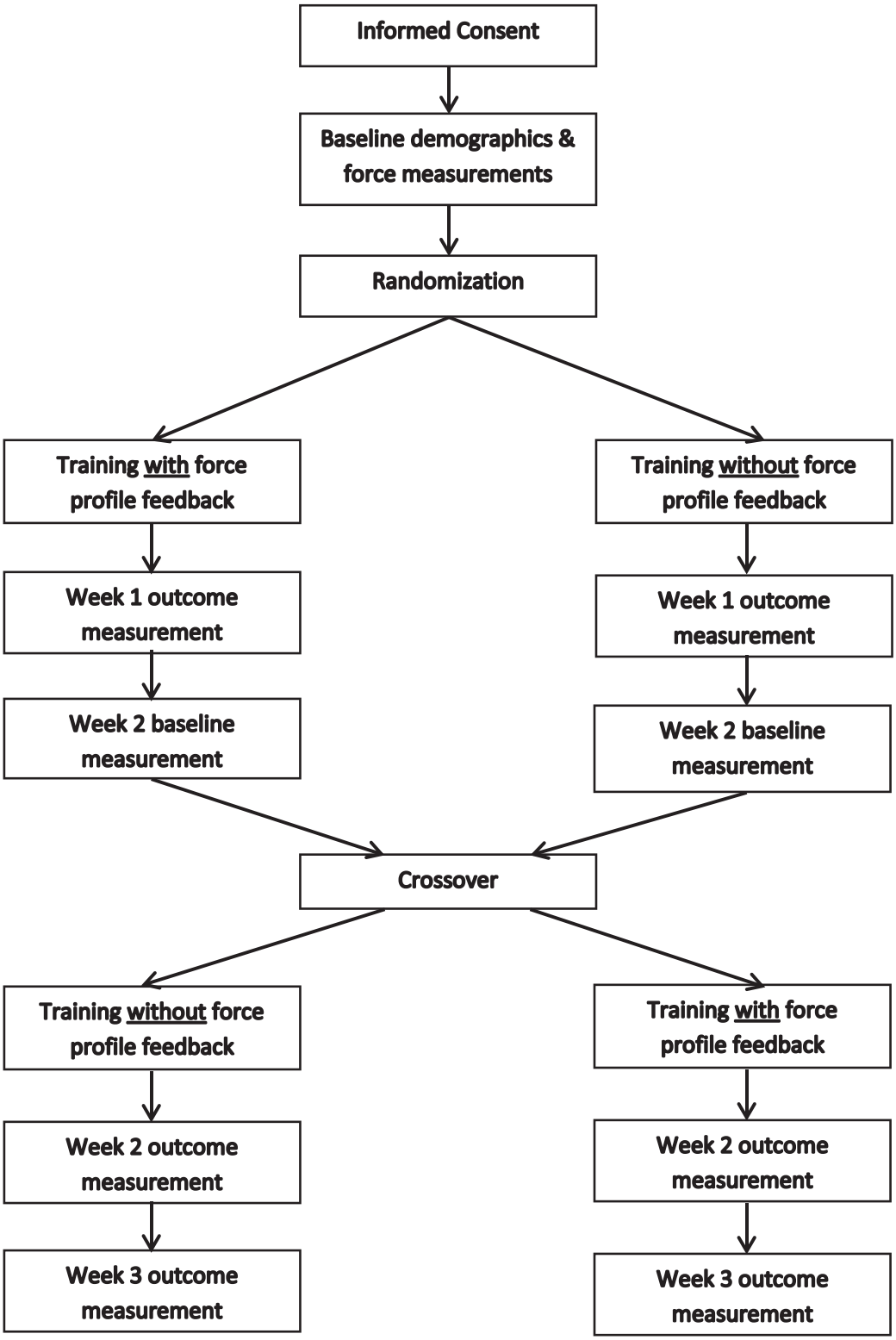

Figure 1 - Study flow chart.

Table 1 - Baseline Participant Characteristics

	Group 1 ($n = 16$)	Group 2 ($n = 15$)
Sex (F:M)	5:11	5:10
Age	25.5 (1.46)	26.1 (2.02)
Height (inches)	68.8 (4.2)	68.9 (2.93)
Weight (lbs.)	171.4 (30.35)	190.5 (62.8)

Data reported as mean (SD).

directed from P to A (Fz), I to S (Fx), and from medial to lateral (Fy). The Fz force was the largest and the Fy force was closest to zero. Figure 2 is an example of forces measured during the study and demonstrates the graph students were able to see for feedback.

Students in both groups delivered very similar forces at baseline. Following force feedback training of group 1 students, forces in both groups were measured again (measurement 2, Table 2). Forces were higher in group 1, while those in group 2 were unchanged. One week later group 1 forces were measured again with no intervening training. The third measurements were very similar to the second (measurement 3, Table 2).

Group 2 students crossed over into training with force feedback for week 2 of the class. Their forces were higher than their second measurements and very similar to those of group 1 students (measurement 3, Table 2). The final measurement in Group 2 students (measurement 4, Table 2) occurred 1 week after the class, which was similar to the 1-week post-training measurements of group1 (measurement 3). The forces at measurement 4 for group 2 were very similar to those at measurement 3 of group 1.

The majority of students (24/29) rated the helpfulness of force feedback as either 1 (very helpful) or 2 (somewhat helpful). When asked whether they experienced discomfort during the study, the majority of students answered that they had experienced discomfort as a patient (24/29) and a large number experienced discomfort as a student-doctor (10/29). These responses are displayed in Table 3.

DISCUSSION

Gudavalli and Cox[16] used the same measurement and feedback system that was used in our study. In their study, they provided clinicians with real-time visual graphic feedback on the magnitude of forces applied to the participant's lumbar spine.[16] In the P to A direction, mean

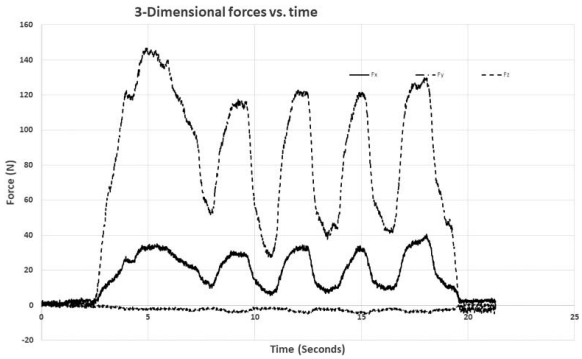

Figure 2 - Example of a force time profile that students were able to see for feedback.

and SD preload force delivered by experienced chiropractors was 95 N (34). Mean (SD) P to A peak force was 140 N (43). I to S mean (SD) preload force was 44 N (16), and mean (SD) I to S peak load was 65 N (10).[16] Inexperienced chiropractors delivered lower forces at first, but with training they were able to more closely approximate the preload and peak forces of the experienced chiropractors. In our study, students achieved peak forces closer to those of experienced clinicians. However, student preload forces, while they increased somewhat, did not approximate those of experienced clinicians. Emphasis during training sessions was directed toward the peak and not the preload forces. Future studies should target training for preload and peak forces.

In the previous study of the forces applied during the FD technique,[16] the Fz force (P to A) was the greatest force applied during treatment. The smallest force measure was the Fy force (medial to lateral). Our results were consistent with these findings. In the application of FD technique, students are taught to stabilize the spinal segment by applying a force from P to A and simultaneously from I to S, but without pushing toward the lateral direction. Students were able to perform the technique correctly in terms of the direction of the force applied. However, the magnitude of the force before force feedback training was much less than that applied by the experienced doctors in a previous study.

As stated above, the amount of force that is optimal for spinal manipulation is not known. Studies to date have measured the amount of force delivered during different types of spinal manipulation by experienced and novice

Table 2 - Preload and Peak Force Measurements by Group

Measurement	Group	Pre-Fz	Peak Fz	Pre-Fx	Peak Fx	Pre-Fy	Peak Fy
1	1 ($n = 32$)	2.7 (5.3)	63.0 (26.2)	5.2 (5.6)	13.5 (9.7)	−1.0 (3.7)	−.9 (5.3)
	2 ($n = 30$)	2.9 (5.6)	70.3 (25.8)	5.8 (7.5)	14.4 (11.4)	−2.7 (3.6)	−2.6 (5.6)
2	1 ($n = 30$)	14.1 (9.4)	127.3 (23.7)	17.7 (10.7)	26.2 (11.9)	−3.8 (6.7)	−4.8 (7.2)
	2 ($n = 28$)	5. 3 (10.1)	76.2 (20.0)	8.3 (11.2)	16.1 (12.8)	−2.0 (3.6)	−2.4 (4.7)
3	1 ($n = 30$)	17.7 (11.4)	127.5 (28.4)	22.0 (14.3)	35.1 (15.0)	−3.2 (5.3)	−3.3 (6.1)
	2 ($n = 28$)	15.2 (12.3)	113.5 (25.1)	20.2 (14.3)	37. 9 (17.6)	−.9 (5.9)	−.6 (7.3)
4	2 ($n = 28$)	10.7 (16.1)	114.2 (21.2)	16.1 (17.5)	24.7 (21.5)	−2.7 (6.2)	−3.4 (7.0)

Forces reported as mean (SD) Newtons (N). Measurement 1, Groups 1 and 2 baseline force measurements. Measurement 2. Group 1 post-training, Group 2 post-no training. Measurement 3, Group 1 one week post-training, Group 2 post-training. Measurement 4, Group 2 one week post-training.

Table 3 - Student Rating of the Usefulness of Force Feedback.

Response	Number (%)
Very helpful	9 (31)
Somewhat helpful	15 (52)
Neither helpful nor unhelpful	3 (10)
Somewhat unhelpful	2 (7)
Very unhelpful	0 (0)
Total	29
Mean (SD)	1.9 (0.8)

Total of 29 due to two missing responses.

chiropractors. Unfortunately, we are not aware of any studies comparing clinical outcomes from manipulations using different amounts of force. We assume that the amount of force used by an experienced chiropractor is necessary for therapeutic benefit. It is possible that the amount of force they use is arrived at by trial and error and after a number of years it is refined, but unfortunately, there is no evidence to support that supposition. This is clearly a limitation to this study.

In this study, students performing the FD technique were shown graphs of their forces while being trained with force feedback. The amount of force delivered by students during the FD technique previously could only be estimated by the instructor. We believe it is beneficial for students to be taught to deliver a similar amount of force as an experienced chiropractor. Gudavalli and Cox[16] identified the forces delivered by experienced chiropractors in preload and peak load during the FD technique. We used force feedback training to augment the training received by chiropractic students. Students who received force feedback training were able to learn to deliver higher forces, which were closer to those delivered by experienced DCs. Those students who did not receive force feedback did not increase the forces they delivered. The force feedback system was effective at increasing student's peak forces, and those improvements lasted at least 1 week after training.

A drawback to this system is discomfort from the force transducer that students experienced as a clinician and patient. The discomfort occurs for two reasons: the transducer consists of hard metal with rubber padding and students practiced several times in rapid succession on the same volunteer patient. Patient discomfort could be minimized by training using simulation mannequins in the future.

Students gave their opinion as to the helpfulness of the force feedback training and felt that it was somewhat or very helpful.

Limitations

Forces used by experienced clinicians were measured in a previous study. We conducted this study under the assumption that the force used by experienced clinicians is the appropriate amount of force for our students to deliver for optimum therapeutic effect. To our knowledge no studies of FD technique have compared the clinical results of different levels of force. We followed students in both groups 1 week after their force feedback training and found that the forces remained higher and closer to those of experienced clinicians after 1 week without training. One week is a short follow-up period. Future studies should follow students after a longer interval.

Conclusion

Students in this pilot study reported that force feedback training was helpful for learning FD technique. Students were able to deliver peak forces closer to the desired force level and to learn this delivery faster than students who were not trained with force feedback. Their ability to deliver these forces lasted at least 1 week after the training sessions. A future study must have a larger sample size for better power and to allow calculation of inferential statistics, as well as a longer follow-up period.

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Author Contributions

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REFERENCES

1. Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012;380:2163–2196.

2. Murray CJ, Vos T, Lozano R, et al. Disability-adjusted life years (DALYs) for 291 diseases and injuries in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet*. 2012; 380:2197–2203.
3. Buchbinder R, Blyth FM, March LM, Brooks P, Woolf AD, Hoy DG. Placing the global burden of low back pain in context. *Best Pract Res Clin Rheumatol*. 2013;27:575–589.
4. Deyo RA, Ching A. Surgical trials for pain relief: in search of better answers. *Pain*. 2012;153:2155–2156.
5. Deyo RA, Weinstein JN. Low back pain. *N Engl J Med*. 2001;344:363–370.
6. Hayden JA, Dunn KM, van der Windt DA, Shaw WS. What is the prognosis of back pain? *Best Pract Res Clin Rheumatol*. 2010;24:167–179.
7. Hayden JA, Chou R, Hogg-Johnson S, Bombardier C. Systematic reviews of low back pain prognosis had variable methods and results: guidance for future prognosis reviews. *J Clin Epidemiol*. 2009;62:781–796.
8. Tiira AH, Paananen MV, Taimela SP, Zitting PJ, Jarvelin MR, Karppinen JI. Determinants of adolescent health care use for low back pain. *Eur J Pain*. 2012;16:1467–1476.
9. Martin BI, Deyo RA, Mirza SK, et al. Expenditures and health status among adults with back and neck problems. *JAMA*. 2008;299:656–664.
10. Friedly J, Standaert C, Chan L. Epidemiology of spine care: the back pain dilemma. *Phys Med Rehabil Clin N Am*. 2010;21:659–677.
11. Christensen MG, Mark G., Kollash MW, Hyland JK. *Practice Analysis of Chiropractic 2010: A Project Report, Survey Analysis, and Summary of Chiropractic Practice in the United States*. Greeley, Colorado: National Board of Chiropractic Examiners; 2010.
12. Snodgrass SJ, Rivett DA, Robertson VJ. Manual forces applied during posterior-to-anterior spinal mobilization: a review of the evidence. *J Manipulative Physiol Ther*. 2006;29:316–329.
13. Snodgrass SJ, Rivett DA, Robertson VJ, Stojanovski E. Real-time feedback improves accuracy of manually applied forces during cervical spine mobilisation. *Man Ther*. 2010;15:19–25.
14. Triano JJ, Scaringe J, Bougie J, Rogers C. Effects of visual feedback on manipulation performance and patient ratings. *J Manipulative Physiol Ther*. 2006;29: 378–385.
15. Triano JJ, Descarreaux M, Dugas C. Biomechanics–review of approaches for performance training in spinal manipulation. *J Electromyogr Kinesiol*. 2012; 22:732–739.
16. Gudavalli MR, Cox JM. Real-time force feedback during flexion-distraction procedure for low back pain: a pilot study. *J Can Chiropr Assoc*. 2014;58:193–200.