Research

Pilot Study of Spinal Manipulation Impact on Sport-Specific Reaction Time and Core Proprioception Amongst College Students with Spine Pain

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Abstract

Objective: To determine whether spinal manipulative therapy (SMT) beneficially affected reaction time and/or core proprioception in individuals with spine pain during two sport-specific simulation tasks.

Methods: Fifty-four college students each stood on a force plate while holding a basketball in the triple threat position. After receiving a visual computer prompt to jump left their reaction time was recorded in milliseconds. Next, participants stood in a football player receiver position with fixed footing and were asked to rotate their body 90° to the left while being recorded with motion analysis cameras. Their ability to attain exactly 90° with their hips/core was recorded. Participants were then assigned to study groups based on absence or presence of spine pain; the latter group was further allocated to SMT or no SMT intervention groups. Following the intervention phase all participants repeated the baseline tests. A between-within repeated-measures analysis of variance (ANOVA) using between-subjects factor "group" and within-subjects factor "time" (baseline and post-test) was used to analyze study data.

Results: There was no statistically significant difference for the reaction time task for group*time $F(2,51) = 1.577$, $p = 0.219$, $r = 0.17$. Similarly, for core proprioception angle there was no statistically significant effect for group*time, $F(2,51) = 0.273$, $p = 0.762$, $r = 0.07$.

Conclusions: Preliminarily, a single spinal manipulation did not improve reaction time or the ability to increase approximation to 90° during the hip/core rotation task for chiropractic college students with low levels of spine pain.

Introduction

Physically demanding sports, such as football, gymnastics, and wrestling place a high level of stress on the spine and increase the likelihood of developing neck or low back pain[1-5] Spine pain has been shown to result in reduced athletic performance in sport activities.[6] Zamani *et al*, in their athlete focus group study, found that one of the greatest concerns of athletes with spine pain was the dramatic limitation in range of motion and ability to change direction quickly.[7] Due to these impairments spine pain is one of the most common causes of missed play.[8]

Individuals with neck and low back pain have been found to have significantly more impairments in proprioception than asymptomatic controls.[9-13] This includes impairments in psychomotor speed,[14-18] repositioning accuracy,[9-10,19-20] and postural control.[12,14,21-24] When performing motor tasks, individuals with spine pain often exhibit aberrant patterns of muscle contraction.[25-27] Often agonists and antagonists are both active throughout motion, which is believed to be due to guarding.[28-29] It also takes longer for localized spinal muscles to relax as well as to be activated if a person has spine pain,[28] which can contribute to making their motions slower.[30-31] In addition, the fear of causing further injury may lead to self-restraint on athletic performance.[15,32]

The utilization of Spinal Manipulative Therapy (SMT) to treat spine pain is common among professional athletes. Chiropractic doctors provide such interventions for the Olympics,[33] National Football League,[34] National Hockey League,[35] world-class bicycle motocross (BMX),[36] national level Taekwondo competions,[37] and several other sports events/organizations. Although significant research about SMT has been published in peer-reviewed journals to substantiate its positive impact on neck pain[38-42] and low back pain,[43-48] there is very little evidence about its impact on athletic performance. Specifically, there is limited evidence to address the ability of spinal manipulation to improve athletic performance in an athlete currently experiencing spine-related pain. The majority of existing exercise science research that includes asymptomatic participants (that is, individuals without spine pain), appears to suggest that SMT neither improves nor diminishes athletic performance.[49-54] Studies of lower thoracic, lumbar spine, or sacroiliac SMT have demonstrated that manipulation does not impact runner performance on maximal graded exercise tests (GXT),[49-50] cyclist cycle ergometer power output and hamstring flexibility,[31] or track-and-field athlete sprint performance[52-53] and jump height.[53]

Studies involving the impact of SMT on proprioception are limited. Learman *et al* suggest that SMT has a small capacity to impact trunk proprioception short-term for chronic low back pain patients.[55] They found a positive effect for threshold to detect passive motion (TTDPM) induced by a researcher following SMT ($p=0.008$), but found it had no impact on force reproduction or sensation of direction of motion.[55]

The purpose of this study was to determine whether there was a difference in reaction time or hip/core proprioception in sport-related tasks between participants with spinal pain who received SMT and controls.

Methods

This study was reviewed and approved by the Texas Chiropractic College (TCC) Institutional Review Board for human subjects in accordance with the Declaration of Helsinki. This trial was registered with the University hospital Medical Information Network Clinical Trials Registry (UMIN-CTR), trial number: UMIN 000020808 (Reg# R000024022).

Study Design and Setting

The study focused on the immediate impact of SMT on reaction time and hip/core proprioception during two sport-specific tasks amongst participants with spine pain (**Fig. 1**). Initially, participants engaged in a basketball reaction time task on a force plate (**Fig. 2**). The test measured how quickly participants could jump off of a force plate in response to a visual prompt. Participants then simulated an offensive football blocking and turning task by rotating their hips 90° to the left from an initial stationary position after receiving a verbal command (**Fig. 3**). A VICON motion analysis system (Vicon, Centennial, CO, USA) was used to determine how accurate participants were at attaining exactly 90°. Participants were then initially divided into no spine pain and spine pain groups. Participants in the spine pain group were further randomized into an SMT and no-SMT group to yield three total study groups: no spine pain-no SMT (control group #1), spine pain-SMT (experimental group), and spine pain-no SMT (control group #2). Control group #1 was utilized to measure within-group variability with repeated testing. Control group #2 was needed for perspective in case there were significant changes observed within the experimental group. After the intervention, or lack thereof, participants engaged in a post-test of the same basketball reaction time and football hip/core proprioception tasks within 2-minutes of baseline testing. Researchers chose these two sport-specific tests because they simulated actions a person could experience while playing a sport. This experiment occurred in a research lab over several weeks between 12-1 PM at one 10-min data collection session per participant. Researchers avoided playing music in the lab to avoid distracting participants and acting as a covariate to try harder in some manner.[56]

Figure 1. Study design.

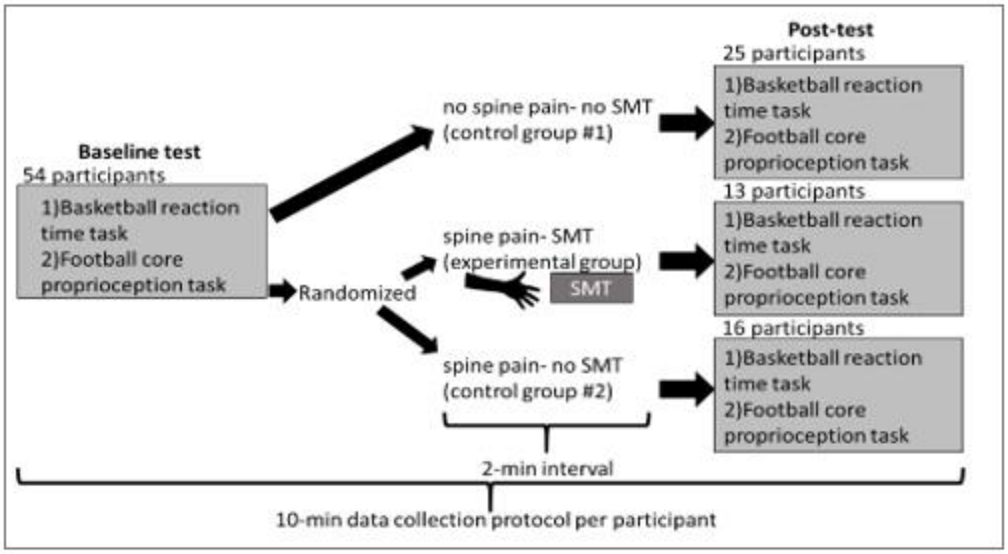


Figure 2. Basketball reaction time task: A) triple threat start position and C) finish position. Image B is from the Bertec force plate at baseline. Participants were instructed to cut left as fast as they could once they saw a visual computer prompt in front of them.

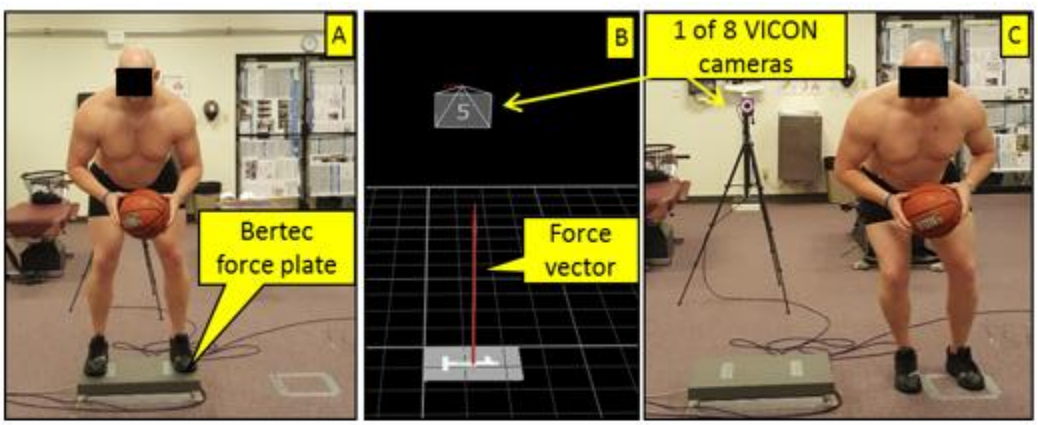
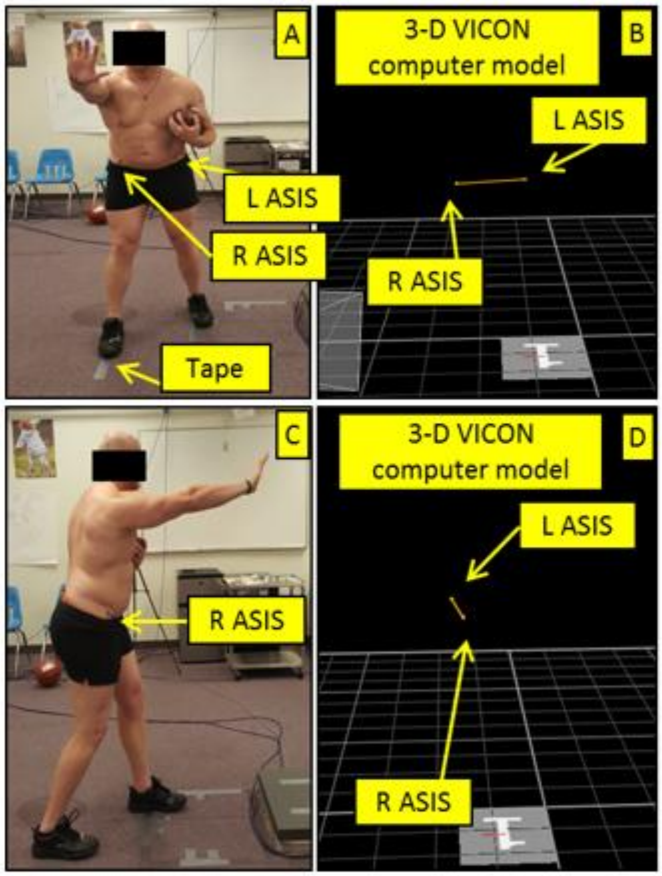


Figure 3. Football core proprioception task: A) start position and C) end position. Silver motion analysis reflective markers were placed on the right and left ASIS of participants. Images in B and D illustrate the line drawn between the ASIS markers with the VICON motion analysis system. During this task, participants attempted to accurately rotate their body 90° to the left. Tape was used to mark heel placement to keep it similar at baseline for all participants.



Participant recruitment and preparation

Student volunteers were recruited via word-of-mouth through multiple college classes. Study applicants contacted the researchers for screening to determine whether they met the inclusion and exclusion criteria (**Fig. 4**). The study criteria and protocol were available to interested participants in advance of the study.

Figure 4. Study inclusion and exclusion criteria.

Inclusion criteria were:
1) college students 18-50 years of age

Study participants with any of the following were excluded from the study:
1) severe osteoporosis
2) multiple myeloma
3) osteomyelitis
4) bone tumor
5) Paget's disease
6) cauda equina syndrome
7) spinal cord tumor
8) rheumatoid arthritis
9) ankylosing spondylitis
10) psoriatic arthritis
11) unstable bleeding disorder
12) any additional condition that would make spinal manipulation unsafe for the participant

All study applicants gave written informed consent prior to participating in this study. **Table 1** lists the attributes of the three study groups at baseline. Pain was only recorded at baseline and not post-intervention using a 0-10 numeric rating scale (NRS).[57] This was purposely done because researchers felt participants would feel compelled to provide a lower number if asked in such close succession to intervention. This pilot study utilized a convenience sample and did not follow an *a priori* power analysis. There were 25 participants in the no spine pain-no SMT group, 13 participants in the spine pain-SMT group, and 16 participants in the spine pain-no SMT group. During the experimental procedure, males wore only black shorts and black tennis shoes. Females wore black shorts, a non-reflective sports bra, and black tennis shoes. Standardized attire was provided by the research lab and was used to reduce the likelihood of any reflective clothing interfering with the VICON camera recordings. Additionally, participants were asked to remove any reflective jewelry to further reduce light reflections that would impair motion analysis recordings.

Table 1. Baseline participant demographic, anthropometric, and pain attributes.

	no spine pain- no SMT	spine pain- SMT	spine pain- no SMT	*P*-value
Sex (M/F)	10/15	9/4	6/10	
Age (y)	27.0 ± 5.2	26.4 ± 6.5	27.8 ± 5.8	0.812
Mass (kg)	74.0 ± 18.6	88.6 ± 17.1	79.4 ± 18.7	0.077
Height (m)	1.71 ± 0.07	1.77 ± 0.09	1.72 ± 0.11	0.132
Body Mass Index (kg/m^2)	25.3 ± 5.9	28.4 ± 5.6	26.6 ± 4.3	0.256
Pain (0-10 NRS)	na	3.0 ± 1.9	3.1 ± 1.6	0.847
Age range (yrs)	22-43	22-44	22-44	

Most data listed as mean ± SD.
na= not applicable.

Basketball reaction time task

Prior to utilizing the force plate during each data collection it was zeroed. Participants stood in a crouched “triple threat” basketball position on top of the Bertec 4060-NC (Bertec Corp., Columbus, OH, USA) force plate. Two strips of duct tape were placed on top of the force plate to mark foot placement for all participants for standardization. The participants were instructed to place their feet just lateral to the two strips of duct tape and hold a basketball in their hands. A computer screen displayed a timed PowerPoint (Microsoft, Redmond WA, USA) to the participants, which instructed them to cut to their immediate left off of the force plate as quickly as possible. The “jump left” command appeared after 5-seconds. The VICON software was synchronized to begin recording at the same time as the PowerPoint display began. Participants were all asked to perform one practice cutting maneuver prior to being recorded. A small gray box was taped to the left of the force plate as a target for participants to aim for with their lead outside foot. Researchers chose to have participants only cut left for standardization. The time to get both feet off the force plate was recorded. This was determined by the force plate reaching 0 Newtons of force relative to time. Force plate data was recorded at 1,000 Hz.

Football hip/core proprioception task

Participants stood with their right upper extremity extended to the front at shoulder level simulating a blocking maneuver, while holding a football just above their left hip, as shown in Fig. 3. The right lower limb was extended forward in line with the right shoulder, while the left lower limb was extended to the back, in line with the left shoulder. Participants were asked to place their heels at the base of tape marks on the ground before starting the activity. Silver 19mm MoCap (MoCap solutions, Huntington Beach, CA, USA) reflective markers were placed on their right and left anterior superior iliac spine (ASIS) using surgical tape. The Vicon MX camera motion analysis system consisted of 8 infrared Bonita 0.3 megapixel cameras and was calibrated daily as suggested by the manufacturer. Kinematic data were recorded at 100 Hz using Nexus 1.7.1 software. After participants assumed the starting position the motion recording was begun. Within approximately two seconds, participants were verbally commanded to turn their hips 90° to the left, along with the rest of their body, and then freeze. At baseline, mathematically a line was formed between their ASIS. After turning to the left and freezing, a second line was established between their ASIS at the new position and the angle between the two lines was calculated as described in **Fig. 5**. The ability of the participant to accurately reach 90° was used as a measure of a participant's core proprioception capability. Participants practiced once before their actual recording.

Figure 5. Illustration of how hip rotation angle was determined in the horizontal plane utilizing x and y coordinates in relation to our localized horizontal plane coordinate system. The x and y position of centroid A was determined using the middle x point between the R and L ASIS points at base and the middle y point between the R and L ASIS points post. Next, ray AB, ray BC, and ray CA length were determined in millimeters. For example, for ray AB the absolute difference between A and B x were determined. Then the absolute difference between A and B y were determined. Next the following formula was applied to determine ray length: After this, ray length (ray BC= a, CA= b, and AB= c) was entered into the following formula: . Lastly, =(ACOS(answer)*180)/3.14 was used in Excel to determine the angle of A. This procedure was performed pre and post intervention to measure angle accuracy for participants in each of the three study groups.

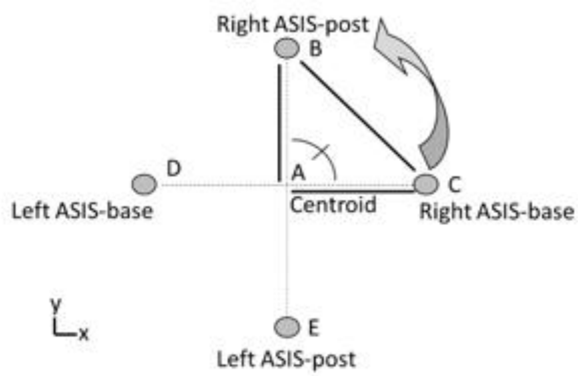


Table 2. Comparison of the study groups on mean reaction time and the degrees participants were off from 90° for the hip/core proprioception task.

	no spine pain-no SMT	spine pain-SMT	spine pain-no SMT	*P*-value
Baseline reaction time (s)	5.59 ± 0.09	5.55 ± 0.12	5.63 ± 0.16	0.296
Post-test reaction time (s)	5.60 ± 0.20	5.56 ± 0.09	5.56 ± 0.11	0.618
Baseline - post-test diff.	-0.01	-0.01	0.07	0.219
Baseline degrees off (°)	11.9 ± 9.1	12.6 ± 7.1	9.1 ± 6.9	0.522
Post-test degrees off (°)	12.4 ± 8.9	11.9 ± 5.1	11.6 ± 8.3	0.964
Baseline - post-test diff.	-0.5	0.7	-2.5	0.762

Most data listed as mean ± SD.

Spinal Manipulative Therapy

The intervention phase of the study was performed by a chiropractor with 22 years of experience. SMT was performed at regions of the spine that the patient reported feeling pain. Individuals with cervical spine pain received a supine index push to the articular pillars of the affected cervical spine motion unit.[58] Participants with thoracic pain received an anterior thoracic manipulation.[58] If the participant had lumbar spine pain, a side-posture hypothenar mammillary push occurred at the affected lumbar vertebrae.[58] All spinal manipulations consisted of a Diversified high-velocity low-amplitude force.[58] No attempt to record an audible sound from SMT was made. All SMT was performed on the side of pain, or focused on the side of pain as in the case of the anterior thoracic SMT, as recommended by existing treatment guidelines.[38]

Statistical analysis

The data were analyzed in SPSS version 20.0 (IBM, Armonk, NY, USA). Results are reported as mean ± standard deviation (SD) unless otherwise specified. A one-way analysis of variance (ANOVA) was used to compare between-group differences at baseline for age and anthropometric data amongst all three groups. The Levene's test of homogeneity of variances was observed. An independent samples *t*-test was used to compare pain for the two spine pain groups on the NRS. The alpha level of $P \leq 0.05$ was considered statistically significant for between-group baseline data.

Data in the form of .csv files was processed with a Butterworth filter before being exported from VICON Nexus software and entered into Excel (Microsoft Office, Redmond, WA, USA). Simple geometry was used to determine horizontal plane angles for the football hip/core rotation task as described in Fig. 5. The absolute value of the degrees off from 90° was determined in Excel per participant at baseline and again at post-test for the hip rotation task. Force plate-derived reaction time and hip rotation angle proximity data were then exported to SPSS for further analysis. A between-within repeated-measures analysis of variance (ANOVA) using between-subjects factor "group" (no spine pain-no SMT, spine pain-SMT, and spine pain-no SMT) and within-subjects factor "time" (baseline and post-test) was used to analyze study data. Mauchly's test of sphericity was not observed due to having only two levels of the within-group repeated measure (pre vs post).[59] Levene's test of equality of error variances was observed. A Bonferroni post hoc test was conducted on data among all ANOVAs to determine which condition was significant.[59] The alpha level of $P \leq 0.05$ was considered statistically significant for all data analyses. The researcher analyzing force plate and motion analysis data was blinded as to participant group designation until after all data was processed individually per participant and was ready to be compiled into three groups for analysis.

Results

Two participants were excluded from the study, both due to possessing knee surgeries. There were no statistically significant differences between the three groups at baseline for anthropometric or age data (as shown in table 1). There was no statistically significant difference between the spine pain-SMT and spine pain-no SMT groups for baseline pain on the NRS (p=0.847).

There was no statistically significant difference for the reaction time task for group*time, $F(2,51) = 1.577$, $p = 0.219$, $r = 0.17$. Participants, generally, were able to jump off of the force plate within 0.6 seconds of the computer prompt. For absolute value of hip/core proprioception off of 90° there was no statistically significant effect for group*time, $F(2,51) = 0.273$, $p = 0.762$, $r = 0.07$. All groups generally were within 12° of rotating their hips exactly 90° on their pre and post attempt. No adverse events were observed in this study.

Discussion

Pain is known to impair motor control.[60-64] Generally speaking, when individuals feel pain, they guard against actions which would provoke further pain.[65] The researchers theorized that if SMT resulted in pain relief, then it might have a short-term beneficial impact on motor control. Several studies and treatment guidelines demonstrate SMT lowers spine-related pain.[38-48]

Balance and coordination require the integration of sensory input and coordinated motor output.[66] Patients with spine pain have been shown to have impairments in proprioception.[10] Preliminary studies have suggested that SMT can stimulate proprioceptors in joints and muscles.[67-68] The implications of this for improved motor control in individuals with spine pain has not been thoroughly studied. The findings of this study were that there was no difference between the study groups in terms of their ability to approximate 90° during the hip/core proprioception task.

Reaction time, represents the time it takes to initiate a response after being presented with a stimulus.[69] Reacting quickly to the localized environment is an important attribute for optimal athletic performance. Impairments in neurologic function, as has been clearly demonstrated in sport concussion research, can slow reaction time and increase the variability of performance on reaction time tests.[70-73] In the present study there was no difference between groups for reaction time.

Possible future directions of research that could stem from this study could be: 1) test SMT impact on proprioception among individuals with spine pain in the general public, preferably using athletes, 2) perform a similar study utilizing a more standardized test of reaction time (such as catching a ruler between the thumb and forefinger when dropped)[70-73] or proprioception, or 3) test-retest reliability and validity studies could be performed utilizing the tests that were performed in this experiment.

Limitations

One consideration with this study design was the way that reaction time and hip/core proprioception were measured. Although it is not uncommon for researchers to develop new ways of measuring reaction time or proprioception,[74-75] the results may have been different had we used a measure that had been tested more often in research to allow for comparison.[70-73] There is some debate about the most ideal way of measuring proprioception for individuals with spine pain.[19,55] Visual input has been shown to enhance joint position sense,[76] and thus it is generally preferred to have proprioceptive tests block visual input in some manner.[24,76-77] It could also be argued that the core rotation task likely would not have significantly amplified pain as the participant turned, because they were rotating their trunk as a whole. As a result, future studies should attempt to develop a new proprioceptive task that would be more physically taxing.

The researchers did not measure pain post-SMT. This was intentional because the researchers felt, based on their own previous SMT research, that a participant might feel compelled to provide a lower NRS pain value if asked in such close succession to the intervention. It could be argued; however, that this was a design limitation because if the study's premise was that lowered pain would result in improved function the only way to confirm that would be to ask the participants about their pain after the intervention phase.

It could be argued that mean pain level on the 0-10 NRS of participants in this study was not high enough to significantly impair function. Perhaps for future studies a higher minimum pain threshold could be used for participant inclusion criteria.

This study involved only one SMT treatment. It could be argued that multiple SMT treatments would be necessary to positively impact the variables studied. Most research on SMT that demonstrates significant change in outcomes involves multiple SMT treatments over weeks and not a singular treatment.[38-48]

There were also two limitations on external validity in this study. The sample population used in this experiment consisted of chiropractic college students. They are accustomed to undergoing spinal manipulation often and may have responded differently than the general public. Additionally, the population sampled for this study consisted of typical college students and was not specifically composed of athletes. As a result, athletes may have reacted differently because they would likely have had greater motor control over their body.

Another limitation is the study did not follow a power analysis. After the study was completed, researchers performed a post-hoc power analysis using G*Power version 3.1.9.2 (Universität Kiel, Germany) to determine what an ideal sample size would be for this study.[78-79] For a repeated measures ANOVA with between factors analysis with an effect size f of 0.25, alpha error probability of 0.05, power of 0.8, number of groups at 3, number of measurements at 2, and correlation among repeated measures at 0.5, a total of 120 participants would need to be recruited. Although this pilot study did not have a large enough sample size for appropriate study power it does provide information that can help guide future chiropractic-related exercise science researchers.

Conclusion

Neck and low back pain are associated with impairments in motor control patterns. Motor control capabilities impact sport-related reaction time and proprioception. Spinal manipulation has been shown to lower spine-related pain. Spinal manipulation for chiropractic college students with spine pain in the present study did not result in statistically significant improvements in reaction time or hip/core proprioception. The findings of this pilot study demonstrated the study protocols are feasible; however, performing this study on individuals in the general public with a larger sample size would be more informative.

Funding sources and conflicts of interest

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