Effects of Spinal Manipulation on Trunk Proprioception in Subjects With Chronic Low Back Pain During Symptom Remission ☆

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ABSTRACT

Objective: The purpose of this study was to examine the immediate effects of spinal manipulative therapy (SMT) on trunk proprioception in subjects with asymptomatic chronic low back pain (CLBP) and determine if those effects lasted 1 week.

Methods: This unbalanced randomized controlled crossover design examined 33 subjects with CLBP. Proprioception was tested via joint position sense, threshold to detect passive motion (TTDPM), direction of motion (DM), and force reproduction. Each subject received lumbar manipulation or a sham procedure followed by proprioception retest. This procedure was repeated 1 week later using the opposing treatment. Subjects receiving SMT in the second session returned a third time receiving the sham procedure again.

Results: Spinal manipulative therapy produced an effect for TTDPM in the manipulation first group ($P = .008$), the sham procedure produced an effect for joint position sense in the sham first group ($P = .005$). Spinal manipulative therapy had a 1-week effect for the manipulation first group ($P = .006$). No effect was noted for either DM or force reproduction.

Conclusions: Results suggest SMT had minimal immediate effect on trunk proprioception. The effects noted occurred in session 1, implicating learning as a potential source. Learning, from repetitive proprioception training, may enhance neuromuscular control in subjects with CLBP before the use of therapeutic exercise. Subjects showed smaller deficits than previously reported for TTDPM or DM, suggesting proprioception deficits may correlate with pain level. (J Manipulative Physiol Ther 2009;32:118-126)

Key Indexing Terms: *Low Back Pain; Manipulation, Spinal; Proprioception; Randomized Controlled Trial*

Proprioception is a key component of the sensorimotor system and is responsible for providing the central nervous system with afferent information used for neuromuscular control (NMC) while contributing to dynamic joint stability.[1] Proprioception is defined as the afferent input of internal stimuli from proprioceptive fibers within the body screened from the external environment responsible for body segment stability, posture control, and certain conscious sensations.[2] There is evidence suggesting that NMC remains dysfunctional after a reduction of symptoms during an acute period of low back pain (LBP).[3] Neuromuscular control is dependent on proprioception as a

component of the sensorimotor system.[2] Proper return of NMC demands proper selection and dosage of germane therapeutic interventions.

At present, selective spinal strengthening exercises have been associated with improvement in NMC. Past studies have shown that an increase in cross-sectional area of multifidus can be obtained through the use of selective muscle activation (transversus abdominis and multifidus)[4] and bilateral lower extremity leg lifts, incorporating 5-second isometric holds.[5] The success of these exercises may implicate a reduction in reflexive inhibition of those muscles involved. Other studies have suggested that muscle recruitment patterns in trunk stabilizers can be enhanced with selective deep muscle training,[6] resulting in a more favorable internal oblique to rectus abdominis recruitment ratio. Temporal changes have also been noted with an increased rate of intra-abdominal pressure development during functional challenges to trunk control.[7] This point implicates an improvement in anterolateral trunk control from an exercise program of specific exercises to activate the anterolateral trunk with rotational movements.[7] What is unknown is the utility of other therapeutic techniques such as spinal manipulative therapy (SMT) and the degree of influence on NMC, specifically proprioception.

Spinal manipulative therapy is purported to relieve pain through modulation of nociceptive input through a barrage of afferent input to the central nervous system,[8] resulting in pain reduction and improved perceived function for up to 6 months.[9] Past findings have identified additional neurophysiologic effects associated with SMT such as electromyographic alteration[10] and increased range of motion[11]; therefore, it may be reasonable to surmise that SMT affects additional mechanisms, potentially beyond the exclusive domain of nociceptive control, such as proprioception.

The objective of this study was to examine the immediate and temporal effect of SMT on subjects with a history of chronic LBP (CLBP) who currently have little or no pain symptoms, to determine if one of the underlying physiologic mechanisms of action for SMT is the enhancement of proprioception. We hypothesized that SMT would enhance proprioception evidenced by reduced absolute error (AE) rates for joint position sense (JPS), direction of motion (DM), and force reproduction (FR), and would reduce the angle for threshold to detect passive motion (TTDPM). Findings may support the use of SMT to improve trunk proprioception in subjects with chronic low back conditions.

METHODS

This study was a randomized, controlled, unbalanced crossover design comparing SMT with a sham procedure on trunk proprioception in subjects with CLBP. Dependent variables included trunk proprioception measured by JPS, TTDPM, DM, and FR. Independent variables included treatment procedure and time. The study was approved by the university's institutional and ethics review board, and the subject's rights were protected.

Subjects

Potential subjects, with a targeted age of 18 to 65, were recruited from the community for a 3-month period. Upon contact and consent for participation in the study, subjects met inclusion criteria if their general physical examination criteria was consistent with a history of CLBP defined by one episode of LBP of at least 3 months' duration[12] during the past year or recurrent episodic LBP[13,14] with at least 2 significant bouts within the past year. The subjects needed to be experiencing minimal to no pain at the time of testing. The examination included a comprehensive history of their CLBP, past treatments, and general medical questions to rule out contraindication for spinal manipulation. Range of motion and strength testing for the spine and hips, neurologic testing, and special tests were performed as appropriate. The examination was used to confirm that each subject showed signs and/or symptoms consistent with mechanical LBP defined by activity and/or positional dependent behavior and to rule out the presence of systemic pathology, acute nerve root irritation, acute disk herniation with foraminal stenosis, and/or advanced central stenosis. Subjects showing any of the aforementioned findings were excluded from participation. Each subject showed at least one dysfunctional segment at the time of testing.

All subjects completed the Oswestry Disability Index (ODI), the visual analog scale for average pain rating during the past 24 hours (VAS-24),[15] and the numeric rating scale (NRS), 0 to 10[16] for current pain. Because of the well-documented effect of pain on proprioception, and because we desired to control this confounding element, we targeted subjects with a pain score of lower than 1 on the NRS and an average pain level during the previous 24 hours (VAS-24) of lower than 3.

Instrumentation

Trunk proprioception was assessed using the Biodex System 3 (Biodex Medical Inc, Shirley, NY) with a sagittal plane trunk attachment (Fig 1). For proprioception application, the intraclass correlation coefficient (standard error of measurement) ($ICC_{3,k}$ [SEM]) was examined in our laboratory for 16 subjects tested in 3 sessions for a 1-week period. A grand ICC was established as a combined intraday and interday value and found to be substantial[17] for FR and JPS with 0.607 (0.1937 N m) and 0.785° (0.1058°), respectively, and outstanding[17] for TTDPM with 0.904° (0.0471°). The Biodex Systems 3 was equipped with software allowing passive velocities of 0.25°/s, making it more appropriate for assessing TTDPM.[18] Custom protocols allowed investigators to perform multiple repetition trials while altering visual input to assess FR.

Fig 1. *Biodex Systems 3 with sagittal plane trunk attachment.*

Outcome Measures

Pain and disability measures were used, including the NRS and VAS-24 for pain and the ODI and Fear and Avoidance Behavior Questionnaire (FABQ) for disability. The VAS is a self-reported pain assessment tool with established test-retest reliability of ICC = 0.99 for acute pain.[19] The VAS-24 is more responsive to change than either the standard VAS or the McGill pain questionnaire, making it the preferable pain tool for clinical trials and practice.[15] The NRS is a self-reported pain scale that is the most frequently used scale in clinical practice.[20] The test-retest reliability and validity have been found to be sufficient for use in subjects with CLBP.[21]

The ODI is a self-report questionnaire measuring perceived disability related to LBP. The ODI has a sufficient scale width to detect positive or negative changes with validity,[22] and the test-retest reliability (r = 0.94-0.99), construct validity, and responsiveness properties have been repeatedly evaluated as clinically effective.[23] The minimum clinically important difference has been established at 6% and is used to distinguish a difference that can be interpreted as a true change from a stable condition.[24,25] The FABQ was used to assess the subject's perception of how activity affects their back

pain. It is divided into 2 sections, normal physical activity and work-related activity.

Testing Procedures

Proprioception testing. Subjects were randomized to their respective treatment groups by drawing marked coins, receiving either manipulation first (group A) or sham procedure first (group B). After assignment, the subject was firmly secured to the attachment using Velcro straps to stabilize the sacral base, to minimize hip and pelvic involvement, and to ensure trunk movement consistent with the dynamometer.

Joint position sense was assessed starting from a neutral spine position with a blindfold to limit visual cueing. The subject actively moved forward to the 30° target position and was instructed to remember the position while it was held for 5 seconds. The subject returned to neutral, then was instructed to actively move back to the target position and mark the position by depressing a hold button. This procedure was repeated until 6 trials had been collected. The mean AE (the difference between reposition angle and target angle) was determined and recorded for data analysis.

Threshold to detect passive motion and DM were tested by placing the subject in the neutral starting position while blindfolded and wearing headphones with white noise to reduce external visual and auditory input. The Biodex was started in passive mode at 0.25°/s. The investigator instructed the subject to press the hold button upon first perception of trunk motion and identify in which direction the movement occurred. The time from initiation of white noise to commencement of motion was varied for each trial, between 2 and 20 seconds. Six trials were performed, 3 toward flexion and 3 toward extension, in a variable fashion to establish accuracy of direction as well as sensitivity to movement. The threshold angle of movement (angle of detection−starting angle) was averaged, and the percentage of correct directional responses was recorded for statistical analysis.

To measure FR, we performed a maximal voluntary isometric contraction toward extension from neutral to establish a target force value for testing. Fifty percent of this value was used as the target force because it has been established as an appropriate submaximal value for force replication studies in peripheral joints.[26,27] This value was located on the computer monitor as a target line. After a familiarization trial of up to 5 repetitions to get accustomed to a specific, targeted, force level production, the subject performed an isometric contraction against the dynamometer to the target. The force was held for 5 seconds. After a 5-second pause, visual feedback was eliminated, and the subject attempted to replicate the force for 5 seconds. This procedure was performed for 5 pairs of trials. The force value for the last 4 seconds of each repetition was averaged, and the error rate (mean replication trial − mean visual reference trial) was averaged for statistical analysis.

Fig 2. *Neutral gapping spinal manipulation procedure in side lying.*

Fig 3. *Joint position sense.*

Table 1. *Subject characteristics*

	Group A Mean (SD)	Group B Mean (SD)	t	χ^2	P
Age (y)	37.4 (9.21)	37.25 (8.65)	0.052		.959
Height (cm)	176.2 (9.2)	175.9 (8.7)	0.113		.911
Mass (kg)	85.53 (11.48)	85.43 (17.77)	0.019		.985
Sex				0.081	.776
Male	12 (70.6%)"	12 (75%)			
Female	5 (29.4%)	4 (25%)			
ODI (%)	22.12 (16.7)	25.33 (19.68)	−0.772		.446
NRS	0.12 (.49)	0.25 (.68)	−0.645		.524
VAS-24 (cm)	0.769 (.79)	1.0 (1.05)	−0.489		.628
FABQ—PA	16.0 (6.02)	16.57 (4.20)	0.059		.953
FABQ—W	9.65 (7.51)	9.62 (9.09)	−0.478		.636

PA, physical activity subscale; *W*, work subscale.

Controlled Intervention

After initial testing, the subject received a segment-specific neutral gapping spinal manipulation or a sham procedure in the manipulative position to simulate a manual technique and blind the subject to treatment group. To perform the manipulation, we positioned the subject on their self-reported painful side. The investigator isolated the involved dysfunctional segment (defined by apparent aberrant or reported symptoms during physical examination) by flexing the subject's spine from below until gapping was felt at the inferior spinous process. The trunk was passively rotated until the superior spinous process moved. The subject was taken to the end of available trunk rotation where the therapist applied a high-velocity and low-amplitude thrust into the barrier of movement (Fig 2). If no cavitation was perceived audibly or by palpation, a second thrust was performed. If cavitation was still not perceived, the subject received up to 2 thrusts on the opposite side using a sequence previously described.[9,28-30]

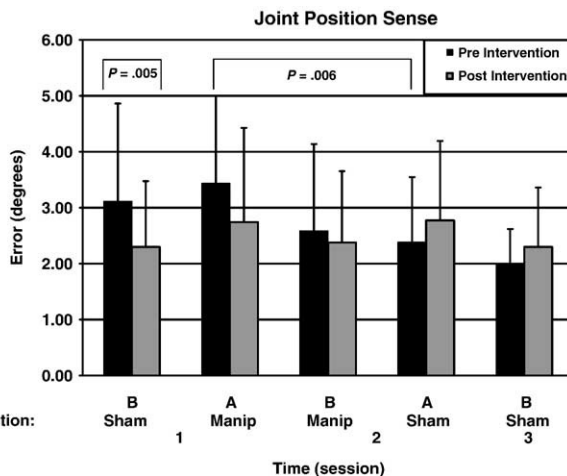The sham procedure was performed by placing the subject on their painful side and flexing their lower body slightly to simulate a premanipulative setup. The investigator placed a hand on the thoracolumbar junction to shield the lumbar region from movement, whereas the other forearm was placed on the shoulder to rotate the thoracic spine into midrange. This position was held for 15 seconds before being returned to neutral. The subjects were instructed that 2 interventions were being compared to blind the subjects to study goals. After the intervention, all testing was repeated in a predetermined randomized order. The subject then filled out the NRS to assess for treatment effect.

One week later, each subject returned for a second session. Before testing, each subject filled out an activity questionnaire to determine if any substantive change occurred in their back condition during the preceding week. In this testing session, each subject received the opposite treatment, and testing followed a new randomized order. One week after the second testing session, subjects from group B returned for a third testing session. This final session was used to assess the 1-week residual effect of manipulation.

Data Analysis

An a priori power analysis determined that 13 subjects were required for each treatment group to obtain a power of .798 for a period effect and .88 for a treatment effect at $\alpha <$ .05. This analysis was based on an estimated effect size derived from a study examining proprioceptive differences between healthy subjects and those with LBP.[31] The proposed effect size may have been inflated because it was not derived from pilot data; therefore, 15 subjects were included per group.

The average AE rates for JPS, DM, and FR and the angle for TTDPM were analyzed using a mixed-model univariate analysis with repeated measures in SPSS 15.0 (SPSS, Chicago, Ill). If statistical significance was found, multiple comparisons were performed using paired *t* tests with the
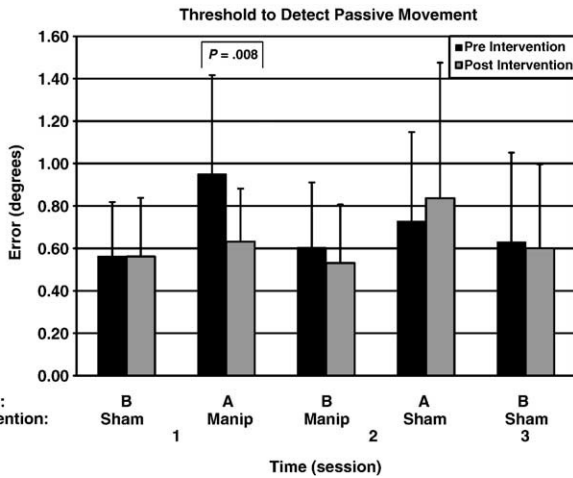
Fig 4. *Threshold to detect passive motion.*

Fig 5. *Direction of movement.*

appropriate Bonferroni adjustment. Paired *t* tests were restricted to those comparisons that would directly measure pairs corresponding to the study hypotheses of immediate treatment effect and 1-week residual effect. For group A, 3 comparisons were made resulting in a Bonferroni adjustment of $\alpha = .017$. For group B, having 3 testing sessions and 6 periods, 5 pairs were analyzed resulting in a Bonferroni adjustment of $\alpha = .01$.

RESULTS

Thirty-five subjects between 24 and 54 years of age were initially recruited for the study. Two subjects did not meet inclusion criteria (pain level >1/10) and were not examined. No subject attrition occurred; therefore, all 33 subjects tested completed data collection and were eligible for data analysis. All subjects reported pain levels of 1/10 or lower during the time of the study. The subjects included 24 males and 9 females equally divided between the 2 randomized groups, which showed no significant differences in baseline comparisons (Table 1). Collectively, the subjects reported a current disability level between 0% and 20% on the ODI. Random assignment allocated 17 subjects to the group receiving manipulation first (group A) and 16 subjects to the group receiving sham procedure first (group B).

Analyses for the effects of SMT on JPS showed statistical significance for a period effect ($F = 3.026$, $P = .016$). Multiple comparisons showed an immediate treatment effect for the sham procedure during the first treatment session for group B ($t = 3.247$, $P = .005$) with a mean error reduction of 0.82° (99% confidence interval [CI], 0.08°-1.56°). A 1-week residual effect for SMT was noted in group A ($t = 3.151$, $P = .006$) with a mean error reduction of 1.05° (98.33% CI, 0.16°-1.94°) (Fig 3).

Examining TTDPM showed a group-period interaction ($F = 4.048$, $P = .013$) and a period effect with $F = 2.514$ and
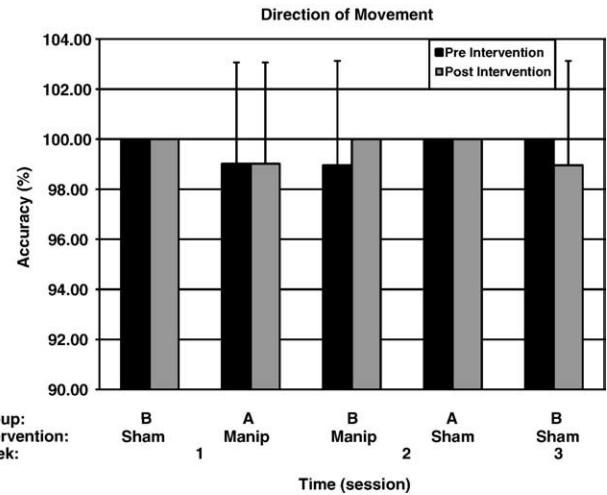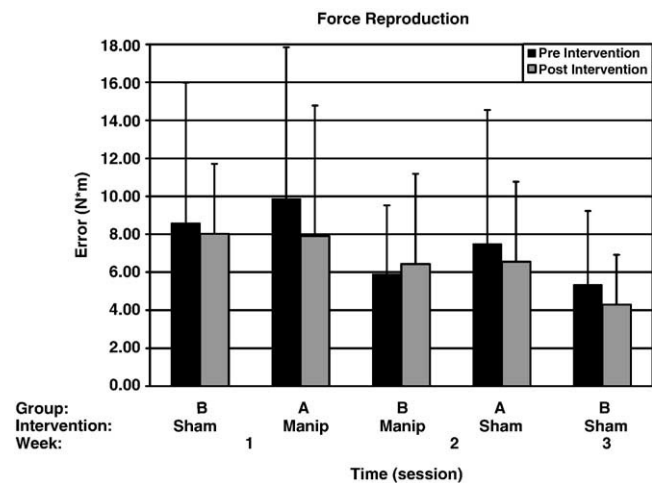

Fig 6. *Force reproduction.*

$P = .044$. Multiple comparisons revealed an immediate treatment effect for SMT with $F = 3.026$ and $P = .008$ with a mean reduction of 0.317° (98.33% CI, 0.04°-0.60°) for group A (Fig 4). No statistically significant difference was noted for the analysis of DM or FR with $F = 0.480$, $P = .791$, and $F = 2.258$, $P = .063$, respectively (Figs 5 and 6).

DISCUSSION

There has been little examination of the effects of therapeutic intervention on proprioception. The purpose of this study was to examine the effects of SMT on subjects with chronic back conditions currently experiencing no pain. Proprioception was measured using 4 submodalities including DM and FR, both of which are rarely reported on in spine

literature. The results of this study indicate that there was no consistent effect of SMT on conscious proprioception in this sample. In light of the fact that a crossover design was implemented, both groups had the opportunity to show an effect of SMT on each of the 4 submodalities of proprioception, and the unbalanced design allowed both groups to be examined for a 1-week residual effect for each of those dependent variables.

Joint position sense tended to improve for both groups after spinal manipulation. During the session after manipulation, preintervention trials showed further improvement, but this difference was lost in the postintervention trials because AE increased after the sham procedure. Comparing the second sham testing session (3) with the first sham session (1) for group B, it is clear that the statistically significant improvement shown in session 1 was not repeated in session 3 (Fig 3). The initial improvement noted for both groups (session 1) might suggest that any cutaneous input from SMT or the sham procedure may result in enhanced proprioceptive response in CLBP. In the sham procedure, cutaneous input was provided simply by placing hands on the spine during the procedure setup, a finding previously reported.[32] Once initial improvements had been made, the cutaneous input was no longer sufficient to replicate the improvement in the follow-up session for group B.

Figure 3 suggests the sham procedure produced greater reduction in error for JPS than manipulation in session 1, but the improvement in JPS from manipulation (group A) was maintained, and, in fact, enhanced to statistical significance in session 2. The significant improvement noted after the sham procedure during session 1 was partially lost to a nonsignificant level in session 2 for group B.

Threshold to detect passive motion showed different tendencies from JPS. Group B test results revealed little change throughout testing irrespective of treatment condition. There was minimal improvement in error after the manipulation intervention with no residual effect noted a week later. Group A showed a statistically significant improvement after the manipulative intervention, but the improvement was not maintained during the following testing session. Like JPS, TTDPM error rates increased after the sham procedure in the week after manipulation. This postintervention deterioration is perplexing because the sham intervention should have no deleterious effect on proprioception and it questions the potential role of learning throughout the study.

Upon review of the mean values of the errors (Fig 4), it is apparent that a difference may exist between the treatment groups during their initial testing session for TTDPM. This potential difference may explain the difference noted in response to the interventions. Group B preintervention error rates progressively increase throughout the study. This observation is specific to TTDPM because it was not observed in any of the other dependent variables.

In this study, DM showed error rates of 0.04%, which is considerably lower than reported in previous studies (Fig 5). Leinonen et al[33] found that 76.9% of subjects reported the wrong direction of trunk rotation in at least 20% of trials, a significantly higher error rate than shown in the current study. The study of Leinonen et al[33] examined subjects with a specific diagnosis, spinal stenosis, which may result in differences from the current study. Subjects with spinal stenosis are often older, and the average age of subjects in the study was 19 years older than the current study. Age-related variation in TTDPM has been reported on in the literature.[34] Although DM differs from TTDPM, they may be fundamentally linked because both proprioception subsystems depend on detection of passive motion and the 2 subsystems showed deficits when studied concomitantly.[33]

Subjects may have altered their strategy by stopping the Biodex when they knew the direction rather than when they felt movement, which would impact both variables. They would improve their performance in the DM but compromise their performance in TTDPM. Comparing the error rates observed in this study with error rates reported in previously published literature[13,33,35] suggests that the observed error rate was comparatively low for both variables. Because the instrumentation used in this study was not the same as reported in previously mentioned studies, conclusions about comparisons should be made with caution.

Force reproduction may not have shown any meaningful change over the course of the study. The univariate analysis did not reveal a statistically significant difference for a period effect with $P = .063$. A nonsignificant improvement was noted for the group A after manipulative intervention. The 1-week follow-up session also showed improvement in both pre- and postsham intervention trials. Subjects in both groups showed a consistent pattern of reduction in error over the course of testing, suggesting that the improvement observed may be due to learning rather than treatment effects despite the use of familiarization trials (Fig 6). Learning through multiple repetitions of FR has been previously shown in a study examining force production characteristics in subjects with CLBP.[36] However, the number of repetitions required to produce multiple consecutive trials within the 10% variance range was not reported to determine how this study's results may have compared with those of Descarreaux et al.[36]

The impact of learning in conscious proprioception warrants further investigation. When first considered, learning appears to be a negative consequence of the methodological design, but the possible clinical impact of learning must be addressed. It is possible that learning through repetitive training performed for a 2-week period is an acceptable way to treat deficits noted in this population. Two randomized controlled trials have used high repetition to train subjects with CLBP to a specified level of variance in JPS and FR consistent with healthy control subjects.[36,37] It is possible to design a future study that not only looks at error

rates of proprioception but also assesses strategies to obtain these error rates to explore the clinical implications of learning on NMC and function in subjects with CLBP.

Previous research examining proprioception in subjects with CLBP showed variable results with some suggesting that this population has observable deficits in AE,[38-40] but other research contradicts this finding.[41,42] To date, no research has been conducted examining whether or not subjects with CLBP who are currently asymptomatic present with proprioception deficits. The AE measured in this study is fairly consistent with normative values reported in the literature. One cannot conclusively interpret these results because the instrumentation used for many studies has been inconsistent.

Our study has several limitations. The instrumentation used in this study was novel and involved an apparatus intimately attached to the subject, which may have provided enough external stimuli to alter the subject's proprioception through cutaneous stimulation. This particular issue has been documented in the literature.[43,44] Despite this methodological limitation, the Biodex Systems III was used for the speed of testing. Previous literature on the neurophysiologic effects of spinal manipulation has reported a transient nature of the effects making rapid reassessment imperative to examine transient effects.[45,46] This limitation should not impact FR because cutaneous input is required to push against an unyielding surface; however, this could impact JPS, TTDPM, and DM. Variable cutaneous input secondary to differing instrumentation is present in many studies examining JPS and TTDPM of the trunk.[13,31,33]

By targeting subjects who did not report LBP during testing sessions, one might argue that this sample fails to accurately reflect a traditional CLBP population seen in clinical practice. Nonetheless, the pursuance of subjects with lower levels of pain was purposeful to reduce the effects of pain on proprioception. Motor control literature suggests that this may not be a limitation because periods of reduced pain may not be associated with normal levels of NMC[47,48]; however, it is not currently known how variable trunk proprioception may be based on symptom level.

The manipulative intervention provided in this study may not accurately reflect typical clinical practice. Each subject received between 1 and 4 thrusts in a single intervention session, depending on whether or not a cavitation was perceived during the procedure. This methodology replicated a format used in previous clinical studies.[9,28-30] Fourteen subjects received all 4 thrusts, and 19 subjects received between 1 and 3 thrusts. Even though this particular dosage may have provided immediate symptom and disability relief previously,[9,28-30] it may not be sufficient in magnitude to achieve the threshold required for alteration of proprioception. It is also unknown whether or not the SMT technique used in this study is more or less effective than any other technique in provoking a neurophysiologic effect on proprioception.

The statistical analysis of the subject characteristics (Table 1) would suggest that the randomization technique used adequately nullified any potential differences that may have been apparent between the groups tested; however, this cannot be stated with complete confidence. Randomization minimized the differences noted between the groups but did not minimize differences that might be observable within groups. There may be subgroups of individuals that behave differently than the group as a whole confounding results.[49] The sample size in this study is insufficient to perform a secondary analysis of potential subgroups.

Future studies, designed to ascribe the contribution of learning and intervention to the variation observed in conscious proprioception, are needed to ascertain the true effect of SMT. If learning is a viable treatment option, as existing literature suggests,[36] the training program may nullify the deficit that SMT seeks to resolve.

Conclusions

It does not appear that a single session of 1 to 4 thrusts of SMT produced an immediate or lasting impact on proprioception AE in subjects with chronic low back conditions who are pain free at the time of testing. Because a crossover design was used, this effect may be independent of whether the SMT intervention session occurred a week before (week 1) or after (week 2) the application of a sham intervention. This finding may implicate another mechanism of action for SMT besides the purported effect on proprioception to impact NMC. Before any firm conclusions can be drawn, additional research may be needed to explore a number of factors that may influence the results of this study.

Practical Applications

- Spinal manipulative therapy had minimal effect on trunk proprioception for the 33 subjects in this study.
- Learning may occur from multisession proprioception testing.
- Subjects with asymptomatic CLBP may not have proprioceptive deficits.

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