IMMEDIATE INFLUENCE OF LUMBAR SPINE MANIPULATION ON PAIN, FUNCTIONAL REACH, STATIC BALANCE, AND WALKING GAIT KINEMATICS OF INDIVIDUALS WITH ACUTE LOW BACK PAIN

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ABSTRACT

Objective: The purpose of this study was to assess the immediate impact of lumbar spine manipulation on pain, functional reach, static balance, and walking gait kinematics of individuals with acute low back pain (LBP).
Methods: 68 participants (age= 49.0 $\pm$ 16.2 years, height= 1.65 $\pm$ 0.10 m, body mass= 78.3 $\pm$ 20.4 kg: mean $\pm$ SD) with LBP engaged in a baseline numeric rating scale (NRS) pain score assessment, functional reach test (FRT), static one-legged balance test of both lower limbs, and 1.5 mph walking gait evaluation utilizing VICON motion capture technology. They were randomly and equally assigned to 1 of 2 interventions: 1) bilateral lumbar spine manipulation at L-3 with the intent of impacting most of the lumbar spine (Manip group) or 2) no manipulation (No-Manip group). A post-intervention assessment was conducted on each participant.
Results: There was a significant main effect for NRS pain score for participants in the Manip group, $F(1, 66) = 27.71$, $p < 0.001$, $r = 0.54$ (large effect size), decrease of 1.4 points. There was a significant main effect for step length for participants in the Manip group, $F(1, 66) = 4.69$, $p = 0.037$, $r= 0.26$ (small to medium effect size), increase of 13.5 mm. No other significant study variables were noted.
Conclusions: Following a single spinal manipulation for acute LBP, participants' pain decreased and they experienced an improvement in step length. Functional reach, single-leg balance, hip functional range of motion (ROM), knee functional ROM, ankle functional ROM, stride length, and percent stance time were unaffected.
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Key Indexing Terms: Low Back Pain; Patient Outcome Assessment; Chiropractic; Spinal Manipulation; Manual Therapy

INTRODUCTION

Low back pain (LBP) is a common health condition that is economically costly for multiple reasons (1-4) and develops more commonly in individuals with high physical demand jobs. (5,6) Lifetime prevalence of LBP is estimated to be 39%,7-8 with many individuals reporting recurrent episodes (7-11), and some cases leading to chronic LBP. (12) Loss of work productivity due to absenteeism (13-17) and presenteeism (18-20) related to LBP has been estimated to cost the United States between 7-20 billion $US dollars per year. (21,22) These financial costs are projected to continue to rise both locally and globally. (23-25) In addition to the sheer financial costs of healthcare and

lost work productivity, LBP is also associated with a significant negative impact on quality of life (QOL). (26-31)

Spinal manipulative therapy (SMT) is a form of care that has been shown to improve patient outcomes amongst individuals suffering from acute and chronic LBP. (32-37) Studies have demonstrated that SMT results in improvements in pain sensation (35,38,39), range of motion due to spinal hypomobility (40-43), and function. (44)

The clinical course of LBP demonstrates that most cases exhibit significant recovery within 6 weeks, with more gradual improvement occurring thereafter. (35,45) More research is needed on symptomatology compression35 and the impact it can have on absenteeism, presenteeism, medical care costs, QOL, and other relevant variables. If patients could recover from acute LBP in less than 6 weeks, then there would be significant personal and societal savings. Furthermore, only limited studies have been performed on the impact of LBP on balance and coordination. Thus, this neglected topic warrants further review, especially considering the prevalence rates of falls in the elderly population. (46-48)

The purpose of this study was to measure the impact of SMT on acute LBP patients through measurement of pain, functional reach, static balance, and walking gait.

METHODS

This study was reviewed and approved by the Texas Chiropractic College 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 000017159 (Reg# R000019905) April 18, 2015.

Study Design, Rationale, and Setting

This study focused on the immediate impact of lumbar spine SMT on pain, functional reach, static balance, and walking gait kinematics of individuals with acute LBP (Fig. 1-2). Sixty-eight participants with LBP engaged in a baseline numeric rating scale (NRS) pain score assessment(49), functional reach test (FRT) (50,51), static 1-legged balance test of both lower limbs (52,53), and 1.5 mph walking gait evaluation utilizing Vicon motion capture technology. (54) Following this, participants were randomized to receive 1 of the 2 following interventions: 1) lumbar SMT bilaterally at L-3 in an attempt to impact most of the lumbar spine, or 2) no manipulation. Study participants in both groups then engaged in a post-test assessment of the same dependent variables.

This research experiment occurred in a biomechanics lab with the ambient room temperature set to 74°F. Researchers intentionally avoided playing music in the lab background during the walking gait analyses in order to reduce the possibility that the music beat could alter walking cadence. (55)

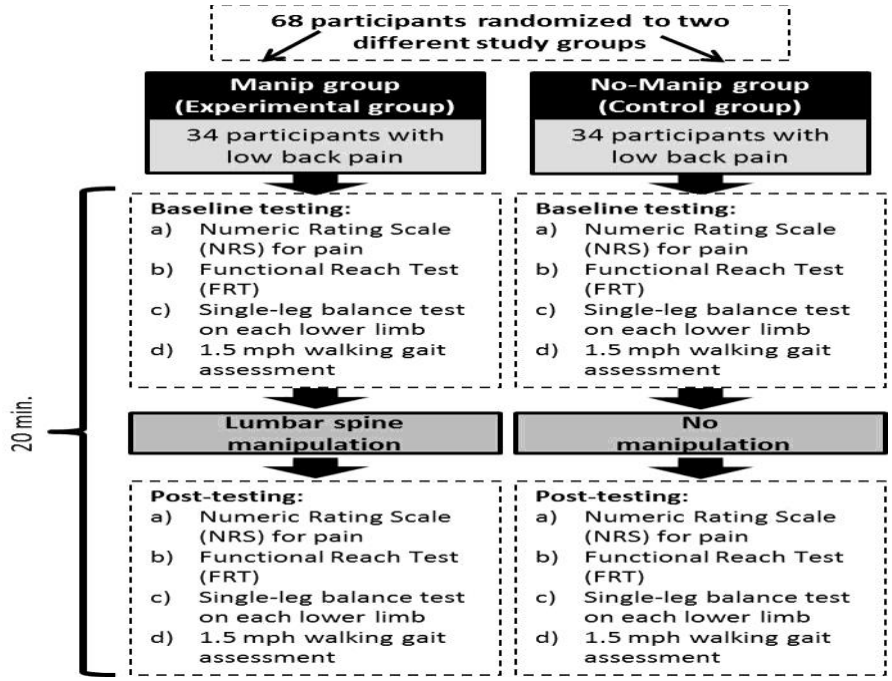

Figure 1. Experimental design.

Participant Recruitment

Study enrollment took place from June 2014 to November 2014 using English recruitment materials. Participants were recruited from the greater Houston area, an ethnically diverse region of America with over 2 million residents. According to the 2010 Census report, the racial make-up of the area was approximately 50.5% white, 23.7% black, 6.0% Asian, 0.7% American Indian and Alaska Native, 0.1% Pacific Islander, 19% mixed races, with 43.8% of the population classifying themselves as Latino.56 A media blast was used to publicize the study through online resources (Craigslist), print media (Greensheet), and word-of-mouth. Study applicants contacted the primary investigator for screening to determine if they met the inclusion and exclusion criteria (Fig. 3). A chiropractic clinician performed a brief physical examination on study participants to confirm they had LBP.

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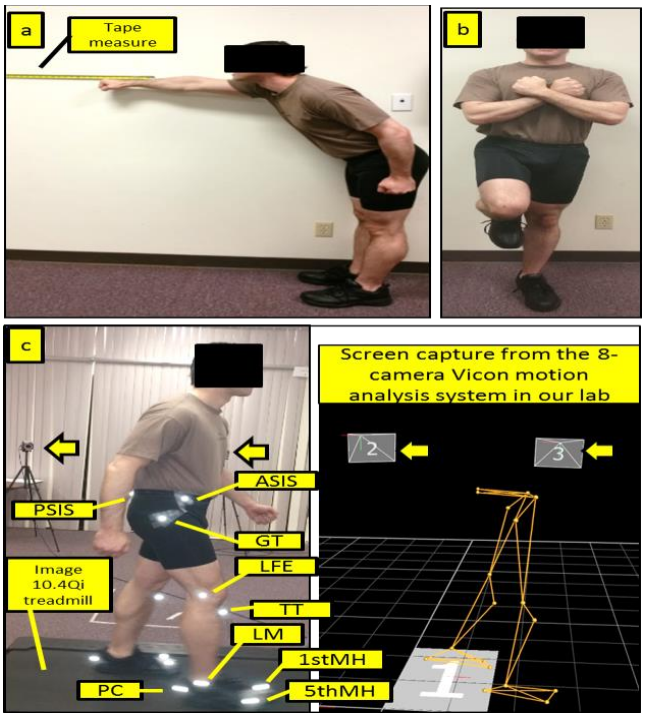

Figure 2. Image of: (a) Functional Reach test (FRT), (b) single leg balance test, and (c) walking gait analysis at 1.5 mph. In the motion analysis photograph (2c) a flash was used to emphasize how the silver reflective surface markers glow to allow the Vicon infrared cameras to track them. Arrowheads signify Vicon cameras, both real (bottom left picture) and virtual (bottom right picture). Leader line key: PSIS= posterior superior iliac spine; ASIS= anterior superior iliac spine; GT= greater trochanter; LFE= lateral femoral epicondyle; TT= tibial tuberosity; LM= lateral malleolus; 1stMH= 1st metatarsal head; 5thMH= 5th metatarsal head; PC= posterior calcaneus. Only the right side of the participant was labelled to avoid image clutter.

All study applicants provided written informed consent prior to participating in this study. Table 1 lists the attributes of study participants. Researchers performed an a priori power analysis using G*Power version 3.1.9.2 (Universität Kiel, Germany) and determined that 34 participants per group were needed for a study with an effect size d of 0.7, two-tailed α of 0.05, power of 0.80, and allocation ratio N2/N1 of 1 to compare two independent means.58-59 Seventy-seven participants applied to participate in this study. Nine participants were excluded due to the following reasons: 6 did not possess acute LBP, 1 was not capable of walking 1.5 mph, 1 had a diagnosis of Parkinson's disease, and 1 was taking medication that negatively impaired their balance. Participants were randomized to the 2 study groups based on a pre-generated computer randomization list. Care provided in this study was free to participants. They also received a $30 prepaid Target gift card upon successful completion of the study.

Inclusion criteria were:
1) possess acute LBP (for less than 6 wks)
2) between 18-90 years of age
3) provide written informed consent
4) report no contraindication to spinal manipulation
5) answer "no" to all sections on the Physical Activity Readiness Questionnaire (PAR-Q) [57]
6) capable of walking 1.5 mph for a few minutes
7) participant did not engage in strenuous exercise the day of the study

Study participants with any of the following were excluded from the study:
1) any surgery in the past year
2) any broken bones in the past year
3) reported neurologic conditions that would impact gait (multiple sclerosis, myasthenia gravis, etc.)
4) diagnosis of any lumbar, sacral, hip, or lower limb pathology that would prevent walking
5) pregnancy
6) history of alcohol abuse
7) hypertonia
8) use of a cane or similar assistive walking device
9) visual impairment that would make walking dangerous for them
10) vertigo or history of falls within the past 60 days
11) taking medications that altered motor function
12) they could not be a faculty member or student of our college

Figure 3. Study inclusion and exclusion criteria.

Table 1. Participant demographic and anthropometric attributes.

	Manip group	No-Manip group	*P*-value
Sex (M/F)	12/22	15/19	
Age (y)	45.1 ± 15.0	52.9 ± 16.6	*0.048
Mass (kg)	80.8 ± 17.1	75.9 ± 23.2	0.328
Height (m)	1.64 ± 0.08	1.66 ± 0.12	0.414
Body Mass Index (kg/m^2)	29.9 ± 6.1	27.0 ± 5.3	*0.042
Age range (yrs)	18-70	18-89	

Most data listed as mean ± SD.
*= statistically significant.

Numeric Rating Scale (NRS) for pain

Participants were verbally asked to describe their level of LBP on a 0 (no pain) to 10 (excruciating pain) NRS for pain. Responses were recorded by a researcher at baseline and again at post-test.

Functional Reach Testing (FRT)

Participants were asked to stand with their right side adjacent to a wall onto which a tape measure was attached at approximately shoulder height (Fig. 2a). Their bodies were positioned so that the tips of the metacarpophalangeal joints of their right hand were in line with the 0 mark on the tape measure. Participants were then instructed to reach as far as they could parallel to the wall with their right arm straight, without losing their balance or taking a step. The correct performance of the test was demonstrated by a researcher. A spotter stood next to the participant during the test. Study subjects performed the test 3 times at baseline and 3 additional times during post-testing. The farthest distance reached during each testing period was recorded in inches to the nearest ¼ inch by visual inspection. These measurements were subsequently converted to international units (mm) to keep all data formatted the same.

Single Leg Stance Test

Participants were instructed to stand on 1 foot, with their eyes open, for as long as they could (up to a maximum of 30 seconds) on flat level ground (Fig. 2b). A stopwatch was used to signal the start of the test with an audible “beep” and record the duration that they were able to hold their balance on 1 leg in seconds. A spotter stood by to reduce any anxiety about fall risk, particularly amongst older study participants. The right lower limb was tested first, and then the left lower limb. Participants were told to cross their arms across their chest during testing. Data from both lower limb trials was averaged together at baseline and again during post-testing for analyses.

Motion Analysis Technology

Participants were asked to wear tight-fitting non-reflective shorts and non-reflective shoes for the study. Researchers purchased several sizes of black spandex shorts (small, medium, and large) and dark New Balance shoes (New Balance, Brighton, MA, USA) for participants before the study began in case they did not possess the appropriate dress attire. The New Balance shoes purchased for this study were MX409 (male sizes 7, 8, 9, 10, 11, and 12) and WL574 (female sizes 4, 5, 6, 7, 8, and 9). Researchers additionally spray-painted any reflective logos/markings on the shoes flat black. Participants were also instructed to remove all reflective jewelry. Non-transparent tape was used to cover any reflective logos/markings on clothing participants might be wearing.

Eighteen silver 19-mm MoCap solutions (MoCap solutions, Huntington Beach, CA, USA) reflective markers were placed on the participants' lower body using surgical tape. Reflective markers were placed on the following anatomic landmarks bilaterally: anterior superior iliac spine (ASIS), posterior superior iliac spine (PSIS), greater trochanter of the femur, lateral epicondyle of the femur, tibial tuberosity, lateral malleolus, posterior calcaneus, top of the 5th metatarsal head, and top of the 1st metatarsal head (Fig. 2c), using a marker set and model as described by Robertson et al.60

The VICON MX camera motion analysis system, consisting of 8 infrared Bonita 0.3 megapixel cameras (Vicon, Centennial, CO, USA) was calibrated daily as suggested by the manufacturer. Once dressed properly in non-reflective clothing with the reflective silver markers in place, participants stood on top of the Image 10.4Qi treadmill (Sears, Hoffman, IL, USA) for a baseline 10-second computer calibration model generation. They were then instructed to walk at 1.5 mph for 75 seconds. Kinematic data were recorded at 100 Hz. The displacement of the 18 silver reflective markers over time was recorded. At the conclusion of the data capture session the Vicon computer and then the treadmill were stopped. Participants were not given any indication of when the treadmill would be stopped. Immediately after the 75-second recording was made the initial 15 seconds of the gait trial was clipped from the data to remove any initial steps as the participant became acclimated to the treadmill velocity. A velocity of 1.5 mph was chosen to make it more likely that participants with significant LBP would still be able to complete this portion of the study.

Lumbar Spine SMT

The state-licensed chiropractor providing SMT in this study has 28 years of clinician experience and 25 years of experience as a chiropractic college instructor. During that time, he primarily taught spinal manipulation courses. A singular chiropractor was used in this study to eliminate any inter-provider variability. The SMT consisted of a side-posture, high-velocity, low-amplitude force applied at the L3 mammillary process bilaterally, as described by Bergmann and Peterson. (61) The intent of the SMT was to reduce localized pain and possibly increase spinal mobility. No attempt to record an audible sound from SMT was made, as research has demonstrated its lack of significance. (43) The SMT used in this study occurred on an Ergostyle ES2000 (Pivotal Health Solutions, Watertown, SD, USA) patient table. The control group sat for approximately 1-minute instead of receiving SMT during their intervention phase time.

Kinematic Post-Data Processing and Blinding

The data were processed with a 0-phase 8^{th}-degree Butterworth filter and then analyzed through a customized Matlab script. (62,63) The kinematic data were analyzed to calculate characteristics of movement for each participant, including active range of motion of the hip angle, knee angle, and ankle angle. In addition, percent stance time (duration 1 foot was on the ground in relation to the gait cycle), step length, and stride length bilaterally were calculated. Researchers merged data from both lower limbs for data analysis at baseline and again for the post-test for each study group to garner an

overall view of data trends. The researcher analyzing the biomechanics data was blinded as to participant group designation. Due to research personnel scheduling limitations during the time period of this study the NRS pain score assessment, FRT, and single leg stance tests were not blinded.

Statistical Analysis

The data were analyzed in SPSS version 20.0 (IBM, Armonk, NY, USA). Results were reported as mean ± standard deviation (SD) unless otherwise specified. An unpaired samples t-test was used to compare between-group differences at baseline for age and anthropometric data. The Levene test for equality of variance was used and followed for homogeneity of variance violation. The alpha level of $P < 0.05$ was considered statistically significant for between group baseline data.

A between-within repeated-measures analysis of variance (ANOVA) using between-subjects factor intervention (Manip vs No-Manip) and within-subjects factor time (baseline and post-test) was used to analyze study data. A Bonferroni post hoc test was conducted on statistically significant data among all ANOVAs to determine which condition was significant.64 An alpha level of $P < 0.05$ was considered statistically significant for all tests.

RESULTS

Comparison of baseline differences in demographic and anthropometric variables demonstrated that there was a statistically significant difference between groups for age ($p=0.048$) and body mass index ($p=0.042$). Participants in the No-Manip group were, on average, 7.8 years older than participants in the Manip group. Additionally, participants in the Manip group possessed a BMI, on average, 2.9 points higher than participants in the No-Manip group. For height data, Levene's test for equality of variances was violated ($p=0.031$) and thus equal variances were not assumed for the calculation of that P-value, which ultimately did not demonstrate statistical significance.

All assumptions of the between-within repeated-measures ANOVA were met. Every participant completed baseline and post-testing (Fig. 4). There was a significant main effect for NRS pain score for participants in the Manip group, $F(1, 66) = 27.71$, $p < 0.001$, $r = 0.54$ (large effect size). Pain mean decreased by 1.4 points after manipulation. There was a significant main effect for step length for participants in the Manip group, $F(1, 66) = 4.69$, $p = 0.037$, $r= 0.26$ (small to medium effect size). Step length mean increased by 13.5 mm after manipulation. There were no other statistically significant main effects observed. Although functional reach and stride length did not reach statistical significance their changes clinically are worth mentioning. Post-manipulation, functional reach mean increased 41.5 mm ($p=0.059$) and stride length mean increased 40.0 mm ($p=0.068$) for the Manip group.

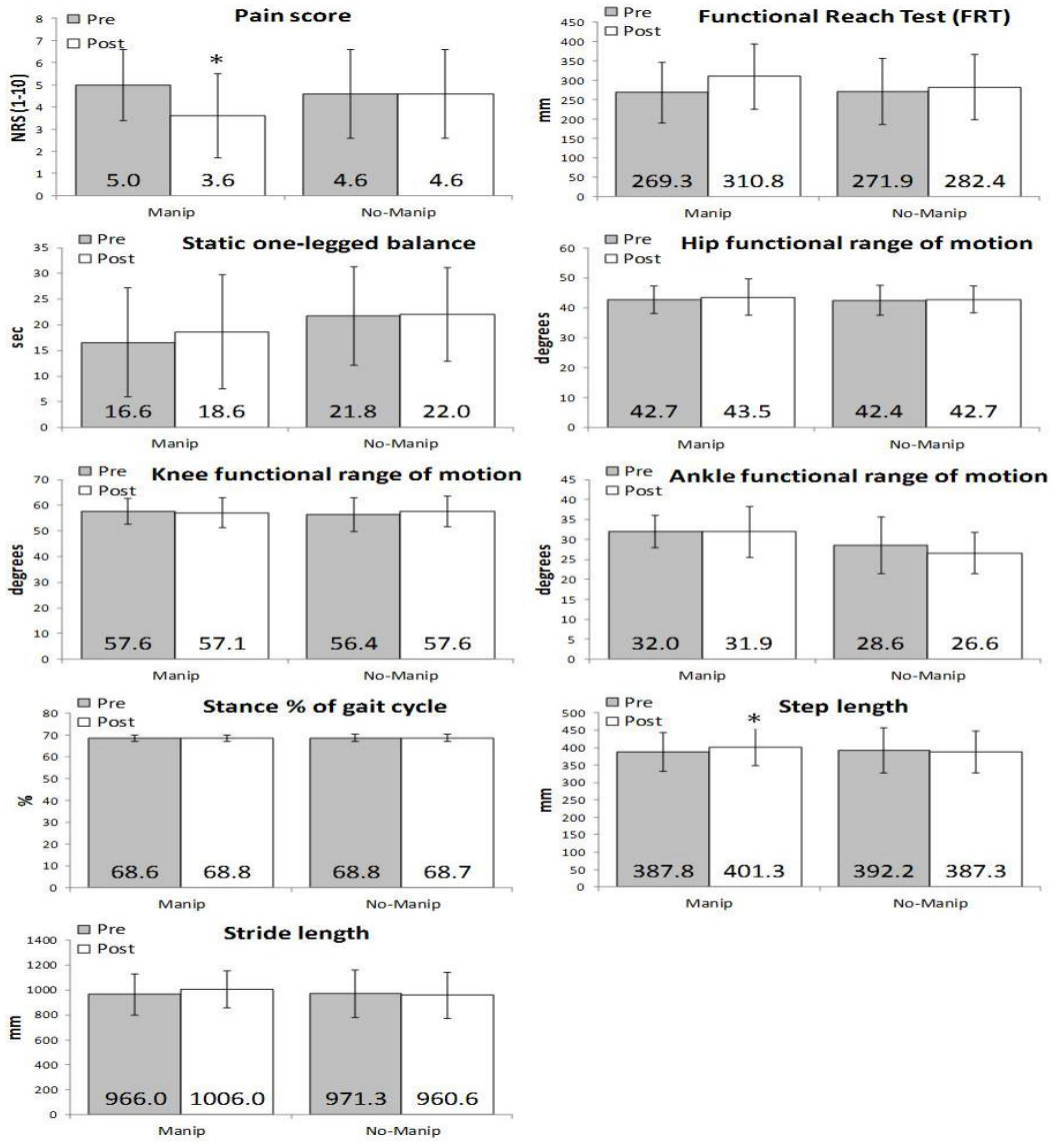

Figure 4. Pain, functional reach, balance, and gait variables. Errors bars represent individual SD per bar. *= statistically significant.

DISCUSSION

Preliminarily, this study demonstrated that following a single SMT treatment for acute LBP that participants' pain decreased and they experienced an improvement in step length. A decrease in pain has been demonstrated in other studies of the effects of SMT (35,38-39) but the increase in step length represents a relatively novel finding. The gain in function may be associated with the decrease in pain due to the SMT. However, it is important to note that several other gait variables did not demonstrate a statistically

significant difference between groups to include: hip functional ROM, knee functional ROM, ankle functional ROM, stride length, and percent stance time. Thus the true impact of spinal manipulation on overall mobility may be limited.

Gait studies have demonstrated that step length and walking velocity decrease with LBP. (65-69) The theory is that the slower walking velocity is due directly to pain and/or avoidance of physical actions expected to cause pain (fear-avoidance behavior). (65) The premise of this study was that if spinal manipulation could lower back pain then it might positively impact mobility.

Although improvements in mean step length occurred, researchers are unaware of any minimal clinically important difference (MCID) for walking gait to compare this study's findings against. The question remains, how important to a patient is an increase in step length of 13.5 mm? Would this have any implications for older patients engaging in a functional walking test such as the Timed Up and Go test? (70)

Limited studies have been performed on the impact of SMT on human gait biomechanics. Sandell et al found that after SMT to the sacroiliac (SI) joints of hypomobile runners there was an increase in hip extension capabilities; however, this did not translate into increased running velocity over a distance of 30 m. (71) Herzog described how corrective SI joint SMT resulted in increased gait symmetry based on ground reaction force (GRF) analysis over the course of a multi-week study. (72) Additionally, Ward et al found that after manipulation of the SI joints, walking stride length increased 19-38 mm in asymptomatic study participants. (73) The findings from these 3 studies and the present study suggest some attributes of gait may be impacted by SMT; however, due to limited research on this specific topic more study is warranted to gain clarity.

The results of this study suggest a few possible future directions that may be explored: 1) measure how lumbar and/or SI joint SMT impacts a special population with known spine hypomobility, such as obese adults, (74-76) 2) determine if lumbar and/or SI joint manipulation can act as an ergogenic by increasing runner stride length and step length in asymptomatic participants, (71,73) and 3) determine the implications of lumbar and/or SI joint SMT on mobility and balance of older adult patients. (77)

Limitations

The findings of this study are weakened by the fact that a placebo was not utilized. (78-81) Current research debates the optimal placebo for LBP SMT studies since placebo development is not as simple as in pharmacological studies (e.g., a sugar pill instead of an actual medication). (81) Despite this, some form of placebo (i.e., an Activator device at the 0 force setting) (82) would have increased the external validity of this study's findings.

Another weakness of this study was the lack of blinding that occurred for the NRS pain scale assessment, FRT, and single leg balance test. Complete blinding would have

increased the quality of this study. Unfortunately, that did not occur due to research assistant scheduling issues that occurred during the initial implementation of this study. Despite lack of full blinding, researchers made no attempt to encourage patients during this study to perform better under any given condition.

It can be argued that the definition of acute low back pain is debated in research literature and that can make it difficult to compare research findings between journal publications. (83,84) Some sources further divide acute low back pain into early acute, which is less than 2 weeks in duration and late acute, which is 2-6 weeks in duration. (83)

Due to statistically significant differences in age and BMI between the 2 study groups at baseline the researchers cannot exclude that these variables may have factored into differences between the groups in outcome. The manipulation group was approximately 8 years younger on average and their body mass was slightly greater than the control group.

An additional limitation of this study was a lack of long-term follow-up. Perhaps the positive changes observed only lasted a few hours. As a result, their clinical significance might be marginal. It is unclear also how repeated SMT, through receiving care from a chiropractor over several weeks, would impact the attributes measured in this experiment.

CONCLUSION

Short-term, spinal manipulation of acute LBP patients resulted in a decrease in pain and improvements in walking gait step length. Possibly the reduction in pain post-manipulation helped contribute to the increased step length. Additional studies are warranted to corroborate the trend demonstrated by this study that manipulation can positively impact step length. Functional reach, single-leg balance, hip functional ROM, knee functional ROM, ankle functional ROM, stride length, and percent stance time were unaffected. Future exploratory study on this topic should attempt to determine which attributes of gait may be impacted by spinal manipulation.

Funding Sources and Conflicts of Interest

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