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Effects of Lumbosacral Manipulation on Isokinetic Strength of the Knee Extensors and Flexors in Healthy Subjects: A Randomized, Controlled, Single-Blind Crossover Trial

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Abstract

Objective: The purpose of this study was to investigate the effect of manual manipulations targeting the lumbar spine and/or sacroiliac joint on concentric knee extension and flexion forces. Torque production was measured during isometric and isokinetic contractions.

Methods: This was a randomized, controlled, single-blind crossover design with 21 asymptomatic, college-aged subjects who had never received spinal manipulation. During 2 separate sessions, subjects' peak torques were recorded while performing maximal voluntary contractions on an isokinetic dynamometer. Isometric knee extension and flexion were recorded at 60° of knee flexion, in addition to isokinetic measurements obtained at 60°/s and 180°/s. Baseline measurements were acquired before either treatment form of lumbosacral

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manipulation or sham manipulation, followed by identical peak torque measurements within 5 and 20 minutes posttreatment. Data were analyzed with a repeated measures analysis of variance.
Results: A statistically significant difference did not occur between the effects of lumbosacral manipulation or the sham manipulation in the percentage changes of knee extension and flexion peak torques at 5 and 20 minutes posttreatment. Similar, nonsignificant results were observed in the overall percentage changes of isometric contractions (spinal manipulation 4.0 ± 9.5 vs sham 1.2 ± 6.3, $P = .067$), isokinetic contractions at 60°/s (spinal manipulation −4.0 ± 14.2 vs sham −0.3 ± 8.2, $P = .34$), and isokinetic contractions at 180°/s (spinal manipulation −1.4 ± 13.9 vs sham −5.5 ± 20.0, $P = .18$).
Conclusion: The results of the current study suggest that spinal manipulation does not yield an immediate strength-enhancing effect about the knee in healthy, college-aged subjects when measured with isokinetic dynamometry.

Introduction

Spinal manipulation (SM) is a therapeutic procedure used by health care practitioners such as chiropractors, osteopaths, and physical therapists with the intent of ameliorating joint hypomobility and positively influencing neurologic functioning.[1,2] In addition to global utilization within the clinical setting to alleviate acute and chronic musculoskeletal complaints,[2] this form of treatment is also delivered for the purpose of enhancing the performance and augmenting the rehabilitation of collegiate and professional athletes.[3]

Research efforts from the past few decades have investigated the effects of SM on topics such as strength modulation, muscle inhibition, electromyographic (EMG) activity, motor training/reaction time, and balance.[3] Regarding strength, at least 22 different studies have recorded changes in force exerted during maximum voluntary contractions (MVCs) post-SM. Within these articles, a range of muscle groups was selected, such as the quadriceps femoris muscle group, cervical musculature, thoracolumbar erector spinae, biceps brachii, shoulder external rotators, lower trapezius, and gluteus maximus, in addition to measurements of knee flexion and grip strength.[4–25] Although these studies as a whole report changes in strength post-SM, each investigation must be considered individually because different muscle groups cannot be directly compared. Although many of the aforementioned studies reported increases in strength and/or increased EMG amplitudes, an important consideration is that only isometric contractions have been measured (with a hand dynamometer, isokinetic dynamometer, or load cell). Presently, no information exists in relation to strength changes after SM measured at various angular velocities during dynamic contractions. These data would prove useful in generating a more complete picture of the mechanisms occurring within the muscle after chiropractic treatment, as different motor recruitment patterns exist for concentric and isometric contractions. Specifically, this study investigated changes in torque, which is force applied to an object on an axis. This measurement differs from strength, which is the maximum amount of force that a muscle can exert against some form of resistance, and also from power, which is the rate of performing work.[26] This measurement was obtained after SM or the sham manipulation only, and did not include other therapeutic modalities typically included in chiropractic care. Because all athletic actions involve dynamic force generation, the data gathered would have a greater application than the single measurement of a maximal voluntary isometric contraction (MVIC). The addition of knee flexion would add to the results of previous experiments which measured the effects of SM on knee extension.[4–8]

It was hypothesized that significant differences would be found between the peak torques following high-velocity, low-amplitude (HVLA) SM and the sham manipulation at 5 minutes posttreatment but not at 20 minutes. This postulation was congruent with previous authors' findings that strength-modulating effects of SM do not exceed 10 to 20 minutes.[4,8,19] It was also estimated that the significant increase in peak torque generation would be most notable during the isometric contractions, considering the increases in isometric torque reported in prior research.[4–25]

Methods

A randomized, controlled, single-blind crossover design was used with 21 healthy subjects (12 men, 9 women) who were asymptomatic regarding low back, pelvic, or lower extremity pain and between the ages of 20 and 35 (23.6 ± 3.1 years) who had never received

SM. Participants were recruited from various locations both on and off the university campus via flyers and word of mouth. The testing procedure took place over the course of 3 sessions, all conducted in the University of Kentucky Biodynamics Laboratory. During the initial visit, an intake form pertaining to the volunteer's medical history was completed to ensure that the volunteer was eligible to participate in the study. Subjects were excluded based on a medical history of spinal conditions or peripheral neuromuscular disease or injury. This was followed by the completion of an informed consent form and a subsequent physical examination to rule out any further contraindications to SM as well as to the use of the isokinetic dynamometer. The physical examination included blood pressure; cervical/thoracic/lumbar active and passive range of motion; motor and sensory evaluation of C5 though T1 and L1 through S1; tendon reflexes of the biceps brachii, brachioradialis, triceps, patellar ligament, and Achilles; Hoffmann's and Babinski's tests for pathological reflexes as well as Kemp's, Bechterew's, Patrick's/FABER, and Yeoman's tests.

All forms and procedures were approved by the University of Kentucky Medical Institutional Review Board (#12-0280-F1V), and the study was registered with ClinicalTrials.gov (NCT02407418). This study was not supported by grants or other funding from any organization. The principal investigator (PI) performed all screening, data collection, and manipulation/sham procedures during each of the 3 sessions. The final aspect of the physical examination included static and motion palpation of the patient's lumbar spine and sacroiliac (SI) joints to determine the levels of segmental restrictions to be manipulated during the second or third session. If eligibility had been met, the participants then completed an initial familiarization session with the isokinetic dynamometer. Strength testing then began at least 2 days later.

Peak Torque Recordings

During the next 2 sessions, unilateral strength measurements were obtained using the Biodex Multi-Joint System 3 isokinetic dynamometer with the Biodex Advantage software (Biodex Medical Systems, Shirley, NY). During the testing, participants were seated in an upright position on the dynamometer and were stabilized with 2 shoulder straps, a waist strap, and a thigh strap. The participant's range of motion was then established at the knee joint (15° to 95° of knee flexion). Maximal voluntary isometric contractions of knee extension and flexion were measured at 60° of knee flexion.[27] Isokinetic, concentric MVCs of knee extension and flexion were performed at 60°/s and 180°/s. The specific testing sequence of isometric and isokinetic contractions, as well as the order of SM and sham manipulation delivery, was determined for each subject with a random number generator using Microsoft Excel.

Participants began the second and third sessions by completing a low-intensity 5- to 10-minute warm-up on an upright cycle ergometer followed by five 50% submaximal concentric repetitions of knee extension and flexion at both angular velocities. The purpose of this warm-up procedure was to prevent injury during the subsequent maximal effort contractions. After a 2-minute rest, testing began with baseline measurements. This entailed 3 sets of maximal isometric contractions lasting 5 seconds each during knee extension and the same occurring with knee flexion. The isokinetic measurements included 3 maximal repetitions of concentric knee extension and flexion recorded at both angular velocities. The peak torques were recorded in Newton-meters (Nm) as the highest of the three 5-second isometric contractions for both knee extension and flexion, as well as the highest of the three isokinetic, concentric contractions during knee extension and flexion at both velocities. Peak torques were the selected measure for this study because of the prevalence of this measurement in exercise science research.

As depicted in Fig 1, peak torques were recorded 3 times during both testing sessions: at baseline before the treatment (SM or sham procedure), within 5 minutes posttreatment, and again after 20 minutes. The delay in peak torque recordings immediately posttreatment was due to the time needed to transition the subject from the treatment table and be repositioned and secured on the isokinetic dynamometer chair. The PI administered both the treatment and the testing. To limit bias, the PI did not give verbal encouragement during any of the isometric and isokinetic peak torque recordings. A possible Hawthorne/observer effect was also considered but deemed not able to be measured. A minimum of 3 and a maximum of 7 days later, the procedure was repeated, this time incorporating the opposite treatment. All subjects were instructed to not change their activities of daily living with the exception of abstaining from leg workouts within 48 hours and caffeine consumption within several hours of data collection sessions. However, if the subject presented with any delayed-onset muscle soreness (DOMS) as a result of the previous strength testing or other physical activity, and/or caffeine ingestion during the past

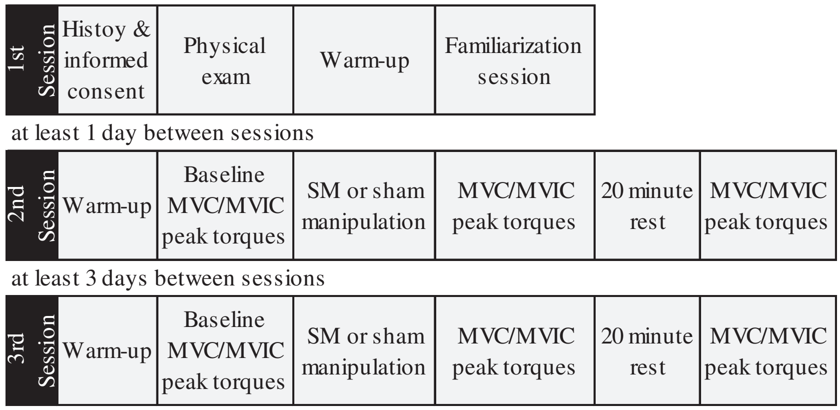

Fig 1. Summary of experimental procedures. MVC, maximum voluntary contractions; MVIC, maximal voluntary isometric contraction; SM, spinal manipulation.

several hours, then data collection was rescheduled. No subjects had to be excluded because of these factors or injuries at any time during the data collection process. In addition, to account for possible hormonal changes as a result of circadian rhythms and their effects on muscle strength, subjects' data were collected at approximately the same time of day during both testing sessions.

SM and Sham Manipulation Treatments

Diversified technique, the most common method of chiropractic treatment, was used in the administration of HVLA manipulations of the lumbar spine and/or SI joints on a chiropractic treatment table (T2000 Portable Drop Table; Inline Tables, Magalia, CA). This form of manual therapy was chosen to include the vertebral segments from which the ventral roots of L2-S1 originate. The anatomical basis for the importance of these levels lies in their innervations of the quadriceps femoris and hamstrings muscle groups via the femoral and sciatic nerves, respectively. Prior investigators[2,6,28,29] have attributed the changes in neural activity post–SM therapy to altered central nervous system (CNS) processing of afferent input from the segmentally innervated structures of the restricted intervertebral joint. It has been further proposed that the perpetual aberrant afferent signals of a fixated intervertebral motion segment are ameliorated by the dynamic stimulus during HVLA SMT. This event is thought to occur in response to the immediate generation of a large amount of afferent signals from mechanoreceptive structures of the joint complex and concomitant neuroplastic changes in CNS processing of the mechanoreceptive input.[30] Based on this concept, it was hypothesized that side-posture SM would enhance the function of the segmentally innervated musculature when tested during maximal contractions with an isokinetic dynamometer. The SM procedure was accomplished by placing the patient in a side-posture position as described by Peterson and Bergmann,[31] with downward pressure applied to the patient's upside flexed knee and a pisiform contact approximately overlying the mammillary process of the fixated lumbar vertebra or to the upside SI joint (the selection of which based on the motion palpation findings of the restricted joint complex). Spinal manipulation was delivered bilaterally to all subjects, necessitated by multiple motion restrictions being found in all cases. The manipulations specifically consisted of a sacroiliac manipulation to one side and a lumbar manipulation to the other. To maintain procedural uniformity, subjects' SI joints were only manipulated into flexion because an SI extension manipulation would require the use of the drop table mechanism, which was reserved for the sham manipulation only. This procedure also resembled typical in-office treatment of HLVA SM being delivered to both sides of the patient's lumbosacral region. Within 5 minutes after the restrictions were manipulated, the subject was repositioned on the isokinetic dynamometer and peak torque recordings began.

The sham procedure involved the use of the lumbar drop mechanism, a component of the treatment table that used a spring-loaded apparatus. It was set by an adjustable tension to hold the patient's lumbar or thoracic region in a half-inch "up" position before the impulse was delivered. A reinforced, unilateral hand contact was used during a prone, nonspecific thrust through lumbar paraspinal musculature. Care was taken to ensure that no vertebral or pelvic contact occurred, as the PI applied pressure only to the lumbar soft tissue on the ipsilateral side of the thigh being tested. The movement and sound of the drop piece returning to its original position resembled the impulse of the PI and cavitations that occurred during the side-posture manipulations. Because neither the spine nor pelvis was contacted, no cavitations were elicited during the prone sham manipulation.

This procedure differed from a drop table/Thompson Chiropractic Technique manipulation. Whereas the Thompson Technique requires specific osseous contacts and lines of drive to correct misalignments of pelvic/sacral obliquity, neither was applied during the sham; consequently, the identified vertebral and pelvic restrictions were not corrected. This sham manipulation was incorporated so that the subjects, specifically recruited without ever having received any form of spinal manipulative therapy and unfamiliar with drop table manipulation, perceived the procedure to also be a valid manipulation technique. This ensured that the subjects were blinded to which treatment was the therapeutic or sham manipulation. The PI performed motion palpation before delivery of both the HVLA SM and sham manipulation to further convince the subject that the sham was a real manipulation. Pretreatment palpation was consistently performed, and regardless of the delivery of SM or sham, the subject would have noted the consistency of the motion palpation.

Subject positioning in side-posture without any contact from the PI as an obvious control procedure was avoided because of the possibility of affecting the subjects' motivation to put forth maximal effort during the subsequent isokinetic and isometric testing. Therefore, it was believed that the delivery of this sham treatment in the same manner as the side-posture manipulation would minimize the impact of this demand characteristic.

Statistics

All data analyses were performed using Microsoft Excel and SPSS version 20.0 (SPSS, Inc, Chicago, IL). A repeated measures analysis of variance was used to analyze the peak torque recordings, with an α level of 0.05 considered significant for all tests. The power analysis was calculated with an effect size of 0.4 based on the averages of previous studies' reported increases in strength post-SM, with an α error probability of 0.05 and at a $1-\beta$ error probability of 0.8.[32]

Results

No statistically significant differences were revealed between the effects of lumbosacral SM or the sham manipulation in the percentage changes of knee extension and flexion peak torques at 5 and 20 minutes posttreatment, displayed in Figs 2 and 3, respectively. Equivalent results were observed in the percentage changes of knee extension and flexion peak torques averaged from both time points posttreatment, illustrated in Fig 4. A significant difference was also not observed between the treatment effects in the overall percentage changes of combined knee extension and flexion during the isometric contractions (SM 4.0 ± 9.5 vs sham 1.2 ± 6.3, P = .067), isokinetic contractions at 60°/s (SM −4.0 ± 14.2 vs sham −0.3 ± 8.2, P = .34), or isokinetic contractions at 180°/s (SM −1.4 ± 13.9 vs sham −5.5 ± 20.0, P = .18). The changes in all peak torque means ranged from 9.6 to −4.6 Nm post-SM and from 7.1 to −3.3 Nm post–sham manipulation.

Discussion

The results of this study indicate that side-posture, HVLA manipulation targeting the lumbosacral spine did not significantly increase the strength of the knee extensors and flexors in comparison to the sham treatment. It was found that neither isometric nor isokinetic measurements revealed a significant increase in strength versus the sham treatment at 5 and 20 minutes compared with baseline. It must be emphasized that these results occurred in healthy subjects and cannot be extrapolated to occur in other subject populations, such as injured patients or fatigued athletes. The testing of injured subjects involves consideration of a number of other factors, such as muscle inhibition, that have the potential to show improvement post-SM that are not present in healthy subjects. For example, in 2 studies, Suter and

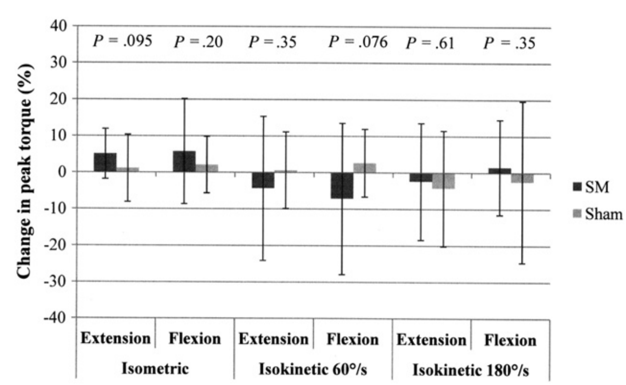

Fig 2. Percentage changes in peak torques at 5 minutes posttreatment compared with baseline. Mean ± SD. SM, spinal manipulation.

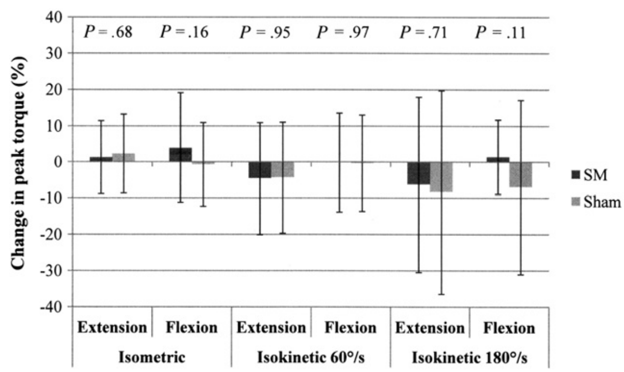

Fig 3. Percentage changes in peak torques at 20 minutes posttreatment compared with baseline. Mean ± SD. SM, spinal manipulation.

colleagues[6,7] recorded decreases in quadriceps femoris inhibition in subjects with anterior knee pain using the interpolated twitch technique following side-posture, HVLA SI joint manipulation. This concept provides possible insight into the discrepancy between these results and the majority of other studies' findings. However, even with a repeated measures design, which increases testing performance reliability because of deceased variability from subjects serving as their own controls, in addition to the established reliability of isokinetic dynamometry,[33,34] the strength-modulating effect of SM was still not statistically significant.

A notable aspect is the substantial standard deviations of the peak torque means. The overall percentage change in isokinetic extension torque at 180°/s serves as the most extreme example. This particular measurement generated a standard deviation more than 6 times greater than the mean postmanipulation and nearly 5 times greater postsham. Nonetheless, the wide spread in the data around the mean apparent in all of the measurements, regardless of treatment randomization, can be partially explained by the variability inherent in strength testing. It has been suggested that the lowest amount of intersession variability attainable during repeated MVC/MVICs is a coefficient of variation range of 5% to 10%,[35,36] and a standard error of the mean of 5%.[37]

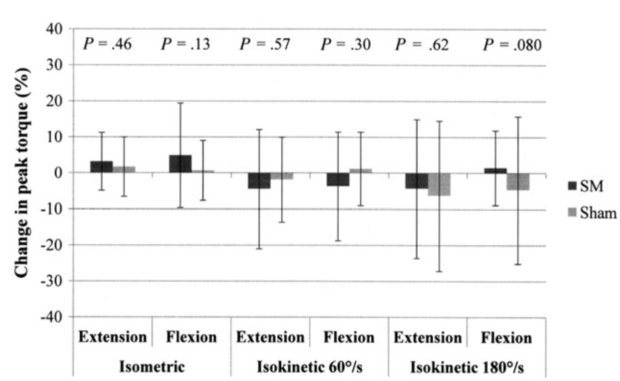

Fig 4. Percentage changes in peak torques averaged at both time points posttreatment compared with baseline. Mean ± SD. SM, spinal manipulation.

Although the overall magnitude of the changes in strength post–lumbosacral manipulation was not large enough to overcome this variability, statistically significant changes in measurements of CNS processing have been reported in previous investigations of the physiological effects of SM.[28,38] These studies incorporated techniques such as EMG, transcranial magnetic stimulation, and the Hoffmann reflex. Accordingly, Pickar and Bolton[28] have concluded that alterations in CNS processing following SM may be produced by a surge of elevated discharge frequencies from paraspinal mechanoreceptors and primary afferent neurons involving temporal and/or spatial summation. Similarly, Haavik and Murphy[38] have elaborated on the neuroplastic changes found to occur within the CNS, placing emphasis on how sensorimotor integration appears to be augmented with the correction of intervertebral hypomobility and associated dysfunction. Nonetheless, the authors conclude that it is currently unknown whether the changes are due to 1 of 2 probable explanations. The first is that SM normalizes the input and processing of aberrant afferent input within the CNS as a result of restoring the biomechanical and neural integrity of the joint complex. The other likely explanation is that the effects are attributable to the impulse of the manipulation producing a bombardment of afferent information from the multiple sensory receptors,[28] congruent with Korr's[29] theory of the facilitated segment.

An additional consideration is an immediate change in EMG amplitudes in response to SM, reported in several investigations.[15,30,39–42] One example is measurements of resting paraspinal activity, in which temporary changes in EMG amplitudes have been recorded in symptomatic and asymptomatic subjects postmanipulation.[39,41] Other studies have reported similar results of both excitatory (increased force production or increased EMG mean/peak amplitudes) and inhibitory (decreased EMG amplitudes) responses after manual and mechanically assisted SM.[15,30,41,42] Spinal manipulation has further been shown to produce these effects through a complex process of positively altering somatosomatic reflexes.[2,43–47] These results might offer additional insight into the differences in subjects' torque measurements within the current study beyond the variability inherent in any form of strength testing.

Limitations

Data collection ended early because of time constraints with 21 subjects, despite the preliminary sample size estimate of 52 subjects needed. Extensive on- and off-campus subject recruitment efforts on the part of the PI had only resulted in this number of subjects after 6 months; therefore, in furtherance of degree requirements, it was necessary to begin a second study. The fact that this study was underpowered provides another likely explanation for the lack of statistically significant differences in the treatment effects between SM and the sham manipulation. In addition, despite denying the presence of DOMS or recent caffeine ingestion, participants' activities between testing sessions could have negatively impacted their ability to generate maximal contractions (such as inadequate sleep and/or energy [caloric] intake). With the exception of these factors, subjects were informed to not change their activities of daily living. A third limitation is that the number, side, and combinations of manipulations received were not documented each time the manipulations were performed. The PI manipulated what was determined to be the levels of restrictions during the palpation which preceded either treatment form of side-posture manipulation or sham. Correlation of these data with the variability of the outcome measures would have provided additional results and should be included in future research.

The time delay in moving the subject from the treatment table to the isokinetic dynamometer chair was another limitation. Because the chair was not able to be used as a treatment table for either the HVLA side-posture or prone drop table sham manipulation, this consequence was unavoidable. Data gathered immediately posttreatment vs a few minutes afterward might have yielded different results.

Another factor is that the subject perturbation during the prone drop table sham manipulation, despite not involving spinal or pelvic contact from the PI, still may have caused a neurologic response. An alternate procedure involving no subject contact or movement should have been used to avoid a possible consequence of altered CNS processing of afferent input from the involved mechanoreceptive structures of the lumbosacral region. A further consideration is the diversity in the amount of physical activity that each subject regularly engaged in, which ranged from competitive bodybuilder to sedentary. Consequently, the resulting heterogeneity in physical fitness levels increased the variability in the subjects' ability to recruit motor units in the production of the MVC/MVICs. This was mostly likely due to the comparative lack of neural recruitment factors in those who were only recreationally active or sedentary. In retrospect, the subject population should have been stratified according to physical fitness levels for a more complete analysis. Likewise, antagonist muscle activity presented another probable source of error in the less active subjects, particularly during the isometric contractions.[48] The discrepancy in subjects' motivation to elicit maximal contractions was another limiting factor, especially when considering that verbal encouragement was not given during any of the peak torque recordings.

In addition to intrinsic performance factors, there was difficulty in obtaining perfect measurement accuracy. Despite the high reliability of the Biodex isokinetic dynamometer, measuring human subjects presents the challenge of completely isolating the involved joint complex. Likewise, it was observed during testing that the action of the MVC/MVIC caused the knee to slightly translate superiorly during flexion and inferiorly during extension. This somewhat-altered axis of rotation, in tandem with a concurrent slight depression of the ankle pad during the initiation of movement, altogether provided further hindrances to completely accurate torque measurements.

Future Studies

Because the results of this experiment were different from other similar investigations, it seems apparent that more studies need to be completed. Accordingly, future related research is needed involving a larger sample size with a sample population that is physically more homogenous and highly motivated to generate maximal contractions, and that is ideally conducted within an environment to allow control of all physical activities. Future investigations should also include strength testing on the same table/instrumentation as the delivery of SM to allow for torque recordings immediately posttreatment. Isometric and isokinetic measurements should also include average torque measurements in addition to peak torques to generate a more complete picture of neuromuscular responses to SM. Furthermore, participants' expectations regarding chiropractic SM, either positive or negative, were not polled. Preparticipation polling should be completed in further research to determine subject bias.

Fatiguing contractions should also be measured postmanipulation to generate an idea of the effect on recruitment of type I fibers for comparison with what has been found involving MVC/MVICs. Finally, in addition to the work of Wang and Meadows,[19] more experiments must also be designed to compare symptomatic and asymptomatic groups of subjects. The protocol used in this study can be used in future research as a basis to compare the results of normal and injured subjects, and to determine a possible effect of SM on strength in subjects with DOMS and acute postexercise fatigue. Given the prevalence of conditions such as patellofemoral pain syndrome,[5–7] further investigation incorporating the experimental design of this study could possibly benefit subject populations with various injuries or neuromusculoskeletal diseases.

Conclusion

The results of this study suggest that SM does not yield an immediate strength-enhancing effect about the knee in healthy, college-aged subjects when measured with isokinetic dynamometry.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

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