SUBCLINICAL NECK PAIN AND THE EFFECTS OF CERVICAL MANIPULATION ON ELBOW JOINT POSITION SENSE

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ABSTRACT

Objective: The objectives of this study were to investigate whether elbow joint position sense (JPS) accuracy differs between participants with a history of subclinical neck pain (SCNP) and those with no neck complaints and to determine whether adjusting dysfunctional cervical segments in the SCNP group improves their JPS accuracy.
Method: Twenty-five SCNP participants and 18 control participants took part in this pre-post experimental study. Elbow JPS was measured using an electrogoniometer (MLTS700, ADInstruments, New Zealand). Participants reproduced a previously presented angle of the elbow joint with their neck in 4 positions: neutral, flexion, rotation, and combined flexion/rotation. The experimental intervention was high-velocity, low-amplitude cervical adjustments, and the control intervention was a 5-minute rest period. Group JPS data were compared, and it was assessed pre and post interventions using 3 parameters: absolute, constant, and variable errors.
Results: At baseline, the control group was significantly better at reproducing the elbow target angle. The SCNP group's absolute error significantly improved after the cervical adjustments when the participants' heads were in the neutral and left-rotation positions. They displayed a significant overall decrease in variable error after the cervical adjustments. The control group participants' JPS accuracy was worse after the control intervention, with a significant overall effect in absolute and variable errors. No other significant effects were detected.
Conclusion: These results suggest that asymptomatic people with a history of SCNP have reduced elbow JPS accuracy compared to those with no history of any neck complaints. Furthermore, the results suggest that adjusting dysfunctional cervical segments in people with SCNP can improve their upper limb JPS accuracy. (J Manipulative Physiol Ther 2011;34:88-97)
Key Indexing Terms: *Proprioception; Upper Extremity; Manipulation, Spinal; Central Nervous System; Posture; Chiropractic*

There is a growing body of evidence demonstrating that adjusting (also known as manipulating) dysfunctional spinal segments can alter central neural function.[1-12] However, it is less certain whether these observed changes in central nervous system (CNS) processing reflect clinically beneficial changes to the individual participants. It has been suggested that these observed changes in sensory processing, sensorimotor integration, and motor control could reflect a mechanism that explains the functional improvements observed after chiropractic care.[6,10,12,13] Our group has proposed that high-velocity, low-amplitude manipulation has a neuromodulatory effect on CNS function.[13] Furthermore, we have proposed that segments of the spine where the movement is functionally restricted in at least 1 plane may represent an ongoing state of altered afferent input that could induce maladaptive neuroplastic changes.[6,10,12,13] The functional segmental restriction could involve restriction in the coronal plane, such as reduced lateral flexion motion, or could include restriction of appropriate movement in the sagittal plane, such as decreased flexion or extension movement. This functional putative manipulable lesion is known by a variety of terms such as joint dysfunction, fixation, or subluxation. It has been suggested in the literature that the maladaptive neuroplastic changes present in long-term pain conditions rather than the actual pain itself are responsible for the individual sufferer's symptoms and functional disturbances.[14-16] In particular, changes in the way the CNS processes proprioceptive information have been suggested as the most important factor responsible for the clinical presentation of neck pain sufferers.[16]

One of our previous studies using somatosensory-evoked potentials has shown that adjusting dysfunctional cervical segments of patients without frank neck pain but

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with a history of some form of subclinical neck pain (SCNP) can alter cortical somatosensory processing and early sensorimotor integration of input from the upper limb.[6] Subclinical neck pain refers to recurring neck dysfunction such as mild neck pain, ache, and/or stiffness with or without a history of known neck trauma. Individuals with SCNP do not have constant symptoms and have not yet sought treatment of their neck complaint. There is an increasing interest in SCNP in the literature because individuals that fall into this category provide an opportunity to explore neurophysiologic dysfunction without the confounding effect of current pain, which is known to alter sensory processing and motor control.[17] Furthermore, it is thought that gaining a better understanding of the features characterizing this group may help improve subgrouping of neck pain patients. In addition, it could provide a marker of altered sensory processing that could aid in determining those individuals showing evidence of disordered sensorimotor integration who need treatment to prevent the progression of neck pain into more long-term pain states.[16] One possibility for the observed changes in early somatosensory processing at the level of the primary sensory cortex (ie, N20 somatosensory evoked potential [SEP] peak changes) after neck adjustments[6] (also known in the literature as manipulation) is that this reflects alterations in proprioceptive processing. SEPs are produced by transcutaneous electrical stimulation of a peripheral nerve and are thought to reflect central processing of signals originating from muscle afferents. Information from muscle afferents are known to be extremely important for central proprioceptive processing (for review, see[18]). Therefore, it is possible that the observed changes in the N20 SEP complex after cervical adjustments[6] reflect changes in central proprioceptive processing.

It is possible that cervical spinal dysfunction disturbs proprioception from the neck and upper limb and that spinal adjustments improve it. Palmgren et al[19] demonstrated that chiropractic care can improve head repositioning accuracy, which is an indicator of improved proprioception, suggesting that spinal adjustments can improve spinal proprioception.

A recent study takes the work of Palmgren et al[19] a step further, as it suggests that cervical spine function can influence upper limb proprioception. Knox and Hodges[20] demonstrated that changes in head and neck position in a group of participants without any history of neck pain or injury led to reduced accuracy of elbow joint position sense (JPS). The authors of this study discussed how accurate execution of movement depends on the ability of the CNS to integrate somatosensory, vestibular, and visual information regarding the position of the body.[20] They argued that placing their participants' heads in full flexion and rotation could have led to an overload of the computational capacity of the CNS, thus resulting in increased JPS error.[20] The same group of researchers also demonstrated that people with whiplash-associated disorder (WAD) are affected by smaller angles of neck rotation than individuals who had no history of WAD,[21] further suggesting that cervical spine dysfunction leads to reduced accuracy of JPS. Taken together, these studies suggest that spinal function can impact central proprioceptive processing not only of the spine itself, as the study of Palmgren et al[19] suggests, but also of the upper limb. It is therefore possible that the changes in the N20 SEP peak after spinal adjustments of dysfunctional cervical segments[6] could reflect such changes in proprioceptive processing of the upper limb.

The aims of the current study were therefore to investigate whether JPS accuracy differs between SCNP participants and those with no history of any neck symptoms or injury and to determine whether manipulating (adjusting) dysfunctional cervical segments in the SCNP group can improve the accuracy of their elbow JPS.

METHODS

Participants

Twenty-five participants (10 women, 15 men; average age, 25.7 ± 4.3 years) with a self-reported history of subclinical neck pain but with no acute neck symptoms on the day of recording were recruited for the cervical adjustment experiment. Twenty of the participants were deemed to be right-handed (mean laterality quotient, 86.5%; range, 57.9%-100%) and 5, left-handed (mean laterality quotient, 57.0%; range, 30.3%-80.3%) using the Edinburgh handedness questionnaire.[22] Data from 18 participants (13 women, 5 men; average age, 23.2 ± 9.5 years) with no history of any neck complaint or injury were used as a comparison group to compare the 2 groups' preintervention data. Of these participants, 17 were right-handed (mean laterality quotient, 81.6%; range, 33.3%-100%), and 1 was left-handed (laterality quotient, 54.6%), determined using the Edinburgh handedness questionnaire.[22]

Of these control participants, 11 (9 women, 2 men; average age, 26.7 ± 12.1 years) participated in a pre-post experiment with no intervention to control for the effects of time alone or the potential for learning or boredom effects. Participants were volunteers recruited via written advertisement at the local university, New Zealand College of Chiropractic, and community notice boards as well as by word of mouth.

Participants were excluded if they reported a history of shoulder or elbow pain, current pain anywhere in the body, diagnosed degenerative joint disease, or any medical condition affecting the sensory system. In keeping with the definition of SCNP, participants were excluded if they had sought previous treatment of neck pain. All the SCNP group participants were questioned regarding contraindications to cervical spine manipulation such as a history of previous fractures, high blood pressure, and metabolic, inflammatory, or neoplastic disease. A history of

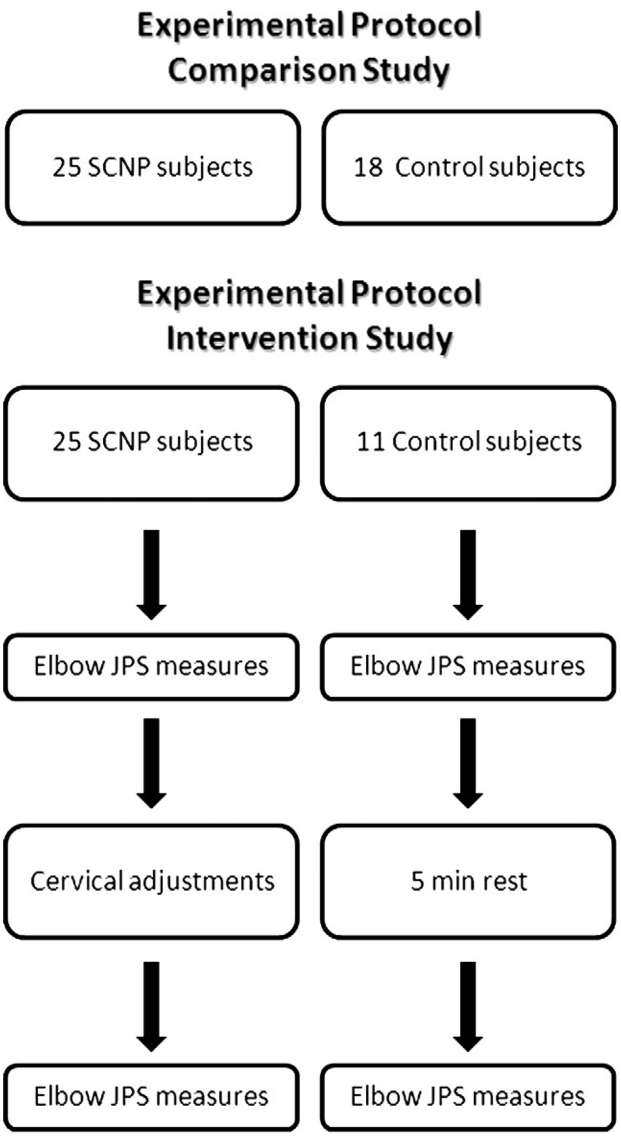

Fig 1. *A flow diagram of the experimental protocol for the comparison study at baseline and the pre-post intervention experiment.*

previous head or neck injury such as concussion or whiplash injury was reported by 14 of 25 participants in the adjustment group. Informed consent was obtained, and the Northern Y Regional Ethics Committee approved this study. All procedures were conducted in accordance with the Declaration of Helsinki.

Experimental Protocol

The experimental protocol for this study is depicted in Figure 1 as a flow diagram. Participants were required to attend 1 session each. All data collection was carried out in the Human Neurophysiology Laboratory at the New Zealand College of Chiropractic. An independent research assistant collected all the data. The interventions were carried out by the principal investigator. Neither the subjects nor the investigators were blinded to which intervention was performed because the control intervention was not in any way intended as a sham adjustment but rather to control for the effects of the repeated measurements. Participants were initially given written and verbal information about the study and were allowed to ask questions. The SCNP participant's spines were assessed for the presence of cervical joint dysfunction by a registered chiropractor with at least 8 years of clinical experience. This was detected in the following manner: the examiner passively moved the participants' head while palpating and stabilizing over the zygapophyseal joints. For each spinal segment, the head was gently and passively moved from neutral position to the maximal range of lateral flexion in the coronal plane to both the left and the right. If this movement appeared restricted, the examiner applied gentle pressure to the joint while watching for signs of discomfort from the participant. The examiner also asked the participant if the pressure to the joint elicited pain and/or tenderness. Cervical segments that were deemed both restricted in lateral flexion range of motion and elicited pain on palpation were noted down for the cervical adjustment intervention. For the purpose of this study, *dysfunctional segments* were defined as the presence of both palpable restricted intersegmental range of motion and tenderness to palpation of the joint because these criteria have been shown to have acceptable reliability in the literature for the cervical spine.[23-27]

Relevant clinical information was also obtained from the participants according to the existing clinical protocol at the New Zealand College of Chiropractic Clinic. This included their name, age, date of birth, handedness, prior chiropractic care, medical history, history of any previous trauma (including head trauma), whether the participant was presently taking any medication, and whether the participant had any history of neurologic disorders.

Continuous electromyography (EMG) was recorded from 6 neck and upper limb muscles to ensure that the participants were totally at rest throughout the passive and rest conditions of the data collection procedure. Six JPS measurement trials were carried out pre and post the cervical adjustment intervention (for the SCNP group) or the control intervention (for the control group), as described in detail below.

Joint Position Sense Measurements

Elbow JPS was measured using a task that requires the participant to reproduce a previously presented angle of the elbow joint, as was done by Knox and Hodges.[20] This methodology has been used in several previously published studies including a pre-post experimental design similar to the one used for this study and is a valid and reliable method

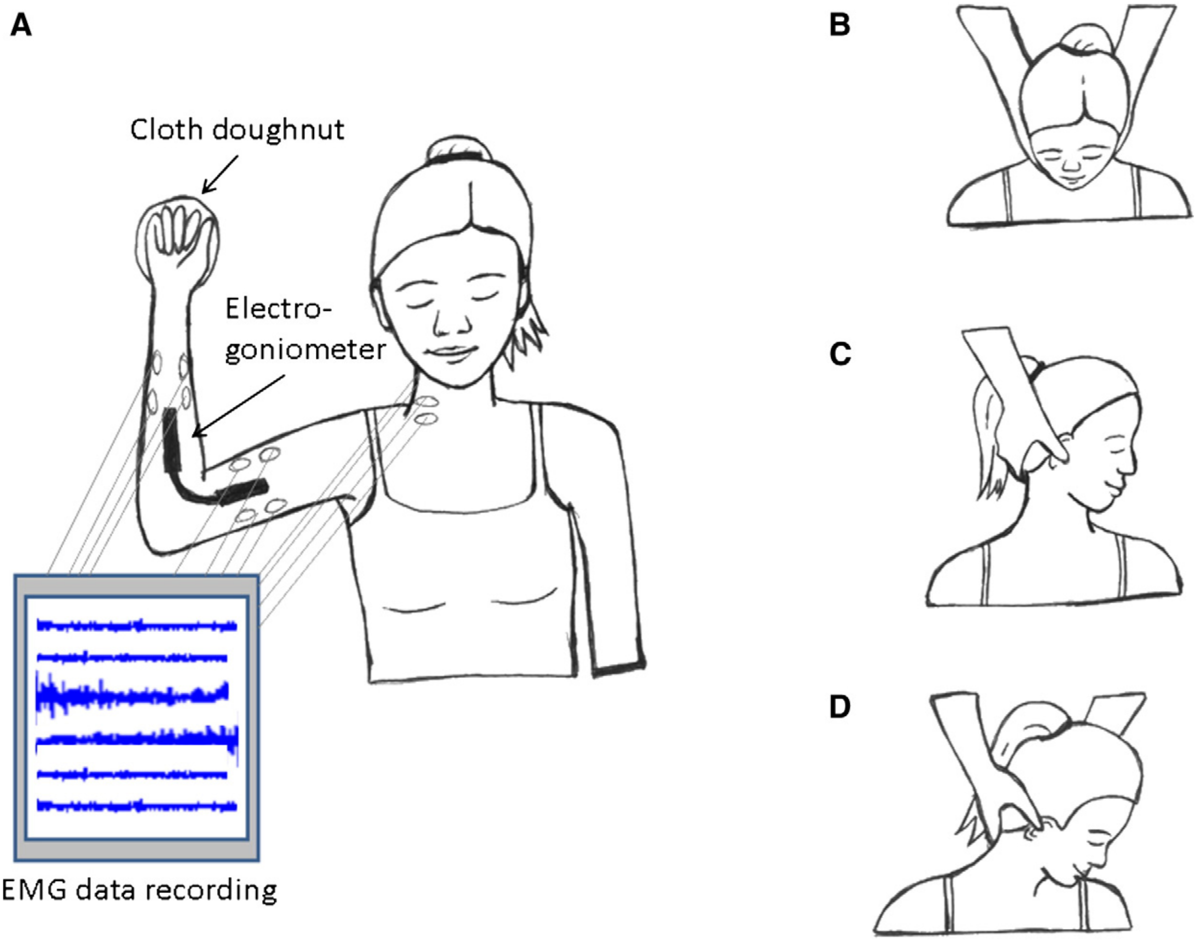

Fig 2. *Experimental procedure for JPS task. Participants were positioned supine on a nonfriction surface with their right arm at 80° abduction and their elbow flexed. The upper arm was supported in a sling (not shown), and the hand was supported with a cloth doughnut on a low friction surface. There was no contact between the forearm and the surface. The participants' eyes remained closed throughout each experimental condition. Continuous electromyography data were collected from the following muscles, as indicated in the diagram: right biceps brachii, triceps brachii, flexor carpi radialis, extensor carpi radialis, sterno cleido mastoid and the upper trapezius. The 4 head positions were neutral (A), flexion (B), left rotation (C), and combined flexion and left rotation (D).*

for measuring JPS.[21,28] Participants were positioned lying on their back with their right arm in an 80° abduction and external rotation, with the upper arm held in a sling (see Fig 2). The hand was placed on a piece of cloth folded into a doughnut shape resting on a low friction whiteboard surface. The cloth doughnut elevated the arm so that the forearm did not touch the meltica surface to minimize sensory cues from the skin that might have helped the participants to identify the elbow joint position. Sensory cues were further minimized by having participants' eyes closed throughout each experimental condition (each of which took about 2 minutes) and having participants perform JPS at the midrange of movement (80° and 100°) to decrease cues from skin and tendon stretch and joint contact at the end range of movement.

The experimenter passively moved the participant's forearm to a randomly chosen target angle and held there for 3 seconds before moving the forearm to a rest position that was also held for 3 seconds. The rest position was either a greater or lesser angle than the target angle, within the range of 70° to 110°, which was also randomly selected by the experimenter. The speed of all movements was varied randomly by the experimenter between 5° to 25° per second, again, to minimize cues for the participant. The participants were then asked to actively reproduce the target elbow joint position.

Six trials for each of the following head positions were conducted with randomly preselected midrange elbow angles: (1) neutral (control position), (2) left rotation, (3) flexion, and (4) combined flexion and left rotation. For each of these positions, the participant's head was passively placed in the target position by the experimenter and kept in this position with the aid of various pillows during the active reproduction of the elbow joint target angle. For each of the head positions 2 to 4, the head and neck was taken almost to the end of each participants' range of motion. Particular care was taken not to move the shoulder or upper limb during these head and neck movements.

Interventions

The cervical adjustment interventions carried out in this study were all high-velocity, low-amplitude thrusts to the spine held in lateral flexion with slight rotation and slight extension. The mechanical properties of this type of CNS perturbation have been investigated, and although the actual force applied to the participants' spine depends on the therapist, the patient and the spinal location of treatment, the general shape of the force-time history of spinal manipulation is very consistent,[29] and the duration of the thrust is always less than 200 milliseconds (for review, see[30]). The high-velocity type of adjustment was chosen specifically because previous research[1] has shown that reflex EMG activation observed after adjusting the spine only occurred after high-velocity, low-amplitude manipulations (as compared to lower velocity mobilizations) and would therefore be more likely to alter afferent input to the CNS and lead to measurable JPS changes. This particular type of CNS perturbation has also been used previously to demonstrate central plastic changes.[6,8,10-12] All cervical adjustments were carried out in the exact same position as during data recording, and great care was taken not to move the participant's upper body or arm position. For the purpose of this study, dysfunctional segments were defined as the presence of both palpable restricted intersegmental range of motion and tenderness to palpation of the joint because these criteria have been shown to have acceptable reliability in the literature for the cervical spine.[23-26] The control intervention consisted of a 5-minute rest period before the joint position measures were recorded again.

Equipment and Data Collection

Elbow joint angle was measured using an electrogoniometer (MLTS700; ADInstruments, Dunedin, New Zealand). Data from the electrogoniometer were sampled at 200 Hz using a PowerLab 26T data acquisition system and Chart software (MLTS700; ADInstruments). Continuous EMG activity (band-pass filtered 20 Hz-1 kHz; sample rate, 2 kHz) was monitored online at high gain with the Bio Amplifiers on the PowerLab 26T data acquisition systems (ADInstruments) to ensure that there was no muscle recruitment during the passive and rest phases of the data collection trials. The EMG electrodes were placed according to published protocols.[31]

The EMG activity was recorded through adhesive surface electrodes (ADInstruments) placed over the following muscles: biceps brachii (BB), triceps brachii (TB), flexor carpi radialis (FCR), extensor carpi radialis (ECR), sterno cleido mastoid (SCM), and the upper trapezius (UT). Electrodes were placed in the following manner: for BB, the electrodes were placed on the anterior surface of the humerus in a vertical plane so that they ran parallel to the muscle fibers. They were placed over the muscle belly approximately two thirds of the distance between the shoulder and the elbow.[31] For TB, the electrodes were placed on the posterior lateral surface of the upper arm over the belly of the muscle, approximately half the distance between the shoulder and the elbow oriented to follow the fibers of the muscle.[31]

For FCR, the electrodes were placed 2 cm apart over the muscle belly, approximately halfway between the wrist and the elbow in the center of the ventral forearm.[31] For ECR, the electrodes were placed 2 cm apart over the muscle belly, approximately 5 cm distal from the lateral epicondyle of the elbow.[31] For SCM, the electrodes were placed 2 cm apart, half the distance between the mastoid process and the sternal notch, slightly posterior to the center of the muscle belly so that they ran parallel to the muscle fibers.[31] For the UT, the electrodes were placed to run parallel to the muscle fibers of the UT. They were placed approximately 1 cm in from the ridge of the shoulder, toward the back.[31] The EMG was band pass filtered between 20 Hz and 1 kHz and sampled at 2 kHz.

Data Analysis and Statistical Analysis

To avoid any bias in data analysis, the data were coded by the principal investigator before the research assistant carried out all the data analysis. After this, the data were decoded, grouped according to intervention, and statistical analysis was performed. The accuracy of the participants' elbow JPS (ie, angle reproduction) was assessed, as done by Knox et al[20,21] and others,[32,33] using 3 parameters. Absolute error was measured to record the magnitude of error and was calculated as the absolute difference (ie, in either direction) between the presented and the reproduced angles. Constant error was measured to record error while accounting for the direction and magnitude of error and was calculated as the difference between the presented and reproduced angles. Finally, variable error was calculated as the SD of the mean constant error. Overall accuracy was compared between head positions and between groups using a multifactorial analysis of variance (ANOVA), with "GROUP" (SCNP vs control group) and "CONDITION" (neutral, flexion, left rotation, and combined flexion with left-rotation head positions) as factors. This was carried out after testing for homogeneity of variance because of unequal group sizes. To assess the effect of adjusting dysfunctional cervical segments, a multifactorial repeated measures ANOVA was used, with "TIME" (pre and post intervention measures), CONDITION (neutral, flexion, left rotation, and combined flexion and left-rotation head

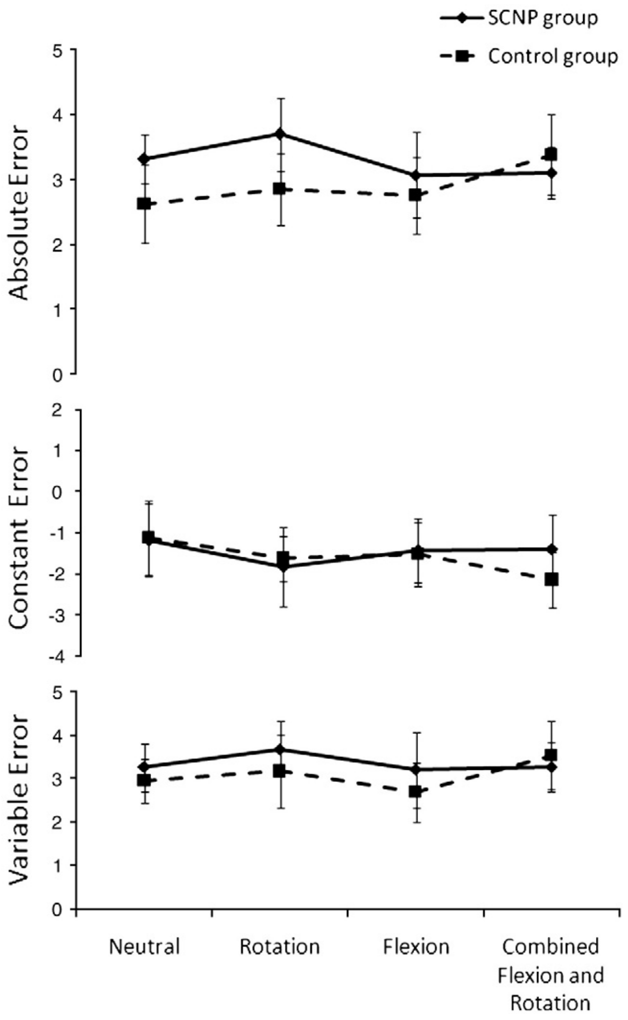

Fig 3. *Average absolute, constant, and variable joint position errors measured in degrees for each head position comparing both groups. Solid line represents the SCNP group, and the dashed line represents the control group with no prior history of any neck complaint. Error bars represent 95% confidence intervals. Note that the SCNP group displayed significantly greater absolute and variable errors compared to the control group. No effects were evident from the various head positions.*

positions) and GROUP (SCNP vs control group) as factors. A priori pairwise comparisons of the pre and post intervention data were carried out when appropriate with Bonferroni corrections for multiple comparisons. All statistical analysis was carried out using SPSS 16 (SPSS New Zealand, Auckland, New Zealand). Significance was set at $P \leq .05$.

Results

For the absolute error data, there was an overall GROUP effect when comparing the 2 groups' preintervention data ($F_{1,172}$ = 4.31; P = .04), with the control group significantly better at reproducing the target angle compared to the SCNP group (see Fig 3). The multifactorial repeated measures ANOVA assessing any effect from the cervical adjustments revealed a significant interactive effect for the factors TIME, GROUP, and HEAD POSITION ($F_{3,136}$ = 4.14; P = .008) and for TIME and GROUP ($F_{1,136}$ = 17.9; $P < .001$). Further analysis of the SCNP group data revealed an overall effect for TIME ($F_{1,96}$ = 16.0; $P < .001$) and a significant interactive effect for the factors TIME and HEAD POSITION ($F_{3,96}$ = 3.25; P = .025). A priori pairwise comparisons of the pre and post adjustment data for each head position revealed a significant improvement in JPS accuracy after the adjustments when the participants had their heads in the neutral position ($P < .04$, with Bonferroni corrections) and in full left rotation (P = .01, with Bonferroni corrections) (see Fig 4). In the neutral control position, when participants were asked to repeat a previously presented angle, the mean absolute error was 3.31° (95% confidence interval, 2.93°-3.68°). After the neck adjustments, this mean absolute error decreased to 2.47° (95% confidence interval, 2.11°-2.83°) (see Fig 4). When the participants' heads were in full left rotation, the mean absolute error was 3.69° (95% confidence interval, 3.13°-4.25°). After the neck adjustments, this mean absolute error decreased to 2.90° (95% confidence interval, 2.49°-3.31°) (see Fig 4). Further analysis of the control group data revealed a significant overall effect only (ie, no interactive effect) ($F_{1,40}$ = 5.73; P = .03), with the control participants less accurately repositioning their arms after the control intervention (see Fig 4).

There were no significant group differences in variance. However, for the variance data, the multifactorial repeated measures ANOVA assessing any effect from the cervical adjustments revealed a significant interactive effect for the factors TIME and GROUP ($F_{1,136}$ = 13.44; $P < .001$). Further analysis of the SCNP group data revealed a significant overall effect only (ie, no interactive effect) ($F_{1,96}$ = 4.64; P = .03), with the variance of error decreasing significantly after the cervical adjustment intervention (see Fig 4). Further analysis of the control group data also revealed a significant overall effect only ($F_{1,40}$ = 7.80; $P < .001$), with the variance increasing significantly after the control intervention (see Fig 4).

There were no significant group differences in constant error. Neither intervention had any significant effect on constant error (ie, there were no systematic differences between groups about the direction of the error and no systematic effects from cervical adjustments in the direction of the error). No significant effect due to head position was found in any of the calculated variables for either group, neither before nor after either intervention. Finally, there were no significant group differences in background EMG for any muscle nor were there any changes in background EMG for any muscle after either intervention.

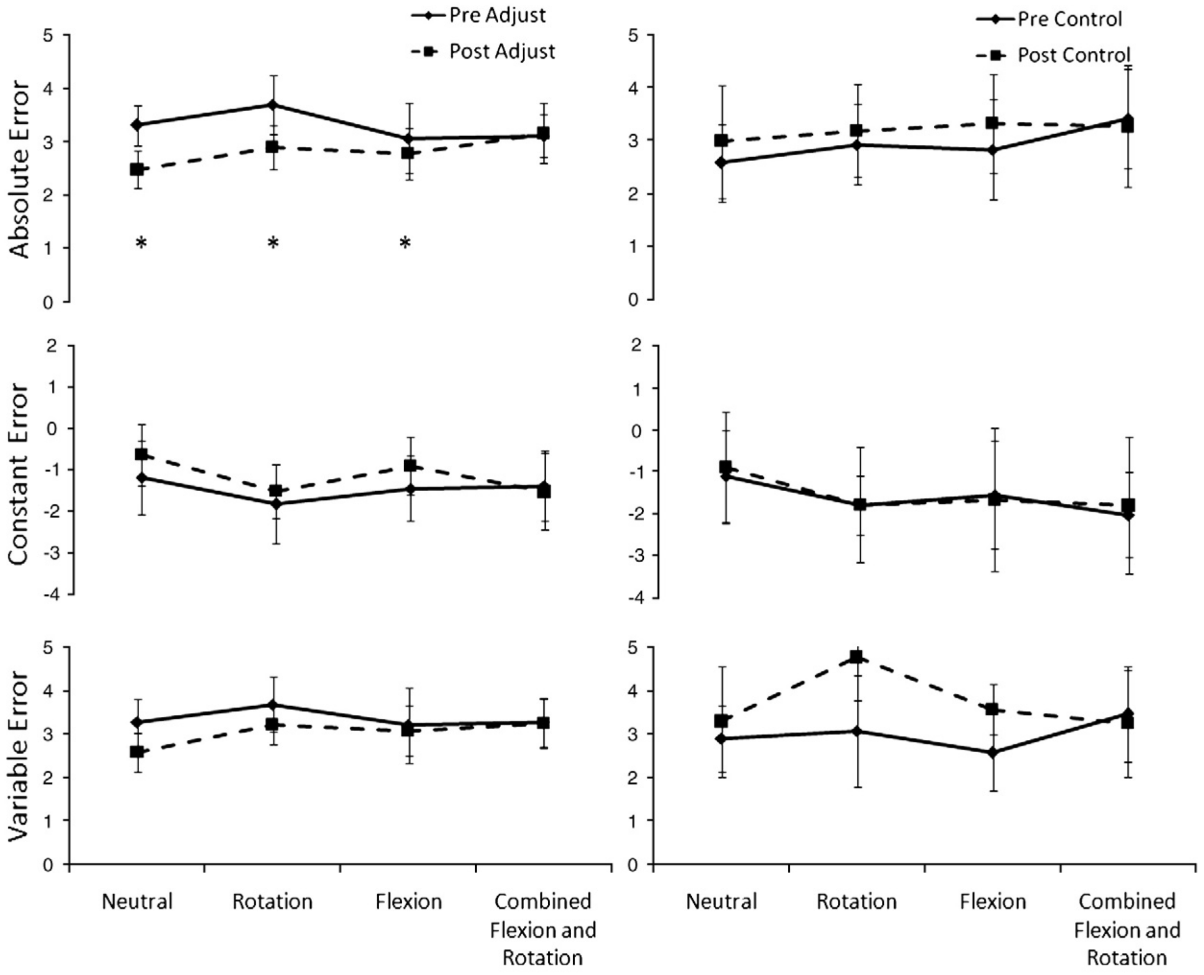

Fig 4. *Average absolute, constant, and variable joint position errors measured in degrees for each head position pre and post the high-velocity, low-amplitude cervical spine adjustment (graphs on the left) and control interventions (graphs on the right). The solid lines represent the preintervention data, and the dashed lines reflect the postintervention data. Error bars represent 95% confidence intervals. Note that there was a significant improvement in absolute error after the cervical adjustments when the head was in neutral and left rotation positions, * P < .05. Note also that there was a significant overall reduction on variable error after the cervical adjustments, a significant overall worsening of absolute and variable errors after the control intervention, although in these instances head position did not have any effect.*

DISCUSSION

The major findings in this study were that participants with a self-reported history of subclinical neck pain have significantly worse elbow JPS compared to people that have no neck complaints and that a single session of high-velocity, low-amplitude adjustments of dysfunctional cervical joints resulted in a significant improvement of elbow JPS.

The Effect of the Spine on Limb Proprioception

Previous research[20,28,34] has demonstrated that both perceived and actual head and neck positions can influence the accuracy of elbow JPS. Thus, the body's internal reference framework appears to be very important for accurate integration of incoming proprioceptive information. It was therefore unexpected that the SCNP participants in the current study did not demonstrate a worsening of JPS because of actual changes in head and neck position; particularly, because Knox et al[21] have also shown that changes in head and neck positions have a greater effect on elbow JPS when people have had head or neck injuries such as WAD. Of the 25 SCNP participants in the current study, 14 reported a history of previous head or neck injury such as concussion or whiplash injury. However, this discrepancy in findings is most likely due to methodological differences. In the current study, the participants' heads were placed in the various positions before presentation of the target angle and were left in that position for all 6 trials. Knox and Hodges[20] moved their participants' heads between the presentation of the target angle and before the participants were asked to actively reproduce this target angle. It is tempting to suggest that the distraction of the movement may have influenced the reduced accuracy in elbow joint angle reproduction in that study. However, because the participants in the study of Knox and Hodges were not influenced by the movement distraction control intervention,[20] this seems an unlikely explanation. It is quite possible because our participants had their heads held in the various positions throughout each set of trials that their CNS may have been able to adapt to this position and more accurately judge their elbow joint position.

The Functional Role of the Spine in Subclinical and Long-term Pain Syndromes

There is evidence in the literature to suggest that muscle impairment occurs early in the history of onset of neck complaints[35] and that this muscle impairment does not automatically resolve even when neck pain symptoms improve.[35,36] Some authors have therefore suggested that the deficits in proprioception and motor control rather than the pain itself may be the main factors defining the clinical picture and chronicity of different long-term pain conditions.[14-16] The finding that the SCNP participants have significantly worse JPS accuracy compared to participants with no history of any neck complaint supports this hypothesis. The current study results suggest that deficits in proprioception identified in the SCNP group may be partly due to the presence of the type of spinal dysfunction that chiropractors and other manipulative therapists treat. The cervical adjustment intervention improved the SCNP participants' elbow JPS accuracy to a similar level as that of the control group and to what has previously been reported in the literature in asymptomatic healthy populations with no history of head or neck symptoms or injuries.[21] This supports the theory that chiropractic care can have a beneficial neuromodulatory effect.[13] The improvements we observed might be even more impressive in a group with a greater level of pain and disability because some authors[35,37] have observed larger repositioning errors in persons reporting worse functional disability scores than those with milder problems.

It is also possible that the putative “manipulable lesion,” also known as “vertebral subluxation” or “dysfunctional spinal joint segment,” may represent a state of altered afferent input that may be responsible for ongoing central plastic changes. It is well established that altered afferent input to the CNS leads to changes in CNS functioning.[38-40] Thus, as previously postulated,[6,10-13] a potential mechanism that could explain how manipulation improves function is that altered afferent feedback from a dysfunctional neck or spine alters the afferent “milieu” into which subsequent afferent feedback from the spine and limbs is received and processed thus leading to altered sensorimotor integration of the afferent input, which is then normalized by high-velocity, low-amplitude adjustments of the dysfunctional areas of the spine.

Limitations and Potential Bias

Another unexpected finding in the current study was that the control participants' elbow joint position accuracy reduced after the control intervention. This methodology has previously been reported to be reliable,[21,28,41] at least for the absolute and variable error measurements.[41] However, the control participants in the current study performed significantly worse after the control intervention. They displayed an overall reduction in absolute error and a greater variable error. However, several of the participants in both groups reported that they felt like their arm was “going to sleep” because of maintaining the supine position with their arm externally rotated and abducted for the length of time the data recording session took. This has not been reported by previous studies using the same participant positioning as used in the current study.[20,34] However, our experiment took longer because we carried out pre and post measures in the same session, and this alone could explain the differences we observed. Juul-Kristensen et al[41] used a seated participant position in their test-retest reliability study, which could explain the better reliability findings for absolute and variable errors. It is therefore possible that the participant positioning in the current study has led to upper limb sensory disturbances because of position-related compression effects on the brachial plexus that caused the worsening of the absolute and variable errors in the control participants. If this is the case, the improvements seen in the SCNP group after the adjustment intervention are all the more impressive because several of the SCNP participants also complained that maintaining the required position for the duration of the data collection procedure was affecting their upper limb. Another possibility is that the control participants worsening JPS accuracy after the control intervention was because of a boredom effect and that the improvements seen in the SCNP group was because of a placebo effect or that both groups participated with a different degree of effort (ie, the avis effect). It is very difficult to avoid these potential biases because sham adjustments (ie, sham spinal manipulation) are near impossible to perform. This needs to be addressed in future studies. Furthermore, the potential biases, although they must be considered, cannot explain the reports from the participants that the position was causing their right arms to go to sleep (described as mild numbness and tingling sensations).

Conclusion

The results of this study suggest that asymptomatic people with a history of recurring neck pain, stiffness, or ache have reduced elbow JPS accuracy compared to those with no history of any neck complaints. Furthermore, the results suggest that even a single session of adjusting dysfunctional cervical segments in people with subclinical neck pain can improve their upper limb JPS accuracy.

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Practical Applications

- The results of this study suggest that asymptomatic people with a history of recurring neck pain, stiffness, or ache have reduced elbow JPS accuracy compared to those with no history of any neck complaints.
- Spinal manipulation (adjustments) delivered to dysfunctional cervical segments in people with subclinical neck pain improved upper limb JPS accuracy in this group.
- These findings support the concept that neck joint dysfunction can impair the way proprioceptive input from the upper limb is processed and provides evidence that this can be improved by cervical spine manipulation.
- This study supports previous research that suggests that altered sensory processing and motor control may be implicated in the development of chronic and recurrent neck pain.

FUNDING SOURCES AND POTENTIAL CONFLICTS OF INTEREST

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