ORIGINAL ARTICLE

UNDERSHOOTING OF A NEUTRAL REFERENCE POSITION BY ASYMPTOMATIC SUBJECTS AFTER CERVICAL MOTION IN THE SAGITTAL PLANE

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ABSTRACT

Objective: The objective of this study was to determine if blindfolded, asymptomatic subjects undershoot or overshoot a self-selected neutral reference position (NRP) when performing a full-cycle, head repositioning accuracy test in the sagittal plane.

Methods: An asymptomatic group of subjects, consisting of 7 men and 5 women with no history of head and neck pain, were recruited for the study. Subjects, performing a full-cycle series of head/neck movements in the sagittal plane, attempted to return to a self-selected NRP, defined at the beginning of the movement sequence, without benefit of visual clues. Data were collected for each subject, and repositioning errors were calculated. The sign of the error was used to determine if undershooting or overshooting of the NRP had occurred.

Results: Subjects undershot a self-selected NRP at statistically significant levels ($P < .01$) when performing the head repositioning accuracy test while blindfolded. Subjects undershot the NRP 83% of the time when moving from flexion to the NRP and undershot the NRP 92% of the time when moving from extension to the NRP. A Fisher exact test showed no significant difference between the number of times subjects undershot the NRP when moving from either flexion to the NRP or from extension to the NRP. To our knowledge, neither undershooting nor overshooting of an NRP has previously been reported for asymptomatic subjects at statistically significant levels.

Conclusion: Knowing that asymptomatic subjects undershoot an NRP may help to direct treatment and rehabilitation of patients who have experienced whiplash-type injuries and are shown to overshoot the NRP when performing the same test. (J Manipulative Physiol Ther 2008;31:547-552)

Key Indexing Terms: *Physical Therapy Modalities; Neck Pain; Whiplash Injuries; Kinesthesis; Proprioception; Outcome Assessment (Health Care); Spine; Cervical Vertebrae*

The ability to characterize statistically significant differences in head positioning patterns between asymptomatic subjects and head and neck pain patients has the potential to direct and facilitate the process of rehabilitation for a number of patient populations, including those having whiplash-type injuries. Accurate positioning of the head depends upon the convergence of visual, vestibular, and neck proprioceptive input to the central nervous system (CNS). Imbalance or dysfunction in any one of these has the potential to impact an individual's ability to perform normal, daily activities.[1] Symptoms that are related to the pathologic condition may include vertigo, eye-head dyscoordination, dysequilibrium, and gait ataxia. When these symptoms persist, they can complicate the recovery process and contribute to long-term loss of functional independence.

Measurement of cervical range of motion (ROM) is a commonly used, easily administered,[2] and inexpensive test that provides positional information related to specific motion restrictions. Individuals who have experienced a motor vehicle injury typically have less cervical ROM than control subjects, with sagittal plane movements being proportionally the most effected.[3-6]

Cervical kinesthetic performance has the potential to provide additional information beyond what may be obtained with ROM tests. Evaluation of kinesthetic performance typically is used to quantify a subject's ability to return to a self-selected neutral reference position (NRP), without benefit of visual or verbal feedback related to accuracy, after moving their head and neck to a position that

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is equal to or less than the maximum active range of pain-free motion.[7] Although some studies have found repositioning accuracy of some patients with head and neck pain to be significantly reduced when compared to control subjects,[7-10] other studies have not observed this relationship.[11,12] Revel et al[7] reported that head repositioning error was significantly less precise ($P < .01$) in patients with the pathology than in control subjects. Rix and Bagust[12] also reported that head repositioning error was significantly less precise ($P < .05$) in patients presenting with neck pain than in control subjects. Heikkila and Astrom[9] reported that head repositioning error was significantly less precise ($P < .007$) in patients with whiplash injury than in control subjects. In sharp contrast to these reports, Armstrong et al[11] reported that they did not observe any significant position sense impairment ($P > .05$) in the mildly disabled cohort of patients who had whiplash that they studied. This reported difference in outcomes might have resulted from methodological differences in the experimental protocols and/or from a multitude of confounding factors in the patient groups that might be related to the type of injury, the time since injury, intervention history, and the resulting pathologic condition. Studies agree that whiplash-type injury patients show either the greatest reduction in ROM and/or the greatest increase in the neutral repositioning error for movements within the sagittal plane.[3-5,11-14] Results from a recent study suggest that both cervical ROM and kinesthetic sensibility should be used together in any attempt to quantify the pathologic condition.[15] In addition to positioning accuracy, kinesthetic performance testing may be used to characterize head and neck positioning patterns such as undershooting and overshooting the NRP. When the final head position does not return to the NRP, this is described as undershooting. Undershooting may result from an overestimation of the actual position of the head. When the final head position goes beyond the NRP, this is described as overshooting. Overshooting may result from an underestimation of the actual position of the head. Some studies have observed that head and neck pain patients, without benefit of visual feedback related to head position, have a tendency to undershoot an NRP when performing a movement sequence in which they moved from extension to perceived neutral[7,9] and have a tendency to overshoot an NRP when performing a movement sequence in which they moved from flexion to perceived neutral.[7,9,11] Other studies have reported that head and neck pain patients overshoot an NRP when performing a movement sequence in which they moved from flexion to perceived neutral at statistically significant levels.[9,13] The inconsistencies among these studies have been attributed to differences in the etiology of the pathologic condition and the methodology of testing.

Undershooting of target positions has been observed in control subjects performing speed aiming tasks with visual feedback that involved use of the finger, elbow, and shoulder.[16,17] In these experiments, subjects typically undershoot the target position with an initial gross motion and then use a series of fine movements to achieve the final target position.[17] It has been hypothesized that this strategy is a compromise between movement speed and the need for the time-consuming, corrective submovements required for accuracy. It has been suggested that temporal and energy expenditures associated with target undershoot are less than those associated with target overshoot[18] and that initial target undershooting provides a "safety margin" that takes variability into consideration.[19] In a goal-directed motion study in which vision was restricted, subjects were found to undershoot the final target when drawing a horizontal straight line.[20] Based upon findings from these studies, it seems reasonable that asymptomatic subjects would also undershoot a final target position when performing a head and neck repositioning test.

Although considerable effort has been expended in studying ROM, positioning accuracy, and positioning patterns in groups of head and neck pain patients, little if any effort has been expended in characterizing head and neck positioning patterns in asymptomatic subjects. Because of the multitude of confounding factors related to the type of injury, the time since injury, intervention history, and the resulting pathologic condition in groups of head and neck pain patients, characterization of head and neck positioning patterns in asymptomatic subjects is considered to be worthy of study.

We hypothesized that there would be a significant difference between the number of times that blindfolded, asymptomatic subjects would undershoot and the number of times that that they would overshoot a self-selected NRP when performing a full-cycle, head repositioning accuracy test in the sagittal plane.

Methods

Subject Selection

An asymptomatic group of subjects, consisting of 7 men and 5 women (mean age, 31.8 years; range, 18-52 years) with no history of head and neck pain, brain injury, whiplash-type injury, or cervical injury, was recruited from faculty, students, and staff at Michigan State University (East Lansing, Mich). Each subject was asked to read and sign an institutional approved informed consent form before proceeding with the study.

Data Collection System

A data collection/analysis system, based upon a personal computer, a frame-grabber board (Matrox Meteor; 640 × 480 pixels resolution; 256 gray levels, Matrox Electronic Systems Ltd, Dorval, Quebec, Canada), and a video camera (Sony XC-77, CCD; Sony Electronics, Los Angeles, Calif), fitted with a standard lens (VCL-16Y-M, f = 16 mm, F1.4), was constructed to measure cervical kinesthetic performance. The experimental design was patterned after Revel