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A study of five cervicocephalic relocation tests in three different subject groups

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Objective: To compare head relocation accuracy in traumatic (whiplash), insidious onset neck pain patients and asymptomatic subjects when targeting a natural head posture (NHP) and complex predetermined positions.
Design: A case–control study.
Setting: University-based musculoskeletal research clinic.
Participants: Sixty-three volunteers divided into three groups of similar gender and age: Group 1 ($n = 21$) an asymptomatic group; group 2 ($n = 20$) insidious onset neck pain; group 3 ($n = 22$) a history of whiplash injury.
Intervention: Five randomly ordered tests designed to detect relocation accuracy of the head.
Outcome measures: A 3-Space Fastrak system measured the mean absolute relocation error of three trials of each relocation test.
Results: A significant difference was found between groups in one of the tests targeting the NHP ($p = 0.001$). Post-hoc pairwise comparisons revealed a significant difference ($p \leq 0.05$) between the asymptomatic group and each symptomatic group. The difference between the symptomatic groups just failed to reach significance ($p = 0.07$). None of the other four tests revealed significant differences.
Conclusion: The test of targeting the NHP indicates that relocation inaccuracy exists in patients with neck pain with a trend to suggest that the deficit may be greater in whiplash patients. Tests employing unfamiliar postures or more complex movement were not successful in differentiating subject groups.

Introduction

The proprioceptive mechanisms controlling the head on the body have been tested clinically by simple target-matching tasks, which aim either to relocate the natural head posture (NHP)[1] or to relocate a set point in range.[2] Studies employing such tests in neck pain populations have provided variable results regarding the presence of kinesthetic deficits.[1–4] This may reflect either the different onsets of neck pain in the populations studied, insidious onset versus whiplash injury, or different measurement methodologies. However we also question whether these simple tests of relocating the NHP[1] or relocating a set point in range[2] are best for detecting disorders in the proprioceptive system of the neck.[5]

Evidence from experimental brain research

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suggests that humans have a remarkable ability to relocate remembered targets and to perform simple movements and common tasks without relying on proprioceptive input.[6–8] The NHP might therefore be relocated without reliance on proprioceptive information. Simple movements and commonly performed tasks, which have been stored in the long-term memory, can also be performed without proprioceptive information.[9,10] The converse is true for nonlearned complex movements.[7,10] This might be a threat to the content validity of the two tests that have been used previously.[1–4]

The purpose of this study was to investigate relocation accuracy with tests of both complex nonlearned movements and traditional tests of relocating either the NHP or a set point in range to determine the ability of the different tests to differentiate between subject groups. Two patient groups with different histories of onset of neck symptoms, traumatic (whiplash) and insidious onset were examined and compared with asymptomatic subjects to determine if any differences related to the history of onset of neck pain.

Methods

Subjects

Sixty-eight volunteers between the ages of 18 and 54 years were provisionally enrolled for the study. There were three study groups and participants in each group were balanced according to age and gender. The asymptomatic subjects comprising group 1 were drawn from a pool of university staff and students. To be included in this group, subjects were to have no current or past history of musculoskeletal pain or injury in the neck or upper limb. Subjects for the insidious onset neck pain group, group 2 and the neck pain group following a whiplash injury, group 3, were sought from the university's Whiplash Research Unit, referring clinicians and through advertising. To be included in either symptomatic group, subjects' symptoms were to be between 3 and 48 months duration (the patient population attending the Whiplash Unit). There was to be no previous history of neck pain (group 3) or injury (group 2). Subjects were not considered for any group if they suffered from diseases affecting the neck or throat, rheumatic or neurological disorders of any kind. Ethical clearance for the study was obtained from the Medical Ethics Committee, The University of Queensland, Brisbane, Australia and all subjects gave informed consent.

Potential participants were initially assessed for their suitability for the study in a telephone interview conducted by a research assistant according to the inclusion and exclusion criteria. At arrival, prior to formal inclusion into the study, all subjects answered a questionnaire regarding the history of neck pain and any associated symptoms. Symptomatic subjects also completed the Northwick Park Neck Pain Disability Index[11] and recorded their average pain level on a 100-mm visual analogue scale (VAS), anchored with 'no pain' and 'the worst pain I can imagine'. Five subjects were subsequently not formally enrolled into the study due to histories of previous trauma or pain duration more than 48 months.

Instrumentation and measurements

A 3-Space Fastrak system was used in this study (Polhemus Navigation Science Division, Kaiser Aerospace, Vermont, USA). The Fastrak is a noninvasive electromagnetic measuring instrument that tracks the positions of sensors relative to a source in three dimensions. The Fastrak was connected to an IBM-compatible PC and continually recorded the positions of the sensors relative to the source during the entire test sequence. A previous study has demonstrated that the 3-Space Isotrak system, which is a similar equipment, is accurate to within ±0.2°.[12]

A software program was written to format and process the data for three-dimensional analysis of movements in space. The software program converted the data directly into angle files and graphs to visualize the process in real time on the screen from the starting position through the excursion of movement. The data obtained from the Fastrak consisted of a 3×3 matrix of direction cosines for the orientation of the forehead electrode relative to the electrode placed on C7. This matrix was then analysed to give three independent rotations of the head relative to C7. In this way, the primary movements in the movement plane and the simultaneous coupled rotations in the associated planes were recorded and represented the accuracy with which the subjects could relocate the target in each task.

Cervicocephalic relocation tests

Test 1: Relocation to the NHP

This test replicated that of Revel *et al.*[1] The starting position was in sitting with the head in the NHP. The subjects were asked to perform full active rotation of the head and neck within comfortable limits and then to return and indicate, as accurately as possible, when they considered they had relocated the starting position. This point was recorded by activation of the electronic marker switch. Between each test movement, the subject's head was manually adjusted back to the original starting position by the principal researcher (EK) who was guided by the real time display on the computer screen.

Test 2: Relocation to the 30° rotation position

In this test, after Loudon *et al.*,[2] the examiner positioned the subject's head in 30° rotation to the left in the first series of tests and to the right in the second series. The visual display unit of the computer guided the researcher where a marker had been placed to indicate the 30° position. The starting position for this test was the neutral NHP and the subjects were required to return to the 30° rotation positions. Recordings were taken on each occasion the 30° positions were relocated.

Test 3: Preset trunk rotation

This test was adapted from the smooth pursuit neck torsion (SPNT) test developed by Rosenhall *et al.*[13] and Gimse *et al.*,[14] where disturbances in eye movement control, indicative of altered neck proprioception, were detected when the neck was positioned in rotation. In the adaptation in this study, the subject sat on a chair positioned on a specially constructed platform. The subject first concentrated on the NHP. The platform with the subject's trunk was then passively rotated to a pre-marked 30° position of left rotation while the principal researcher held the subject's head steadily in the original position of the NHP. The trunk was therefore rotated with respect to the head, which created rotation of the neck to the opposite side. The subject returned to the natural alignment of the head with respect to the body and then returned to the 30° relative neck rotation position (i.e., the original position of the head).

Test 4: Figure-of-eight relocation test

This test was developed to assess relocation accuracy following performance of a nonlearned, complex movement. Subjects were taught to perform a discreet figure-of-eight movement by moving the head. As a guide, a 10 cm diameter diagram of a figure of eight lying on its side was placed on a stand 1 m in front of the subject. The starting position was the NHP. The subject was required to trace the figure-of-eight movement with their nose. Each subject was permitted three practice trials of the movement with their eyes open. The subject performed the movement three times and after each time (i.e., one trial), was required to stop at the start position (NHP) as accurately as possible.

Test 5: Figure-of-eight movement test

This test was designed to test relocation accuracy during movement. The starting position was the NHP. The subject repeated the figure-of-eight movement three times, without stopping, as consistently as possible. Each time a crossover was made in the figure-of-eight movement, the subject was asked to go through the starting position (i.e., the NHP) with their nose as accurately as possible. They therefore crossed the starting position five times in the test sequence.

Procedure

The principal researcher, who was blinded to the subjects' grouping, gave the test instructions to the subjects. The five tests were performed in a randomized order according to random numbers generated in the Excel program. For test 4, three repetitions of the figure-of-eight movements were performed, and in test 5, two sequences of three repetitions of the figure-of-eight movements were performed.

Prior to each test sequence, the subjects were blindfolded. For tests involving relocating a NHP, the subjects sat relaxed with the head naturally positioned to the front. They concentrated on that position for a few seconds. The Fastrak instrument recorded this NHP as the zero starting position. This was the position of reference, both for the subjects and the calculations of repositioning error. The same procedure was undertaken for the 30° positions described in tests 2 and 3, except the examiner manually prepositioned the subject's head to 30° rotation. These two positions were therefore used as baseline values. Each subject was asked to say clearly 'yes' each time a target position was relocated and this point was marked. No verbal cues were given to the subjects about their actual performance.

Data management and analyses

Data analysis was performed with the procedures implemented by SPSS 10.0. The criterion used to measure relocation accuracy (the dependent variable) in this study was error magnitude. In tests 1 and 4, relocation accuracy to the NHP was analysed. Tests 2 and 3 tested reproduction of the 30° rotation position. The absolute value of the error (unsigned) was calculated for the angular motion of axial rotation for each trial. For test 5, the ability to repeatedly move through a target (the centre of a figure of eight) was analysed. The angular values in degrees for the error in axial rotation was calculated at the crossover point and these values were used in the analysis. The linear distance from the forehead sensor to the original start position (NHP) was calculated from three-dimensional Cartesian coordinates. The crossover point was defined as the point at which this distance was smallest.

The mean error of the three trials for each test was calculated for each individual. These values were then used in the analyses. Preliminary analyses indicated that the distributions of positioning errors were positively skewed, and a normal probability plot indicated that the variables failed to meet the assumption of normality. Performing log transforms on the dependant variables from these tests rectified these problems.

One-way analyses of variance (ANOVA) were performed on absolute positioning errors for all tests. The significance level was set at $p < 0.05$. Post-hoc, least significant difference (LSD) pairwise comparisons were used to investigate any significant between-groups differences.

Results

Demographic details of the subjects are presented in Table 1. The current pain rated on the VAS and the Northwick Park Neck Pain Disability Index were the only self-reported characteristics that were statistically significant between the symptomatic groups. The whiplash group rated higher on both these variables.

The descriptive results from the relocation tests are summarized in Table 2. The arithmetic means ±1 SD are shown with 95% confidence intervals. The results of the ANOVAs revealed a significant difference only in test 1 ($F=_{(2,60)} = 8.07$, $p = 0.001$). No differences between groups were determined in any of the other four tests. The post-hoc pairwise comparisons of the three groups in test 1 revealed significant differences between the asymptomatic group and both the whiplash ($p = 0.001$) and the insidious onset neck pain group ($p = 0.04$). The difference between the two symptomatic groups just failed to reach significance ($p = 0.07$).

Table 1 Characteristics of the subject groups

	Group 1 Asymptomatic (n = 21)	Group 2 Nontrauma (n = 20)	Group 3 Trauma (n = 22)
Male/female	10/11	11/9	11/11
Age (years)	26.9 ± 6.4	30.0 ± 9.1	33.4 ± 10.6
Pain duration (months)	–	28.6 ± 15.5	21.9 ± 12.5
Pain in past week (VAS)	–	3.15 ± 2.11	4.50 ± 2.7
Current pain (VAS)*	–	1.82 ± 2.0	3.37 ± 2.8
Neck Pain and Disability Index*	–	20.53 ± 11.18	39.98 ± 18.0

*$p < 0.05$ independent t-test.

Table 2 Repositioning errors and confidence intervals for each task for the asymptomatic (1), insidious onset neck pain (2) and whiplash (3) groups

	Group	Repositioning error, mean (± 1 SD)	95% Confidence interval	
			Lower	Upper
Test 1 NHP	1	2.48° (±1.12)	1.96	2.99
	2	3.33° (±1.42)	2.58	4.08
	3	4.14° (±1.58)	3.46	4.81
Test 2 30°	1	5.46° (±2.05)	4.53	6.40
	2	6.67° (±3.64)	4.97	8.38
	3	5.73° (±2.85)	4.47	7.00
	1	6.72° (±3.13)	5.29	8.14
Test 3 30°	2	7.67° (±3.85)	5.87	9.47
	3	7.01° (±5.85)	4.42	9.61
Test 4 NHP	1	2.15° (±1.15)	1.62	2.67
	2	2.25° (±1.47)	1.56	2.94
	3	2.48° (±1.34)	1.89	3.08
Test 5 NHP	1	6.86° (±3.94)	5.07	8.65
	2	5.82° (±2.75)	4.53	7.10
	3	8.00° (±6.01)	5.47	10.55

Discussion

Relocation inaccuracy was evident in the neck pain groups compared with the asymptomatic group but only with the more traditional test of relocation of the NHP (test 1) as introduced by Revel *et al.*[1] Our contention that the new tests, which involved more complex tasks (tests 3–5), might better depict inaccuracies in relocation in neck pain patients because of a greater challenge to the neck proprioceptive system has to be rejected. Relocating the 30° position in range did not detect differences between the groups in this study in contrast to the findings of Loudon *et al.*[2]

Clinical messages

- Relocating the natural head posture after full active neck range of motion is the best test available to detect differences between neck pain and asymptomatic groups.
- Nonfamiliar starting positions and complex movements were not able to differentiate subject groups in this study.

A similar tendency was noted in test 3, where the starting head–trunk alignment was unnatural and did not involve familiar target positions. The greater error in relocating a position in range supports the equilibrium-point hypothesis for control of movements.[15] Therefore our contention that using nonfamiliar starting positions might be more challenging to the proprioceptive system than use of familiar postures is in part supported through this greater error but, most relevantly, the test failed to distinguish between the symptomatic and asymptomatic groups. In test 4 it is possible that the complex pattern of neck movement might result in considerable stimulation of the neck mechanoreceptors,[16] thereby not challenging the proprioceptive system in the way it was postulated to do so. The familiar target of the NHP may have been the overriding influence. It has been shown that ascending afferent signals can be selectively gated at all levels of the central nervous system according to the relevance of the incoming information.[17,18] The potential for too massive a stimulation of the mechanoreceptors must therefore be avoided when designing a test to detect deficits in proprioception.

It is difficult to measure impairment in proprioceptive activity, the lowest order in the hierarchy of motor control.[18] Target-matching tasks have been those most widely used since introduced by Slinger and Horsley in 1906.[19] These tasks measure position sense, which is only one aspect of proprioceptive function.[20–22] Today more technically advanced equipment is available, making it feasible to assess other aspects of proprioceptive function. To this end, we introduced a test that investigated the accuracy of consistently targeting the starting position of the NHP while performing a figure-of-eight movement (test 5). This was one of the more difficult tests but again failed to show any difference between groups. This might reflect problems in the construct validity of this test, as the test movement was not unpredictable and may not have been performed slowly enough. An important function of the proprioceptive system is to correct movements on a moment-to-moment basis[7] and measuring quality of movements may be of great clinical importance. The development of a test that measures proprioceptive function while subjects are moving (that is, measurement of discreet points within a movement path) could be warranted.

A difference in relocation accuracy was found in relocation of the NHP (test 1) between the asymptomatic subject group and the neck pain groups. This contrasts to the findings of Rix and Bagust[4] who used less sophisticated instrumentation in their study of patients with insidious onset neck pain. There was a trend for relocation errors to be higher in whiplash subjects compared with the insidious onset group but the difference with this sample size was not significant. In parallel, the reported pain and disability of the whiplash group (Table 1) was also higher, which may contribute to this difference. Further study is required with larger sample sizes to better explore the influence of pain versus the influence of injury on cervicocephalic relocation accuracy.

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