A New Clinical Test for Cervicocephalic Kinesthetic Sensibility: "The Fly"

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ABSTRACT. Kristjansson E, Hardardottir L, Asmundardottir M, Gudmundsson K. A new clinical test for cervicocephalic kinesthetic sensibility: "The Fly." Arch Phys Med Rehabil 2004;85:490-5.

Objective: To investigate the reliability and discriminative ability of a new test designed to detect accuracy of neck movements.

Design: Repeated-measures. Case-control.

Setting: University musculoskeletal research clinic in Iceland.

Participants: Twenty women (mean age ± standard deviation [SD], 30.8±9.1y; range, 18–49y) with chronic whiplash-associated disorders (WAD) grades I and II (duration, 6mo–6y), with current pain score on a visual analog scale of 46.8±21.8, and a disability score on the Northwick Park Neck Pain Disability Index of 45%±14%. Twenty asymptomatic women (mean age ± SD, 29.3±8.6y; range, 18–48y) with no history of whiplash or insidious onset neck pain served as controls.

Intervention: A slowly moving object appeared on a computer screen and traced an unpredictable movement path that the subjects were required to follow by moving their heads. Three randomly ordered movement patterns were tested.

Main Outcome Measure: A new software program connected to a 3Space Fastrak system was used to measure the mean absolute error (in millimeters) of 3 trials in each movement pattern.

Results: The mean differences (±2 SD) between days 1 and 2 were .01±.64mm for the asymptomatic group and .33±1.80mm for the WAD group. The between-day intraclass correlation coefficients were between .60 and .77 for the asymptomatic group and .79 and .86 for the WAD group. Repeated-measures analysis of variance revealed a significant difference between groups (P=.02). The Tukey post hoc test showed significant between-group differences for each movement pattern ($P \leq .05$). In each successive trial, a slight improvement for the asymptomatic group and a slight worsening for the WAD group were detected.

Conclusions: Better reliability was detected for the asymptomatic group than for the WAD group. The test could discriminate between the asymptomatic group versus the chronic WAD group.

Key Words: Kinesthesis; Neck pain; Proprioception; Rehabilitation; Whiplash injuries.

SINCE THEY WERE INTRODUCED in 1906 by Slinger and Horsley,[1] simple target-matching tasks have been widely used clinically to measure accuracy of movement. The neuromuscular mechanism controlling the head on the body has been tested either by relocation of the natural head posture[2-5] or relocation of a set point in range.[5] These traditional cervicocephalic kinesthetic tests were recently challenged[6] because they measure only 1 aspect of proprioceptive function: position sense. An important function of the proprioceptive system in neuromuscular control is to correct movement on a moment-to-moment basis.[7] This is especially so when non-learned complex movements are performed.[8,9]

To our knowledge, there has been no clinical test of the neck to detect kinesthetic deficits while subjects are moving, yet the more technically advanced equipment available today makes it more feasible to assess the accuracy of discreet movements during movement. In a previous study,[6] subjects were required to trace a discreet figure of 8 movement by repeated movements of their head. Each time a crossover in the figure of 8 was made, the subjects were asked to move their nose through the starting natural head posture as accurately as possible. This test was too difficult for both asymptomatic and symptomatic subjects for it to be clinically useful.

The clinical experiment with the more difficult cervicocephalic kinesthetic tests led to the design of a new test for detecting the accuracy of neck movements during movement. Different theories about motor control, such as reflex, hierarchical, and system theories, also underpin the design of this new test.[10] These theories suggest that the test movement needs to be slow, unpredictable, and of short duration to challenge deficits in the cumulative input from the mechanoreceptors that give rise to neck proprioception. The slow speed ensures that overstimulation of the neck mechanoreceptors[11,12] and of the specialized mechanoreceptors in the vestibular system is avoided.[13] A slow speed is also necessary if the subjects are to be able to rely on feedback from the neck mechanoreceptors during movement.[11] The movement path must be unpredictable and of short duration to avoid the programming and learning effects described by the hierarchical models.[10] In addition, the system theories tell us that because the final goal of a movement takes priority over everything else during task performance, movement paths for the same task may differ each time the task is repeated.[10,14] An unpredictable test path is therefore preferred.

It is reasoned that deficit neuromuscular control is an important predisposing factor in the maintenance and recurrence of symptoms.[15,16] This may be a reason for the greater difficulty often encountered in the rehabilitation of patients after whiplash loading to the neck. The causes of symptoms in chronic

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whiplash-associated disorders (WAD), grades I and II, remain undefined; therefore, new tests to identify the presence or absence of disordered movement sense in this particular patient group are important. The test movements in this study targeted the upper cervical spine, which is a rich sensory organ because of the abundance of mechanoreceptors in the deep musculature in this region.[17,18] and because it has direct neurophysiologic connections to the visual and vestibular systems via the vestibular nuclear complex and the central cervical nucleus.[17] Altered function or dysfunction of the mechanoreceptors in the upper cervical spine is therefore important clinically because it may contribute to symptoms such as light-headedness, dizziness, blurred vision, cervicogenic headache, and cognitive problems.[19-21]

The purpose of this study was to investigate the reliability of a new moving test and to detect any differences in kinesthetic sensibility between subjects in an asymptomatic group and subjects in a chronic WAD group when they performed 3 different movement patterns.

METHODS

Participants

Forty female volunteers between 19 and 49 years of age (mean age, 30.0±8.8y) were provisionally enrolled for the study. We enrolled only women because they are more prone to develop chronic symptoms after low-speed motor vehicle collisions[22] (MVCs). They were divided equally into an asymptomatic group and a chronic whiplash group. The asymptomatic subjects were a sample of convenience. To be included in this group, subjects had to have no history of musculoskeletal pain or injury in the neck or upper limbs. The chronic whiplash subjects were recruited from physiotherapy clinics. To be included, subjects had to have had symptoms for more than 6 months and less than 6 years that corresponded to grades I and II, as classified by the Quebec Task Force on Whiplash-Associated Disorders.[22] Subjects were not considered for either group if they had diseases affecting the neck or throat, or rheumatic or neurologic disorders of any kind. Before they were included in the study, all subjects completed the Northwick Park Neck Pain Disability Index,[23] and the whiplash subjects recorded their average pain level on a 100-mm visual analog scale. Ethics approval for the study was obtained from the Medical Ethics Committee, University of Iceland, Reykjavik, Iceland. All participants gave their informed consent.

Instrumentation and Measurement

A 3Space Fastrak system[a] was used in this study. The Fastrak is a noninvasive electromagnetic measuring instrument that tracks in 3 dimensions the positions of sensors relative to a source. This system has been used to assess position sense in the neck,[6] trunk,[24] and lumbar spine.[25] In this study, 1 sensor was placed on the forehead and another was placed on the back of the head, in the same sagittal plane. The sensors were fastened on the head with the inner plastic ring from a safety helmet that was adjusted to fit each subject. This ensured the same placement of the sensors during head and neck movements and prevented traction on the sensor's lead. The electromagnetic source (transmitter) was placed in a box attached to the back of a wooden chair. A previous study demonstrated that the 3Space Isotrak system,[26,a] which is similar to the Fastrak system, is accurate to within ±0.2°. The Fastrak was connected to a personal computer (600MHz PII processor with Windows 2000) via a 9600-baud serial port. The Fastrak continually recorded the positions of the sensors relative to the source during the entire test.

A new software program, called the Fly, was written for this study to format and process the data for analysis. In this program, the difference between the location of the forehead sensor relative to the sensor on the back of the head, both vertically and horizontally, is calculated, and this data is used to indicate on the computer monitor the movement of the head. This 2-dimensional movement data is then processed by the Fly and projected into a square (bounding box) on the monitor. Two cursors are visible in this square: a blue one tracing unpredictable movement patterns (derived from the Fly) and a black one indicating the movement of the head (derived from the Fastrak system). It is not possible to predict the movement because only the cursors are visible on the screen.

The movement patterns traced by the Fly are generated randomly and an essentially infinite number of patterns can be produced. The software program makes it possible to record the absolute distance (radius) between the 2 cursors continuously during the entire test sequence and to store this information along with information about how each pattern is generated. This latter option makes it possible to repeat a prechosen movement pattern. The user can adjust the velocity of the Fly on the screen, and the duration of each movement pattern. In this experiment, the velocity was set at a constant speed of 16.2mm/s. Four movement patterns were selected from the program to represent the test sequences used in this study. Two decisions were made at this stage of the test design. First, the movement patterns chosen should have curved, but not acute, angles so that the asymptomatic subjects could complete it without difficulty. Second, the movement patterns should be of short duration.

The new software was thereby considered to fulfill the conceptual basis (construct validity) of a new movement test: to generate slow and unpredictable movement patterns of short duration.

Procedure

The procedure was similar for all test sequences. In advance of the test, an examiner who was blind to the subjects' group placement explained the intention and nature of the task required of the subjects. To familiarize them with the test, 1 movement pattern was performed once by all participants and was not used for measurements. The other 3 movement patterns, A, B, and C, were used for the measurements (fig 1). Subjects were required to repeat each movement pattern 3 times, with a 10-second interval between each trial. The duration of each trial was 30, 20, and 40 seconds for movement patterns A, B, and C, respectively. The test was performed in random order across patterns and trials. The randomization was done in Microsoft Excel 2000.[b]

Figure 2 shows the experimental set-up. In this starting position, the smaller (blue) cursor from the Fly and the bigger (black) cursor from the Fastrak system matched each other in the middle of the screen. The blue cursor then started to move, and the subjects were asked to make the black cursor follow it by moving their heads. The first half of the sample, 10 in each group, were asked to repeat the whole test procedure 1 week later in the same way and at the same time of day. At that time, no exercise sequence was performed before the 3 movement patterns that constituted the Fly were traced.

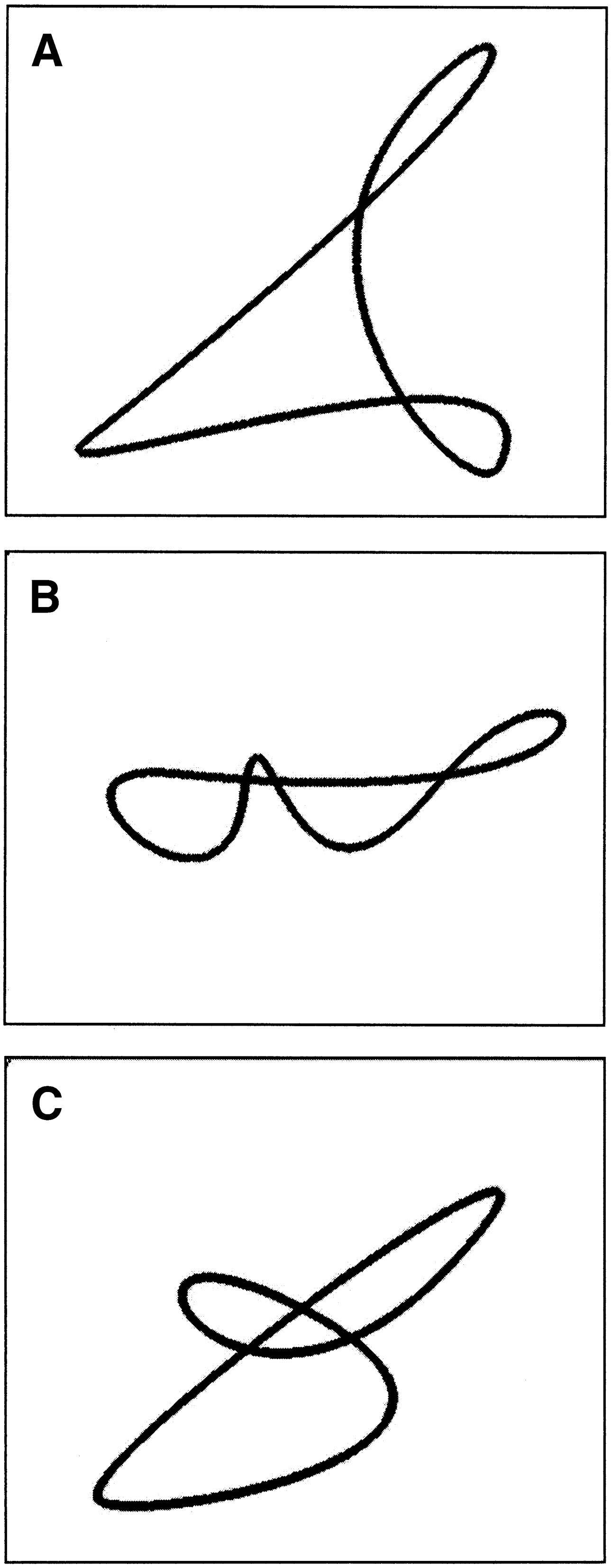

Fig 1. Movement patterns A, B, and C traced by the Fly, which participants were required to follow by moving their heads.

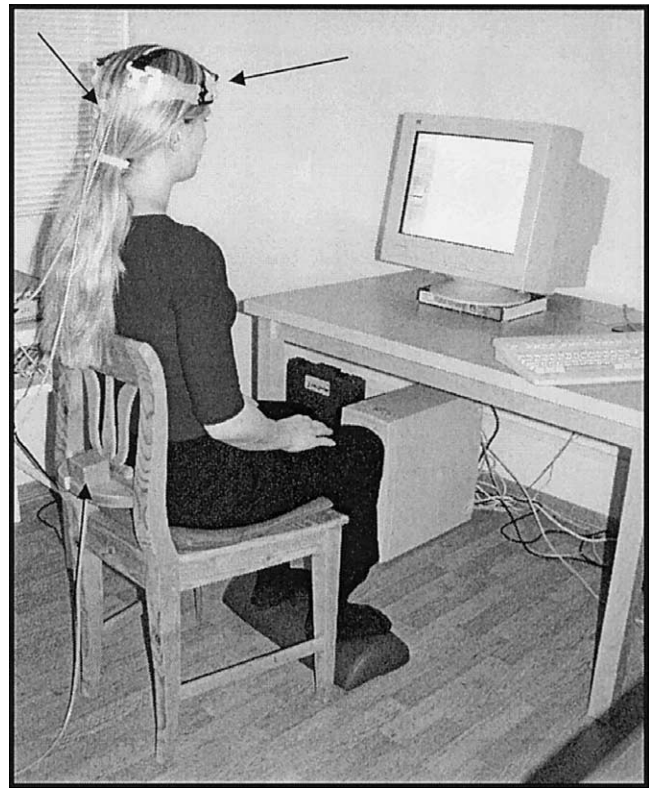

Fig 2. Experimental set-up. The subjects were seated in front of a computer and were asked to find their natural head posture. The distance from the chair back to the computer monitor was 100cm. The arrows point to the sensors attached to the head and the electromagnetic transmitter.

Data Management and Analyses

Data analysis was performed with the procedures implemented by SAS/STAT, version 7.0.[c] The criterion used to measure kinesthetic sensibility (the dependent variable) in this study was error magnitude (test accuracy). The absolute value of the error (unsigned) was calculated in pixels and converted into millimeters by multiplying by .36 (1 pixel=.36mm in this test). The mean error of the 3 trials for each movement pattern was calculated for each individual and represented the accuracy with which the subjects could follow the Fly. Plots were derived for the mean differences (±2 standard deviations [SDs]) between repeated measurements on days 1 and 2 for 10 subjects in each of the 2 groups, according to the method of Bland and Altman.[27] The between-day intraclass correlation coefficients (ICCs) were calculated according to Shrout and Fleiss[28] for the same subjects as in the plots. Repeated-measures analysis of variance (ANOVA) was also carried out on differences between trials and groups for the 3 movement patterns. The statistically significant level was set at *P* less than .05. The Tukey post hoc test was used to detect which test sequences were significantly different.

RESULTS

Table 1 presents the error magnitude for each of the 3 movement patterns for 10 subjects in each of the 2 groups on days 1 and 2, and the corresponding between-day ICCs. The plots of the mean differences and ±2 SDs of the differences

Table 1: Within-Days Average Error Magnitude and the ICCs for Between-Day Agreement

Group	Movement Pattern	Day 1 Mean Error (mm)	Day 2 Mean Error (mm)	ICC
Asymptomatic				
(n=10)	A	4.07±0.96	4.05±1.17	.60
	B	3.79±0.93	4.11±1.05	.67
	C	4.24±1.10	3.90±1.07	.77
WAD grades I–II				
(n=10)	A	5.87±2.60	5.40±1.97	.79
	B	4.90±2.10	4.78±1.72	.86
	C	5.56±2.52	5.16±2.09	.81

NOTE. Values are mean ± SD.

between days 1 and 2 are presented, averaged over all movement patterns for the asymptomatic group and whiplash group respectively (figs 3, 4). The plots between trials and movement patterns on days 1 and 2 were similar to the plots in figures 3 and 4, which confirmed the appropriateness of using averaged values of all movement patterns to plot the difference between days. The descriptive results from the 3 movement patterns are summarized in table 2, which shows the means and 95% confidence intervals. The data suggest that the whiplash group had the poorest outcome in all test sequences. The repeated-measures ANOVA revealed a significant difference between groups (F_{38}=6.36, P=.02). The Tukey post hoc test showed that all movement patterns differed significantly between groups (P=.02 for A; P=.01 for B; P=.03 for C). A graph plotted for the 3 repeated measurements in all movement patterns for each group (fig 5) showed a slight divergence between groups that was not statistically significant (P=.18).

DISCUSSION

The results of this study indicate that the new test can discriminate between asymptomatic subjects and subjects with chronic WAD symptoms, grades I and II. The plots demonstrate that the variance between days was greater in the chronic WAD group than in the asymptomatic group (figs 3, 4). This may reflect the instability of symptoms in chronic WAD patients detected clinically. Interestingly, the ICCs showed better reliability for the WAD group than the asymptomatic group (table 1) and failed to detect the difference in agreement that is obvious when the plots are compared (figs 3, 4). This discrepancy in results between ICCs and plotting the same data has been observed before[6] and it shows the importance of not using the ICCs as the only reliability measure for repeated measures in clinical research. It is important to know, when treating deficits in neuromuscular control, whether an observed change represents real change or is a fluctuation typically observed in the test.[29] The high SD values in the plot for the WAD group (fig 4) indicate that the test can reliably detect only the more gross changes in the performance of WAD patients.

All movement patterns (A, B, C) differed significantly between groups (table 2). The patients in the chronic WAD group had more difficulty following the Fly, which indicates a deficit in cervicocephalic kinesthetic sensibility. The performance of the whiplash group became slightly worse on the 3 successive trials, but the asymptomatic group performed slightly better (fig 5). Theoretically, the WAD group was therefore less able to rely on input from the neck mechanoreceptors than was the asymptomatic group. Adequate firing of the mechanoreceptors is thought to be necessary for feedback and learning effects during neuromuscular control when new movement tasks are performed.[7] This appeared to be so in the asymptomatic group but not in the WAD group, which strengthens the construct validity of the new test, although this difference was not significant.

The visual system, the vestibular system, and the somatosensory system of the upper cervical spine are all neurophysiologically interlinked to serve the orientation of the head with respect to the trunk in 3-dimensional space.[13] This test is therefore a test of cervicocephalic kinesthetic sensibility. It is not possible to move the head and neck without simultaneous

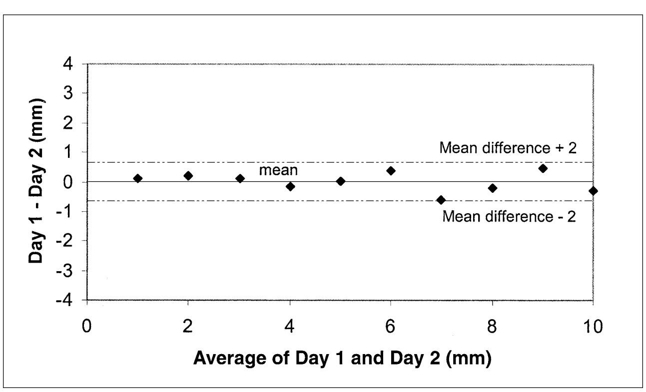

Fig 3. Plot of the agreement between days for the asymptomatic group. Mean difference is .01mm and 2 SDs (±.64mm).

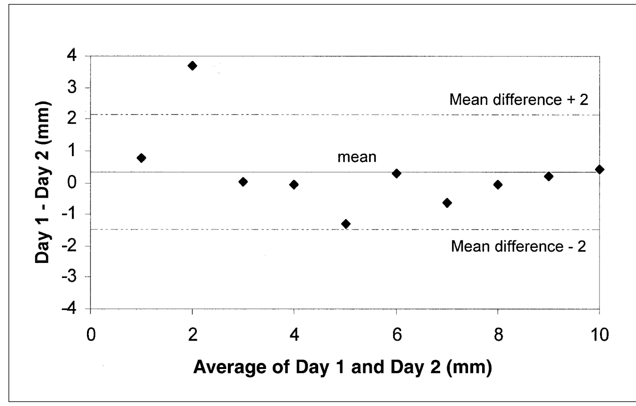

Fig 4. Plot of the agreement between days for the WAD group. Mean difference is .33mm and 2 SDs (±1.8mm).

Table 2: Error Magnitudes and 95% Confidence Intervals for Each Movement Pattern for the Asymptomatic Group (n=20) and the WAD Group (n=20)

Movement Pattern	Group	Error magnitude (mm)	Lower Bound	Upper Bound	*P*
A	Asymptomatic	3.97	3.58	4.36	.02
	WAD	5.17	4.23	6.11	
B	Asymptomatic	3.51	3.10	3.93	.01
	WAD	4.65	3.94	5.36	
C	Asymptomatic	3.97	3.50	4.43	.03
	WAD	4.97	4.09	5.86	

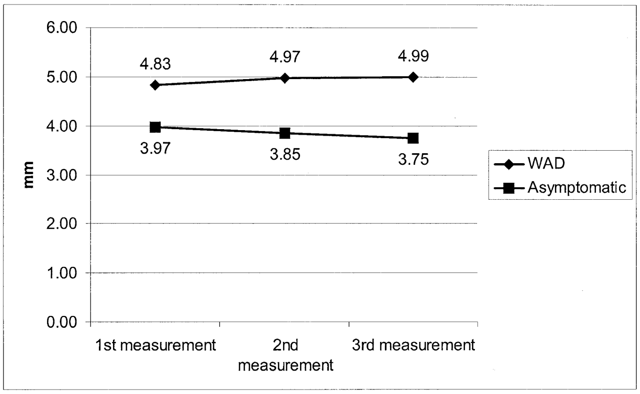

Fig 5. Plot of the 3 repeated measurements in all movement patterns for each group showing a divergent tendency between groups on repeated measurements.

stimulation of the specialized mechanoreceptors in the vestibular system.[13,30] Further research is needed to determine the speed that challenges the neck mechanoreceptors more than the mechanoreceptors in the labyrinth. The test movement in this study was slow in order to create minimal shearing motion within the vestibular system and to prevent too much stimulation of the neck mechanoreceptors. Research indicates that cervical proprioception is superior to the vestibular system for detecting slow movements of the head on the trunk, because of the inertia of the cupula in the semicircular canals.[31]

The symptomatic women in this study had WAD grades I and II, which indicates that they were involved in low-speed MVCs. However, as the peak acceleration of the head in low-speed MVCs is on average 2.5 times that of the struck vehicle,[32] damage can possibly be done to both the specialized mechanoreceptors in the vestibular system and the neck mechanoreceptors. In future development of this test, it will be important to test patients for any vestibular and visual disorders in order to examine the test's content validity as a test for neuromuscular control of the cervical spine. Movement patterns with different speeds, angulations, and duration must be tested to explore whether more between-group differences will be found with other movement patterns. However, the test difficulty must not be at the expense of its reliability. A combination of difficult and easy movement patterns has the potential to differentiate between subjects with biologically genuine symptoms and subjects who try to fake results for personal gain,[33] an issue of great concern for WAD patients because of the medicolegal implications.

CONCLUSIONS

This new test was designed to detect deficit cervicocephalic kinesthetic sensibility while subjects move their head and neck. Better reliability was ascertained for the asymptomatic group than the chronic WAD group. The test was able to discriminate between these 2 groups. The conceptual basis of the test appears to be valid, but more movement patterns need to be studied. With further development, the test has the potential to be an important tool for clinicians in identifying and treating patients with deficient movement control of the cervical spine.

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