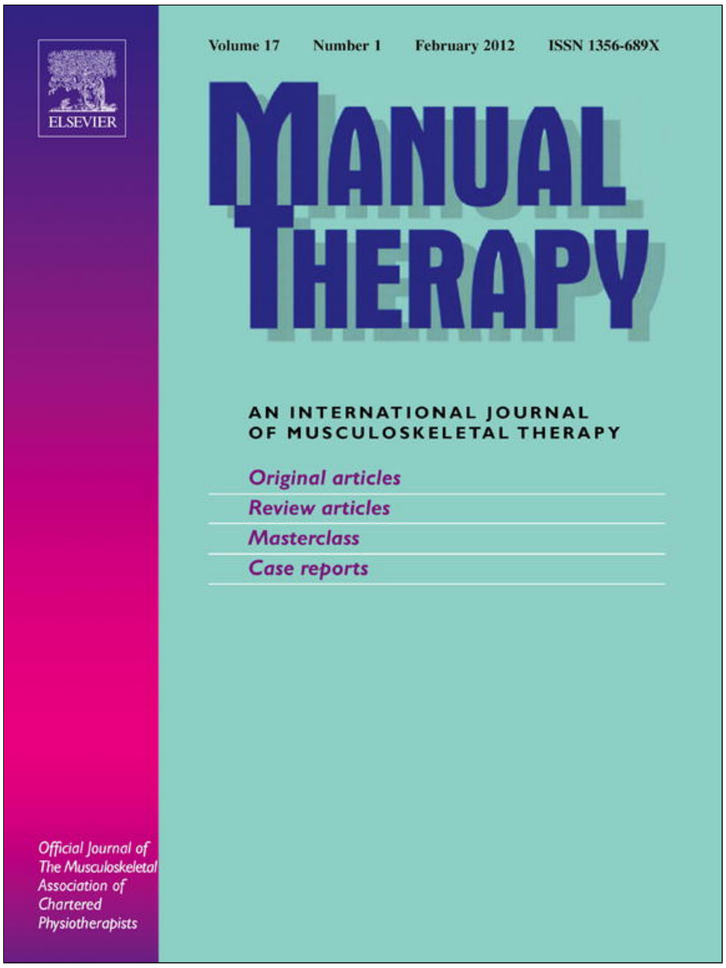
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Original article

Two different courses of impaired cervical kinaesthesia following a whiplash injury. A one-year prospective study☆

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A longitudinal study was conducted to observe persons with neck pain after motor vehicle collisions. The aims were to reveal the prospective development of cervical kinaesthesia and to investigate the association between the test results and self-reported pain and disabilities. Two different cervical kinaesthetic tests, the Fly test and the Head-Neck Relocation test, measured movement control and the relocation accuracy of the cervical spine, respectively. Self-assessment measures included pain intensity (VAS), neck pain and disability (NDI), fear of re-injury (TAMPA) and psychological distress (GHQ-28). Seventy-four subjects entered the study, but 47 were eligible, as they participated in all 4 measurements at 1, 3, 6 and 12 months post-collision. According to the performances on the two kinaesthetic tests, the subjects could be classified into improvement and non-improvement groups, respectively. The result revealed, for the first time, two different courses of deficient cervical kinaesthesia. About half of the participants showed significant deteriorating performances in both kinaesthetic tests throughout the year ($p < 0.002$), while the other half improved their performances ($p < 0.02$). Generally, the relationships between the kinaesthetic tests and the self-assessment scores were not significant, irrespective of the performances on the two kinaesthetic tests. Accordingly, the results of the questionnaires correlated poorly or weakly with the kinaesthetic test results at all assessment points. The need for developing a new questionnaire, capturing the symptoms prevalent in patients with neck pain and cervical sensorimotor impairments is urgent. What determines the two different kinaesthetic courses need to be scrutinised in future research.

1. Introduction

The actual course of impaired cervical kinaesthesia, i.e. whether cervical kinaesthesia is likely to improve, reoccur, persist or worsen, is still unknown regarding patients with whiplash-associated disorders (WAD). Several cross-sectional studies have revealed deficient head-neck relocation accuracy, indicating impaired position sense, in patients with WAD compared to asymptomatic controls (Kristjansson et al., 2003; Treleaven et al., 2003; Sterling et al., 2003; Feipel et al., 2006). Two cross-sectional studies have revealed deficient movement control of the cervical spine, indicating impaired movement sense, in patients with WAD compared to an asymptomatic control group (Kristjansson et al., 2004) as well as a non-trauma group (Kristjansson and Oddsdottir, 2010).

The aforementioned cross-sectional studies provide a "snapshot" in time, as impaired cervical kinaesthesia and prevalent symptoms from the neck are assessed at the same time. Any such factor found to be associated with symptoms from the neck at one point in time could be a precursor (risk factor), a prognostic factor for failure to recover or a consequence of symptoms from the neck (Carroll et al., 2008a).

Research on the course of impaired cervical kinaesthesia requires longitudinal research design, which permits tracking of study participants over time. We suggested that those who show impaired cervical kinaesthesia within 1 month and at 3 months post-collision are at risk of developing persistent cervical kinaesthetic deficits, revealed also at 6 months and 12 months post-collision. Our suggestion was built upon the only published research in this field, a 3-month follow-up study on motor dysfunction in WAD (Sterling et al., 2003). The aforementioned study by Sterling et al. revealed that those with moderate/severe symptoms according to scores on the Neck Disability Index (NDI) had deficient head-neck relocation accuracy within 1 month post-

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collision which remained unchanged at 3 months post-collision (Sterling et al., 2003).

The primary aim of this study was to determine the actual course of impaired cervical kinaesthesia in patients with WAD. Two distinct clinical tests for cervical kinaesthesia measured movement control accuracy and relocation accuracy, respectively. The former test, called the Fly test, replicates that of Kristjansson et al. (Kristjansson et al., 2004). The latter test, the Head-Neck Relocation test (HNR test), replicates that of Revel et al. (Revel et al., 1991).

The secondary aim of this study was to investigate the association between the test results of cervical kinaesthesia and self-reported neck pain and disability as well as fear of movement and general psychological state.

2. Methods

2.1. Study design

A prospective study was conducted to observe persons who had endured a whiplash injury after motor vehicle collisions (MVCs) at four successive assessments over a one-year period. The initial assessment took place 1 month after the MVC and the follow-up assessments at 3, 6 and 12 months post-collision.

2.2. Subjects

The whiplash subjects were recruited through the Emergency Department at Landspitali-University Hospital (LUH) in Reykjavik, Iceland, which maintains a database for people exposed to MVCs. Both genders between the ages of 18–65 were included in the study if they met the criteria of WAD I, II or III. WAD IV, multiple traumas, concussion or head injury from MVC, previous history of whiplash injury or prior symptoms from the head or neck, systematic diseases or psychological disorders of any kind excluded participation. The recruitment took place from December 2006 until September 2009. The subjects were contacted via telephone from LUH at 3 weeks post-collision. Those reporting neck pain at that time and fulfilled the inclusion-exclusion criteria were offered participation 1 week later. Seventy-four subjects entered the study. The participants were advised to "act as usual" during the study period. All gave informed consent after ethical clearance from the National Bioethics Committee.

2.3. The Fly test

The Fly is a clinical test that measures deficits of movement control in the cervical spine. The method is briefly summarised here; for details, the reader is referred to Kristjansson et al. (Kristjansson et al., 2004). The patients were equipped with tracking sensors (Fastrak, Polhemius, USA) on the head and asked to track a cursor (a fly) on a computer screen as accurately as possible. There were two cursors visible on the computer screen; a blue one (derived from the Fastrak system) indicated movements of the head, and the other cursor, a black one (derived from the Fly software program), traced three generated movement patterns (Fig. 1). Only the cursors were visible on the computer screen, not their trajectories, which makes prediction of movements difficult. A custom software program was used to format and process the data for analysis.

2.4. The Head-Neck Relocation test

The HNR test replicates that of Revel et al. (Revel et al., 1991). It measures the accuracy of relocation of the head to natural head posture (NHP). The Fastrak tracking device (Fastrak, Polhemius, USA) was used, with one sensor placed on the forehead and the other placed over C7. For details, the reader is referred to Kristjansson et al. (Kristjansson et al., 2003), who found this test to be the most reliable among several tests relocating a set point in range (Kristjansson et al., 2001).

Fig. 1. The movement patterns A, B and C (from left to right) traced by the Fly, the duration of each trial was 30, 20 and 40 s, respectively.

2.5. Self-assessment

All subjects graded their pain intensity on a 10 cm visual analogue scale (VAS), anchored by "no pain" and "pain as bad as it can be". The subjects also completed the NDI (Vernon and Mior, 1991), measuring activity limitations due to neck pain; TAMPA, an indicator of fear of movement/re-injury (Kori, 1990); and General Health questionnaire-28 (GHQ-28), indicating the general psychological well being (Goldberg, 1978).

2.6. Procedure

The order of the measurements was the same at all 4 successive assessment points. The subjects first completed the VAS, then NDI, followed by TAMPA and GHQ-28. Age, gender and claim status were recorded. The examiner was blinded to the subjects' responses on the questionnaires. The intention and nature of the tasks was explained and the subjects instructed to assume a comfortable sitting position facing forward, with relaxed shoulder girdle and hands resting in their laps. The HNR test was performed first, followed by the Fly test.

In the Fly test, the subjects were asked to use their neck movements to track as accurately as possible a moving fly (the target) on the computer screen. To familiarise them with the test procedure, one movement pattern was performed once and was not used for the measurements. Three movement patterns, A, B and C, were used for measurements. The subjects were required to repeat each movement pattern three times, with a 10-s interval between each trial (Fig. 1). The test was performed in random order across patterns and trials.

In the HNR test, the subjects were blindfolded and the starting position was sitting with the head in the natural resting posture; the subjects were asked to remember that position. They were then asked to turn their head-neck in full active rotation and then return and verbally indicate, as accurately as possible, when they had relocated the starting position. This point was recorded by activation of the electronic marker switch. Three trials of each of the two movement directions, rotation left and right, were performed. Between each trial, the subjects' head position was adjusted back to the original starting position by the examiner, who was guided by the real-time display on the computer screen.

2.7. Data analysis

In the Fly test, the mean error of the three trials for each movement pattern was calculated for each individual and represented the accuracy with which the subjects could follow the Fly. Since there was no difference between the mean accuracy errors across patterns, as revealed by paired *t*-tests ($p > 0.05$), they were

Table 1
The demographics and subdivision of the study participants into groups along with claim status.

	Total participants ($n = 47$)	Fly-IG ($n = 23$)	HNR-IG ($n = 25$)	Fly-NIG ($n = 24$)	HNR-NIG ($n = 22$)
Age in years (mean ± SD)	35.1 (±12.0)	38.0 (±12.6)	36.2 (±13.7)	32.3 (±10.9)	33.8 (±9.9)
Gender (% female)	61.7	60.9	60.0	62.5	63.3
Claim submitted[a]	18/47	10/23	10/25	8/24	8/22

No significant between-group differences in gender, age or claim status was revealed.
[a] Claim status 12 months post MVC.

combined, and the mean error of patterns A, B and C for each subject was used for analysis (FlyABC).

In the HNR test, the relocation error was calculated by using the mean of the absolute errors for the three trials of each movement direction, and these values were used for analysis. Paired *t*-tests indicated no difference in relocation errors between movement directions – rotation left and right ($p > 0.05$) – so the mean relocation errors of left and right rotation were used in further analysis.

A repeated measures general linear model (ANOVA) was used to identify whether the measurements differed over time. The dependent variables were the mean accuracy errors in the Fly test, the mean relocation errors in the HNR test and the scores of VAS and the questionnaires, and a within-subject factor of time (four levels: 1 month, 3, 6 and 12 months post-collision). Age, gender and claim status were used as covariates in this analysis.

Classification into subgroups was based on each subject's test results in the first assessment at 1 month versus at 12 months post-collision, respectively. The subjects were therefore divided into two subgroups that showed improved performances on the two tests, Fly-improvement group (Fly-IG) and HNR-improvement group (HNR-IG), versus two groups that showed deteriorating performances, Fly-non-improvement group (Fly-NIG) and HNR-non-improvement group (HNR-NIG). In order to estimate and adjust the observed measurements for regression towards the mean (RTM) effects, analysis of covariance -ANCOVA- was used, and the coefficient *b* from the regression analysis is the estimated treatment effect adjusted for RTM (Barnett et al., 2005). The dependent variables in the ANCOVA were the mean accuracy and relocation errors in the Fly and HNR tests, respectively, from the 4th measurement, with the group as a fixed factor and the mean accuracy/relocation errors from the 1st measurements as covariates. Independent *t*-test was used to calculate the between-group differences at each assessment time-point.

Two-way ANOVA with VAS and the questionnaires as covariates and Pearson's correlation coefficient were used to ascertain the association between the test results and the scores of VAS and the questionnaires. Number, subjects, means and SDs were used for description of data. Analyses were performed with the procedures implemented by the SPSS 18.0. The significance level was set at $p < 0.05$.

3. Results

3.1. Subjects

Forty-seven subjects (18 males, 29 females), mean age 35.09 years (±12.02), completed all 4 assessments and were included in the analysis. The reasons given by the 27 subjects who did not complete all 4 assessments varied: moving away from Reykjavik municipal area, not having time to attend, lack of interest. None of the 47 participants were in the process of closing a compensation claim during the research period. Demographics of all participants and the subgroups included are presented in Table 1. Overall, about half of the participants improved their performances on both cervical kinaesthetic tests, while the other half showed deteriorating performances (Tables 2 and 3). When viewing the test results of the total subjects ($n = 47$), there was no significant change in accuracy error ($p > 0.05$) on either test over the test period, or any correlation between the two tests, except weak correlation at 6 months post-collision, ($r = .28$, $p = 0.054$).

3.2. The Fly test

Table 2 presents the mean and standard deviation of the accuracy error for the combined movement patterns (A, B and C) across months and the two subgroups with corresponding *p* values.

At 1 month post-collision, the mean accuracy error in the Fly-IG was 3.8 mm (±1.6) and was 3.1 (±.7) mm in the Fly-NIG (Table 2 and Fig. 2). This between-group difference at 1 month did not reach significance ($p = 0.056$). By 12 months, the performances were opposite, as the Fly-IG had improved (2.9 mm ± .7) and was significantly better than in the Fly-NIG (3.8 mm ± .9) ($p = 0.004$). The observed change when adjusted for the effects of RTM indicated that the adjusted difference between the subgroups was significant ($b = -1.15$; 95% CI: −1.50, −.79).

There was no effect of age ($p = 0.61$) or gender ($p = 0.83$) or claim status ($p = 0.75$) on the accuracy error in the Fly test.

3.3. HNR test

Table 3 presents the mean and standard deviation of the combined relocation error from the rotation left and right in HNR test.

The between-group difference at 1 month post-collision was significant, as there was less relocation error in the HNR-NIG (2.3° ±1.2) than in the HNR-IG (3.9° ±1.9) ($p = 0.002$). By the end of the 12th month, the opposite was true, as the performance of the HNR-NIG (4.1° ±2.7) was significantly worse than in the HNR-IG (2.6° ±1.6) ($p = 0.019$) (Fig. 3). The adjusted difference between the subgroups was significant ($b = -3.16$; 95% CI: −4.15, −2.16).

There was no effect of age ($p = 0.36$), gender ($p = 0.51$) or claim status ($p = 0.28$) on the relocation errors in the HNR test.

Table 2
Results of the Fly test showing the mean (±SD) of the accuracy error (mm) for combined movement patterns (A, B and C) at each assessment point over the year.

Subgroup	1 month post MVC mean (±SD)	3 months post MVC mean (±SD)	6 months post MVC mean (±SD)	12 months post MVC mean (±SD) [c]	*p* value
Fly-IG ($n = 23$)	3.8 (±1.6)	3.7 (±1.1)	3.2 (±.9)	2.9 (±.7)	0.019[a]
Fly-NIG ($n = 24$)	3.1 (±.7)	3.2 (±.8)	3.5 (±.9)	3.8 (±.9)	0.001[b]

[a] Bonferroni post hoc test revealed significant differences between 1st and 12th month ($p < 0.05$).
[b] Bonferroni post hoc test revealed significant differences between 1st and 6th month ($p < 0.05$), 1st and 12th month ($p < 0.05$) and 3rd and 12th month ($p < 0.05$).
[c] Significant differences between subgroups ($p < 0.05$). Fly-IG = Fly-improvement group. Fly-NIG = Fly non-improvement group.

Table 3
Results of the Head-Neck Relocation test (HNR-test) showing the mean (±SD) of the relocation errors (in degrees) from rotation left and right combined (absolute mean error) at each assessment point over the year.

Subgroup	1 month post MVC mean (±SD) [c]	3 months post MVC mean (±SD)	6 months post MVC mean (±SD)	12 months post MVC mean (±SD) [d]	*p* value
HNR-IG ($n = 25$)	3.9 (±1.9)	3.5 (±1.3)	3.5 (±1.5)	2.6 (±1.6)	0.001[a]
HNR-NIG ($n = 22$)	2.3 (±1.2)	3.4 (±1.7)	2.7 (±1.4)	4.1 (±2.7)	0.002[b]

[a] Bonferroni post hoc test revealed significant differences between 3rd an 6th month ($p < 0.05$).
[b] Bonferroni post hoc test revealed significant differences between 1st and 3rd month ($p < 0.05$) and 1st and 12th month ($p < 0.05$).
[c] Significant differences between subgroups ($p < 0.05$).
[d] Significant differences between subgroups ($p < 0.05$). HNR-IG = HNR-improvement group. HNR-NIG = HNR-non-improvement group. Note: Twelve participants showed improved performance on both the Fly and HNR tests and 11 participants showed deteriorating performances on both tests. Only 1 subject showed no change between the first and last measurements in the Fly test, and was included in the Fly-IG.

3.4. *Self-assessment*

The results of each questionnaire across the whole sample and the four subgroups indicated no clear-cut tendency towards more or less disability, as no significant results emerged across most items, except the NDI results (Fig. 4). Two subjects reported no disability (score < 10) at 1 month, but 14 (30%) at 12 months. Forty subjects reported mild-to-moderate neck pain and disability (score 10–48) at 1 month, compared to 27 at 12 months. Five subjects reported severe disability (>48) at 1 month, but 6 subjects at 12 months post-collision.

3.5. *Correlation analysis — cervical kinaesthetic tests vs. self-assessment*

Comparison of the correlation between the results of the Fly test on one hand and the results of VAS and the questionnaires on the other hand, for the Fly-NIG at the 4 successive assessment points, are presented in Table 4. The Fly-IG results did not correlate with the scores of the questionnaires, except with GHQ-28 at 1 month post-collision ($r = .65$; $p < 0.001$). The HNR test results did not correlate with the scores on the questionnaires at any assessment point.

4. Discussion

The results of this prospective study revealed two different courses of deficient cervical kinaesthetic sensibility after MVCs. About half of all participants who depicted less movement accuracy and relocation accuracy at 1 month post-collision improved their performances significantly on the two kinaesthetic tests over the one-year period. The opposite was true for the other half of the participants, who depicted significant better performances at 1 month post-collision than at 12 months post-collision. Interestingly, this is in accordance with recent data that indicate that up to 50% of injured people will fail to fully recover after MVCs (Carroll et al., 2008b).

The crossover in improving versus deteriorating performances took place at different time points for the two cervical kinaesthetic tests. In addition, the direction of the two different courses was more straightforward in the Fly test, whereas the two courses in the HNR test were more fluctuating (Figs. 2 and 3). It strengthens the results of this study that the two tests, conceptualised to measure two different but interrelated aspects of cervical kinaesthesia, movement sense and position sense, respectively (McCloskey, 1973; Proske, 2006), showed similar divergences at the start and at the end of the study (Figs. 2 and 3). However, the fact that no correlation was seen between the two tests and only half of the participants depicted similar diverging courses on the two tests, underpin that the two tests represent distinct kinematic variables. Proprioception is a relatively complex sense that consists of a number of distinct "percepts". Proprioceptive percepts are distinct from one another, presumably because they are derived from different sensory receptors and different types of central processing (Cordo et al., 1994, 2000).

Comparison of the results at 12 months in the present study with a study using the same test and measurement method show

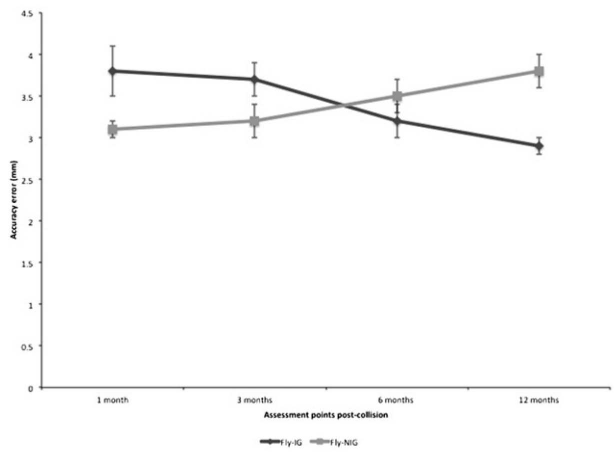

Fig. 2. The means (SE) for the two different performances on the Fly test at 4 successive assessment points over a one-year period. Note: The crossover in performances takes place between 3rd and 6th month post-collision. The subgroup differences at 1 month were not significant ($p = 0.056$) but significant differences were revealed at 12 months post-collision ($p = 0.004$).

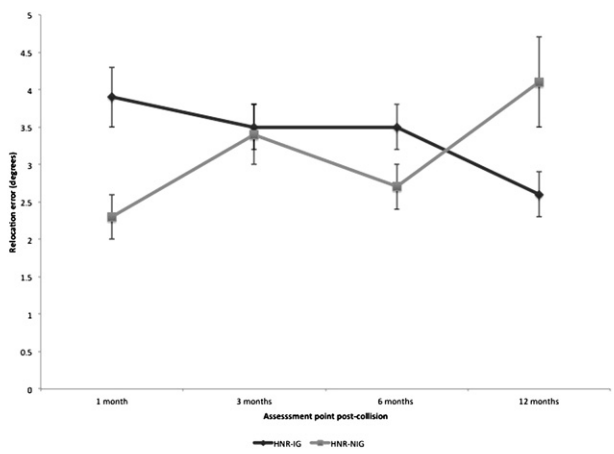

Fig. 3. The means (SE) for the two different performances on the HNR test at 4 successive assessment points over a one-year period. The subgroup differences at 1 month and 12 months post-collision were significant ($p = 0.001$ and $p = 0.019$ respectively).

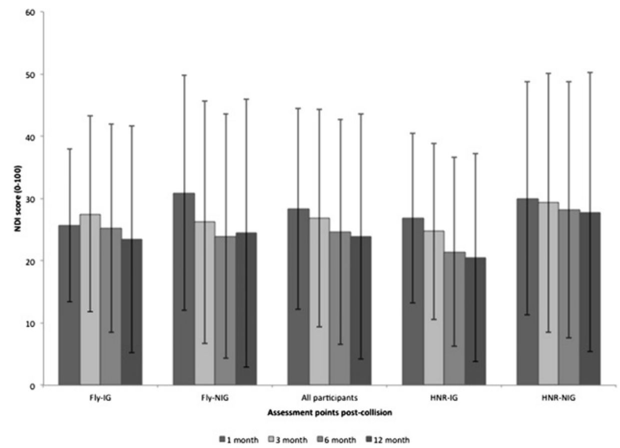

Fig. 4. The means (±SD) on the scores of the NDI at 4 successive assessment points for the 4 subgroups and the total participants. Significant differences were revealed in the HNR-IG and the Fly-NIG ($p = 0.017$ and $p = 0.026$, respectively) over the one-year period, no between-group differences were revealed.

that a similar accuracy error was reported in the Fly test in a small group of asymptomatic people ($n = 10$) as in the Fly-IG. In turn, a chronic whiplash group ($n = 10$) showed a higher average accuracy error (5.4 mm) (Kristjansson et al., 2004) than the Fly-NIG (3.8 mm) in this study. This may indicate that the plateau has not been reached in the deteriorating course in the Fly-NIG in the present study (Fig. 2). A longer follow-up is therefore recommended. There were similar results between the HNR test in the present study compared to both the HNR-IG and asymptomatic subjects in other studies (Kristjansson et al., 2001; Sterling et al., 2003) as well as for the HNR-NIG and test results obtained by the chronic whiplash population in other studies (Kristjansson et al., 2003; Treleaven et al., 2003). The greater movement- and relocation inaccuracies reported in patients with chronic symptoms after MVCs render it very important to find these patients early on according to the course set out in this study. The literature is sparse on when deficient proprioception becomes apparent after injuries as most studies are concerned with proprioception deficits pre- and post intervention. Some prospective studies on the extremities have reported deficient proprioception both early (Friden et al., 1997) and late (Leanderson et al., 1996) after injury but not the two divergent courses revealed in our study.

Neck pain and its associated disorders after MVCs is resistant to most conservative interventions, in both the acute (Verhagen et al., 2007) and chronic stages (Jull et al., 2007; Stewart et al., 2007). Describing the course of deficient cervical kinaesthesia is an important step for identifying a possible modifiable prognostic factor for recovery such that interventions may be more specifically directed and potentially avert the course to chronicity. Deficits of cervical kinaesthesia are a part of a broader entity captured by the term sensorimotor impairments, which describes all the afferent, efferent and central integration and processing components involved in maintaining stability in the postural control system through intrinsic motor-control properties (Gerritsen et al., 1998). Interferences to the afferent input from the cervical region in those with neck pain may be a possible cause of symptoms such as disturbed head-neck awareness, disturbed neck movement control and visual disturbances, as well as signs of altered postural stability including cervicogenic dizziness or unsteadiness. The aforementioned cervical sensorimotor impairments, which may be present to a variable extent in each individual patient, are usually subtle and may not be detected by conventional physical examination procedures (Kristjansson and Treleaven, 2009). In practice this means that disturbed neck movement control and disturbed head-neck awareness has to be continuously monitored as the treatment addressing these impairments progresses. The Fly test and the HNR test seem to be appropriate measures to monitor these impairments. The implications of such impairments for the joints in the extremities have been well described (for review see (Ergen and Ulkar, 2008)), although such an extrapolation is not straightforward as the less researched cervical spine, especially the upper cervical spine, is a very delicate sensory organ due to its direct neurophysiological connections to vital organs and functions in the head (McCough et al., 1951; Dutia, 1991; Hülse, 1998; Neuhuber, 1998).

The self-assessment scores decreased in almost all items in all subgroups, irrespective of the improving or deteriorating performances on the two kinaesthetic tests. The only significant changes over the year occurred in the NDI in the Fly-NIG and HNR-IG (Fig. 4). The correlation between the test results and the questionnaires were better in the Fly test, than the HNR test, particularly in the Fly-NIG, which showed weak to fair correlation (Table 4).

Our study, which is in accordance with many other studies (Bombardier and Tugwell, 1987; Heikkilä and Åström, 1996; Rix and Bagust, 2001; Sterling et al., 2003; Ylinen et al., 2004; Armstrong et al., 2005; Chiu et al., 2005; Sandlund et al., 2006; Treleaven et al., 2006; Kristjansson and Oddsdottir, 2010), revealed a weak or fair relationship between the physical outcome measures under investigation and questionnaires measuring short- and long-term impacts of neck pain and disability. This is in line with new research on the content analysis of ten neck-shoulder pain and disability questionnaires which ascertained that the correspondence between the symptoms expressed by those affected and the content of the questionnaires was low (Wiitavaara et al., 2009). It is therefore urgent to develop questionnaires that are specific to the conditions they are supposed to capture (Bombardier and Tugwell, 1987; Guyatt et al., 1993; Hoving et al., 2003). We therefore recommend, a development of a new questionnaire that assesses the symptoms vocalised in patients with cervical sensorimotor impairments. This can be accomplished by using the experience of those people affected, in combination with relevant research into this field and existing professional knowledge to enhance the validity of such a questionnaire (Wiitavaara et al., 2009).

The next step should be to conduct studies to understand what determines the course set out in this study, not only for deficits of cervical kinaesthesia, but also for cervical sensorimotor impairments as a whole. In other words, to determine whether cervical

Table 4
Comparison of Pearson's Correlation coefficient r (p values) between the results of the Fly test versus VAS and the questionnaires at each assessment point in the Fly-NIG ($n = 24$).

Correlation between	1 month post MVC	3 months post MVC	6 months post MVC	12 months post MVC
Fly-NIG vs. VAS	.38 ($p = 0.06$)	.59 *	.67 *	.56 *
Fly-NIG vs. NDI	.65 *	.60 *	.72 *	.59 *
Fly-NIG vs. Tampa	.11 ($p = 0.60$)	-.06 ($p = 0.77$)	.30 ($p = 0.14$)	.06 ($p = 0.76$)
Fly-NIG vs. GHQ-28	.62 *	.42 *	.37 ($p = 0.07$)	.63 *

* Significant correlation, $p < 0.05$. Fly-NIG = Fly non-improvement group; VAS = Visual Analogue Scale for pain; NDI = Neck Disability Index; Tampa = Tampa Scale of Kinesiophobia; GHQ-28 = General Health Questionnaire-28.

sensorimotor impairments are important prognostic factors for persistent or recurrent symptoms from the neck.

5. Conclusion

This study identified, for the first time, two different courses of deficient cervical kinaesthesia in symptomatic people after MVCs. Significantly diverging results were depicted at 1 month versus at 12 months post-collision in both tests. Those who depicted worse results at the start improved their performances significantly during the one-year course, whereas the opposite was true for those who depicted better results at the start. The study revealed a fair, weak or no relationship between the results of the kinaesthetic tests and the self-assessment measures. The need for developing a new questionnaire that captures the symptoms prevalent in patients with neck pain and sensorimotor impairments is urgent.

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