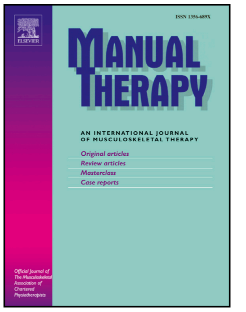



# Extension and flexion in the upper cervical spine in neck pain patients

Markus J. Ernst, PT, OMT, MSc, Rebecca J. Crawford, PT, MMT, PhD, Sarah Schelldorfer, MSc, Anne-Kathrin Rausch-Osthoff, PT, MSc, MSc, Marco Barbero, PT; OMT, Jan Kool, PT, PhD, Christoph M. Bauer, PT, MSc

PII: S1356-689X(14)00260-4

DOI: 10.1016/j.math.2014.12.005

Reference: YMATH 1662

To appear in: *Manual Therapy*

Received Date: 4 March 2014

Revised Date: 17 December 2014

Accepted Date: 22 December 2014

Please cite this article as: Ernst MJ, Crawford RJ, Schelldorfer S, Rausch-Osthoff A-K, Barbero M, Kool J, Bauer CM, Extension and flexion in the upper cervical spine in neck pain patients, *Manual Therapy* (2015), doi: 10.1016/j.math.2014.12.005.

# Extension and flexion in the upper cervical spine in neck pain patients

Markus J. Ernst PT, OMT, MSc [a], Rebecca J. Crawford PT, MMT, PhD [ab], Sarah Schelldorfer MSc [a], Anne-Kathrin Rausch-Osthoff, PT, MSc [a], MSc, Marco Barbero, PT; OMT [c], Jan Kool PT, PhD [a], Christoph M. Bauer PT, MSc [a]

**Institutions:** [a] School of Health Professions, Zurich University of Applied Sciences, Winterthur, Switzerland

[b] Faculty of Health Sciences, Curtin University, Perth, Australia,

[c] Department of Health Sciences, University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Manno Switzerland

**Address:** [a] Technikumstrasse 71, 8401 Winterthur, Switzerland

[b] Via Violino, Stabile Piazetta, 6928 Manno, Switzerland

**Phone:** [a] +41 (0)58 934 64 48

**E mail:** markus.ernst@zhaw.ch

rebecca.crawford@zhaw.ch

sarah.schelldorfer@zhaw.ch

anne-kathrin.rausch@zhaw.ch

marco.barbero@supsi.ch

jan.kool@zhaw.ch

christoph.bauer@zhaw.ch

**Corresponding Author:** Markus J Ernst

Zurich University of Applied Sciences

School of Health Professions

Institute of Physiotherapy

Technikumstrasse 71

8401 Winterthur, Switzerland

# Extension and Flexion in the upper cervical spine in neck pain patients


## ABSTRACT

Neck pain is a common problem in the general population with high risk of ongoing complaints or relapses. Range of motion (ROM) assessment is scientifically established in the clinical process of diagnosis, prognosis and outcome evaluation in neck pain. Anatomically, the cervical spine (CS) has been considered in two regions, the upper and lower CS. Disorders like cervicogenic headache have been clinically associated with dysfunctions of the upper CS (UCS), yet ROM tests and measurements are typically conducted on the whole CS. A cross-sectional study assessing 19 subjects with non-specific neck pain was undertaken to examine UCS extension-flexion ROM in relation to self-reported disability and pain (via the Neck Disability Index (NDI)). Two measurement devices (goniometer and electromagnetic tracking) were employed and compared. Correlations between ROM and the NDI were stronger for the UCS compared to the CS, with the strongest correlation between UCS flexion and the NDI-headache (r = -0.62). Correlations between UCS and CS ROM were fair to moderate, with the strongest correlation between UCS flexion and CS extension ROM (r = -0.49). UCS flexion restriction is related to headache frequency and intensity. Consistency and agreement between both measurement systems and for all tests was high. The results demonstrate that separate UCS ROM assessments for extension and flexion are useful in patients with neck pain.

# Extension and flexion in the upper cervical spine in neck pain patients

**Keywords:**

Upper cervical spine, range of motion, neck pain, headache, disability.

# INTRODUCTION

Neck pain is common in the general population with a 12-month prevalence between 10 - 20% (Hoy et al., 2010). Non-specific (or idiopathic) neck pain predominates (McLean et al., 2010). People in high income countries, particularly women, office, or computer workers are most affected (Hoy et al., 2010). Previous neck pain is a strong risk factor for ongoing complaint or relapse (Hush et al., 2011).

Cervical spine (CS) range of motion (ROM) is inversely associated with neck pain (Dall'Alba et al., 2001), and popularly used for diagnosis, evaluation (de Koning et al., 2008) and treatment (Jull et al., 2008a). CS ROM has been shown to predict recovery in Whiplash-Associated Disorders (WAD) (Dall'Alba et al., 2001)) and non-specific neck pain (Olson et al., 2000). Conversely, a recent, large cohort study found no difference in CS ROM between young subjects with chronic neck pain, and healthy volunteers (Kauther et al., 2012).

The cervical spine is divided into upper (occiput to C2/3) and lower (C3/4 to C7) regions, which differ considerably mechanically (Bogduk and Mercer, 2000). Extension-flexion (E-F) in the upper cervical spine (UCS) involves a head-on-neck motion strategy that reflects the unique shape and structure of the occiput and first two cervical vertebrae (Bogduk and Mercer, 2000). Pathoanatomically, cervicogenic headache has been attributed to the UCS as the site of the trigeminocervical nucleus where trigeminal nerve afferents merge with the upper three cervical nerves (Bogduk, 1994, Jull, 1994). Clinically, ROM of the UCS can be assessed and related to headache and neck pain (Ogince et al., 2007).

Radiographic investigations suggest that UCS E-F may not be effectively detected during ROM tests of the CS (Ordway et al., 1997, Ordway et al., 1999). In particular, Ordway et al. caution that cervical curvature may relax at end of range (EOR). An important example for the UCS is the chin moving forward at EOR flexion, which induces UCS extension. Maximal E-F of the UCS is better assessed by examining retraction and protraction, respectively

(Ordway et al., 1999, Takasaki et al., 2011). However, whether limited retraction or protraction relates to mobility restriction in either the UCS and/or lower CS has not been well identified (Hanten et al., 2000, Severinsson et al., 2012).

Relationships between UCS dysfunction and headache are known (Amiri et al., 2007, Jull et al., 2007, Gadotti et al., 2008, International Headache Society, 2013). However, limited evidence exists for the relationship between UCS E-F, and neck pain (Rudolfsson et al., 2012), or headache (Zito et al., 2006). The supine Flexion-Rotation test examines UCS rotation in a position of full CS flexion (Hall and Robinson, 2004) and is frequently impaired in neck pain and cervicogenic headache (Hall and Robinson, 2004, Smith et al., 2008). The craniocervical flexion test is often positive in patients with neck pain, and with headache (Jull et al., 2007, Jull et al., 2008b). Performed as an exercise, this movement has shown efficacy in treating both clinical presentations (Jull et al., 2002, Falla et al., 2008, Falla et al., 2011). However, association between subjectively reported neck pain or headache, and objectively measured ROM of the UCS, has not been investigated yet. The aim of the present study therefore was to assess the ROM in the UCS and the whole CS in patients, and to investigate a correlation between ROM and the patients' pain and disability.

# METHODS

## Design

Cross-sectional study.

## Subjects

Subjects with non-specific neck pain were recruited through online advertising at the local university campus. Subjects were included according to the following criteria: working-age patients suffering from sub-acute or chronic non-specific head and neck pain, with disability due to their neck pain (at least five points on the Neck Disability Index; NDI), for four weeks (or longer) prior to data collection.

Subjects with comorbidities known to influence the UCS were excluded. Exclusions included: Current or previous head and neck pain due to specific disorders, such as WAD, cervical radiculopathy, migraine, tension or cluster-type headache; Systemic inflammatory disease (like rheumatoid arthritis);Osteoporosis; Central nervous system diseases (like Parkinson's); Ear infection with dizziness or tinnitus; Medication interfering with perception; Diabetes; Tumours; and pregnancy.

Prior to measurements, all included patients signed informed consent. The study was approved by the regional ethics committee.

## **Measurement Systems**

The CROM™[1] is a cervical range of motion device with proven clinical utility in measuring E-F of the UCS (Dhimitri et al., 1998), and validity for use in the CS (Tousignant et al., 2000). Inter-tester reliability for the CROM is reported for the UCS to be ICC>=0.89 (Dhimitri et al., 1998). The Polhemus G4 (originally called the 3-Space, Colchester, Vermont, USA) is an electromagnetic 3D-tracking device used to quantify UCS (Amiri et al., 2003) and CS ROM (Ordway et al., 1997, Tousignant et al., 2000, de Koning et al., 2008). Within and between-day reliability for the 3-Space has been reported to be ICC>=0.97 (Amiri et al., 2003). Using a common protocol, we employed both instruments concurrently to assess extension-flexion motion in the UCS, which broadened our study's relevance to both the clinical and laboratory-based settings, and enabled comparison between the devices.

CS movements were recorded using the CROM™, and the G4. Measurement systems set-up is illustrated in Figure 1. Patients wore the CROM™ without its horizontal magnetic compass for measuring rotation. The G4 sensor was attached to the CROM™ above the nose and plugged into the G4 System Electronics Unit (Hub). The G4 system source was placed 120cm above the ground and distanced 80cm from the patient's stool.

.

[1] Performance attainment associates: http://www.spineproducts.com

## Procedure

All subjects completed the NDI questionnaire within one week before measurement. The NDI is widely accepted for use with neck pain patients (Vernon and Mior, 1991, MacDermid et al., 2009, Swanenburg et al., 2013). Scores range from 0 - 50 points, expressed in percent. According to Vernon and Mior a score below 10% represents no disability, 10 - 28% mild disability, 30 - 48% moderate disability, 50 - 68% severe disability and >68% complete disability.

ROM tests were performed in the seated position as a modification to the standing method described by Dhimitri et al. 1998, and to accommodate subjects with a hyper-kyphotic thoracic spine. During CS E-F tests, subjects were asked to sit upright, with both hands relaxed on their lap. To achieve a neutral head and neck position, they were instructed and manually guided by a tester, to position their forehead vertically. Subjects were asked to move as far as possible into extension, and flexion, without changing their upper body position.

For UCS E-F, subjects were asked to sit upright, rest their hands on their lap, and keep their head in an upright position by leaning their back and occiput against a wall, while maintaining their forehead in a vertical position (Figure 1). Subjects were coached to keep their thoracic spine and shoulder blades in contact with the wall during testing. In assessing UCS extension, subjects were instructed to, “Move the chin upwards while gliding with the occiput downward” (Figure 2) and, “Move the chin downwards, like nodding, and the occiput upwards” for UCS flexion (Figure 3).

Two warm-up trials were completed with verbal and manual coaching from our main tester. Thereafter, three independent repetitions of a full cycle (E-F) were performed by the subject, starting with extension. The test order (UCS or CS motion first) was randomised.

## Tester

A single experienced tester (MJE) monitored subjects' movement, read the CROM™ instrument and recorded the neutral, maximal extension, and maximal flexion values in degrees. A second tester (SS) operated and monitored the G4.

## Data Analysis

As the CROM ™ measurement scale cannot be adjusted to zero, maximal E-F values were computed by subtracting the values of the neutral start position, e.g. maximum flexion value – start position value = flexion ROM. Maximal E-F values derived by the G4 during the different tasks were computed using the VRRS Cervix Software (Kymeia Group, Padova, Italy) and used later for statistical analysis. Extension was expressed as negative values, flexion as positive.

Statistical analysis was performed using the software package *R* (R Development Core Team, 2008). Mean of three repetitions was calculated for each movement and used for comparisons between the UCS versus the CS, and UCS or CS versus the NDI. The total NDI, NDI-pain item (#1), and NDI-headache item (#5) were separately compared to ROM.

Correlations between measurements for the UCS and CS versus the NDI were analysed using Pearson's product moment correlations. Correlations, irrespective of the direction, of < 0.25 indicate little or no correlation, 0.25 - 0.5 fair, >0.5 - 0.75 moderate to good, and values > 0.75 denoted strong correlation (Portney and Watkins, 2000, Friendly, 2002).

Comparisons between the two measurement systems were calculated using Intraclass-Correlation Coefficients of Consistency (ICC, C, 1), and Agreement (ICC, A, 1) for each repetition (Shrout and Fleiss, 1979, de Vet et al., 2006). Values above 0.8 are considered good to high (Portney and Watkins, 2000). Agreement between both measurement systems was additionally analysed using 95% limits of agreement (Bland and Altman, 1986).

## RESULTS

An initial cohort of 116 subjects (21 men) registered for the study. Of these, 70 persons were available for screening by telephone. A further 51 were excluded by not fulfilling inclusion criteria. Nineteen subjects (four men) were included (mean age 29.2yrs SD: 10.3; neck pain duration median 3yrs (interquartile range 1.25-5.5yrs). Further sample characteristics are presented in Table 1.

The CROM™ and G4 measured almost identical ROM values, recording UCS E of -33°± 8.4°(mean ± sd) (CROM) and -32°± 8.5°(G4), and 13 ±4.5 (both devices) for UCS F. All ROM data are presented in Table 1. Based on the strong similarities between measurements derived from both devices, data for CROM™ will be presented further. Comparison data between the devices (Appendix A), and correlation between G4 ROM and NDI (Appendix B) are included as supplementary files.

A Correlation-Matrix between the CROM™ assessments and the NDI is presented in Figure 4. UCS E-F had a fair correlation to NDI-total score. The strongest (fair to moderate/good) association to UCS range of motion was shown between UCS flexion, and NDI-headache. A decreased ROM in UCS F is associated with an increased score for NDI headache (CROM r=-0.62) (Figure 4). Comparing the UCS and CS E-F ROM showed fair relationships. CS E-F showed little correlation with NDI-total score, and fair correlation with NDI-headache.

## DISCUSSION

We employed both a clinic-friendly goniometric device (CROM), and an electromagnetic device (G4) typically used in the laboratory setting, to examine upper and total cervical extension-flexion ROM in 19 subjects with neck pain.

Our results showed that in subjects with non-specific neck pain, UCS E-F ROM has little to fair relationship with ROM of the whole CS. The strongest correlation (fair) occurred between UCS F, and CS E (r=-0.49, Figure 4). Rudolfsson et al. showed reduced UCS E and lower

CS F in subjects with chronic neck pain, highlighting intra-regional differences in motion of the cervical spine (Rudolfsson et al. 2012). These results may confirm a biomechanical difference between the upper and lower cervical spines, and support a need for separate assessment of UCS E-F ROM in neck pain to enable improved treatment specificity.

UCS F is positively related to deep flexor motor control in asymptomatic subjects (Falla et al., 2003). Impaired deep flexor motor control in turn, is associated with increased headache in cervicogenic headache patients (Jull et al., 2002, Jull et al., 2008b). Investigations using the flexion-rotation test to target rotational ROM in the UCS have reported strong associations with headache (Hall and Robinson, 2004, Ogince et al., 2007, Smith et al., 2008). We believe our study is the first to reveal that decreased UCS ROM has a fair (for extension) and moderate/good (for flexion) relationship with an increased NDI headache score. Zito et al. reported reductions of UCS E-F ROM in cervicogenic headache patients compared to asymptomatic controls and migraine subjects. Converse to our results, they found stronger discriminatory validity of CS E-F ROM (Zito et al., 2006). Our findings support the pathoanatomical model for cervicogenic pain as proposed by Bogduk and Jull (1994), and suggest benefit in objectively testing UCS E-F in patients with secondary headache of cervical origin (International Headache Society, 2013) in order to determine regional specificity for treatment direction .

Associations between the total NDI score were in general stronger towards Upper cervical spine ROM compared to cervical spine ROM (Figure 4). No study has previously examined associations between UCS E-F ROM and the NDI. Cramer et al. reported fair correlations with ROM of the whole cervical spine in a large cohort of acute to chronic neck pain subjects (Cramer et al., 2014). Kwak et al. reported little to no correlation for CS flexion, and fair correlations for CS extension in small sample of mildly disabled elderly (Kwak et al., 2005). Our results of cervical spine extension-flexion are in line with these studies. Further investigation that specifically targets the upper cervical spine range of motion in relation to neck pain and/or headache appears warranted in confirming our findings.

We measured mean values of 13°UCS F and 33°UCS E (Table 1). Studies using similar measurement protocols to examine asymptomatic controls showed less UCS extension (Dhimitri et al., 1998, Amiri et al., 2003), and less (Dhimitri et al., 1998) or similar UCS flexion (Amiri et al., 2003). Our UCS E values might be greater compared to those by Dhimitri et al. and Amiri et al. due to procedural inequities where these investigators manually blocked lower cervical motion, while we limited thoracic spine movement. In clinical reality, it might be difficult to isolate absolute upper cervical spine motion in the absence of contributions from the lower CS. Studies using videofluoroscopy showed that cervical segments aren't moving consecutively to end of range but instead show varying contributions during a movement cycle (Wu et al., 2007, Wu et al., 2010). During manual blocking, later occurring movements of the UCS might remain undetected. Our procedure in contrast might overestimate EOR movement by not limiting ongoing motion down the CS. Range variability reported between these studies may reflect normative heterogeneity in selected samples from various origins. Increased UCS E in neck pain subjects seems unlikely to occur, as Rudolfson et al. measured "reduced" average values of 40°UCS E in a chronic female neck pain sample compared to the control group (Rudolfsson et al., 2012). Their results are not directly comparable to ours primarily because they used a different testing procedure in free sitting without restricting ROM (Rudolfsson et al., 2012).

Our UCS F results may be ranked at the lower limit of reported reference values of 15-25° (White and Panjabi, 1990, Ordway et al., 1999, Bogduk and Mercer, 2000). It is probable that our testing procedure at the wall, limits secondary movements like retraction that typically contribute to UCS flexion. Future studies should investigate the validity of this and other measurement protocols that use different blocking motion-limiting methods to isolate the upper cervical spine.

## Limitations

Our subjects showed in general only mild disability (Table 1) (Vernon and Mior, 1991, MacDermid et al., 2009) which may limit its generalizability towards more disabled subjects.

Criterion validity has not been examined in our study. Our results demonstrate the comparability and exchangeability of the CROM, and G4, in subjects with non-specific neck pain, and in measuring CS and UCS extension-flexion. Perhaps the safest skeletal-surface imaging to act as a 'criterion' to validate our methods would be MRI in an upright posture, which should be considered for further investigations.

Correlations do not allow causal relationships between UCS E-F-ROM, and disability or headache. Our sample size was too small for detailed data analysis of additional interacting variables.

Future studies should use case-control designs to examine the capability of UCS range of motion to discriminate between healthy subjects and symptomatic patients. Longitudinal studies should examine the responsiveness of UCS range of motion towards treatment interventions.

## CONCLUSION

Upper cervical flexion shows moderate, and extension fair, correlation with headache frequency and intensity. Higher levels of headache are associated with less UCS flexion. Relationships between cervical spine extension-flexion, and neck pain or disability, are weaker than those for the upper cervical spine. The need for a separate extension and flexion ROM assessment for the upper cervical spine has been supported. Using a common procedure, the CROM ™ and the Polhemus G4 achieve similar results in measuring upper cervical extension-flexion in patients with neck pain.

# REFERENCES


Amiri M, Jull G, Bullock-Saxton J. Measurement of upper cervical flexion and extension with the 3-Space Fastrak measurement system: a repeatability study. Journal of Manual & Manipulative Therapy 2003;11:198-203.

Amiri M, Jull G, Bullock-Saxton J, Darnell R, Lander C. Cervical musculoskeletal impairment in frequent intermittent headache. Part 2: subjects with concurrent headache types. Cephalalgia. 2007;27:891-898.

Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986;1:307-310.

Bogduk N. Cervical causes of headache and dizziness. In: Boyling JD, Palastanga N, editors. Grieve's modern manual therapy. 2nd ed1994.

Bogduk N, Mercer S. Biomechanics of the cervical spine. I: Normal kinematics. Clin Biomech (Bristol, Avon). 2000;15:633-648.

Cramer H, Lauche R, Langhorst J, Dobos GJ, Michalsen A. Validation of the German version of the Neck Disability Index (NDI). BMC Musculoskelet Disord. 2014;15:91.

Dall'Alba PT, Sterling MM, Treleaven JM, Edwards SL, Jull GA. Cervical range of motion discriminates between asymptomatic persons and those with whiplash. Spine (Phila Pa 1976). 2001;26:2090-2094.

de Koning CH, van den Heuvel SP, Staal JB, Smits-Engelsman BC, Hendriks EJ. Clinimetric evaluation of active range of motion measures in patients with non-specific neck pain: a systematic review. Eur Spine J. 2008;17:905-921.

de Vet HC, Terwee CB, Knol DL, Bouter LM. When to use agreement versus reliability measures. J Clin Epidemiol. 2006;59:1033-1039.

Dhimitri K, Brodeur S, Croteau M, Richard S, Seymour CJ. Reliability of the cervical range of motion device in measuring upper cervical motion. Journal of Manual & Manipulative Therapy 1998;6:31-36.

Falla D, Jull G, Hodges P. Training the cervical muscles with prescribed motor tasks does not change muscle activation during a functional activity. Man Ther. 2008;13:507-512.

Falla D, O'Leary S, Farina D, Jull G. Association between intensity of pain and impairment in onset and activation of the deep cervical flexors in patients with persistent neck pain. Clin J Pain. 2011;27:309-314.

Falla DL, Campbell CD, Fagan AE, Thompson DC, Jull GA. Relationship between cranio-cervical flexion range of motion and pressure change during the cranio-cervical flexion test. Man Ther. 2003;8:92-96.

Friendly M. Corrgrams: Exploratory displays for correlation matrices. The American Statistician. 2002;56:316-324.

Gadotti IC, Olivo SA, Magee DJ. Cervical musculoskeletal impairments in cervicogenic headache: a systematic review and a meta-analysis. Physical Therapy Reviews. 2008;13:149-166.

Hall T, Robinson K. The flexion-rotation test and active cervical mobility--a comparative measurement study in cervicogenic headache. Man Ther. 2004;9:197-202.

Hanten WP, Olson SL, Russell JL, Lucio RM, Campbell AH. Total head excursion and resting head posture: normal and patient comparisons. Arch Phys Med Rehabil. 2000;81:62-66.

Hoy DG, Protani M, De R, Buchbinder R. The epidemiology of neck pain. Best Pract Res Clin Rheumatol. 2010;24:783-792.

Hush JM, Lin CC, Michaleff ZA, Verhagen A, Refshauge KM. Prognosis of acute idiopathic neck pain is poor: a systematic review and meta-analysis. Arch Phys Med Rehabil. 2011;92:824-829.

International Headache Society. The International Classification of Headache Disorders, 3rd edition (beta version). Cephalalgia. 2013;33:629-808.

Jull G, Amiri M, Bullock-Saxton J, Darnell R, Lander C. Cervical musculoskeletal impairment in frequent intermittent headache. Part 1: Subjects with single headaches. Cephalalgia. 2007;27:793-802.

Jull G, Sterling M, Falla D. Whiplash, Headache, and Neck Pain: Research-based Directions for Physical Therapies: Churchill Livingstone; 2008a.
Jull G, Trott P, Potter H, Zito G, Niere K, Shirley D, et al. A randomized controlled trial of exercise and manipulative therapy for cervicogenic headache. Spine (Phila Pa 1976). 2002;27:1835-1843; discussion 1843.
Jull GA. Cervical headache: a review. In: Boyling JD, Palastanga N, editors. Grieve's modern manual therapy. 2nd ed: Churchill Livingstone; 1994.
Jull GA, O'Leary SP, Falla DL. Clinical assessment of the deep cervical flexor muscles: the craniocervical flexion test. J Manipulative Physiol Ther. 2008b;31:525-533.
Kauther MD, Piotrowski M, Hussmann B, Lendemans S, Wedemeyer C. Cervical range of motion and strength in 4,293 young male adults with chronic neck pain. Eur Spine J. 2012;21:1522-1527.
Kwak S, Niederklein R, Tarcha R, Hughes C. Relationship between active cervical range of motion and perceived neck disability in community dwelling elderly individuals. J Geriatr Phys Ther. 2005;28:54-56.
MacDermid JC, Walton DM, Avery S, Blanchard A, Etruw E, McAlpine C, et al. Measurement properties of the neck disability index: a systematic review. J Orthop Sports Phys Ther. 2009;39:400-417.
McLean SM, May S, Klaber-Moffett J, Sharp DM, Gardiner E. Risk factors for the onset of non-specific neck pain: a systematic review. J Epidemiol Community Health. 2010;64:565-572.
Ogince M, Hall T, Robinson K, Blackmore AM. The diagnostic validity of the cervical flexion-rotation test in C1/2-related cervicogenic headache. Man Ther. 2007;12:256-262.
Olson SL, O'Connor DP, Birmingham G, Broman P, Herrera L. Tender point sensitivity, range of motion, and perceived disability in subjects with neck pain. J Orthop Sports Phys Ther. 2000;30:13-20.
Ordway NR, Seymour R, Donelson RG, Hojnowski L, Lee E, Edwards WT. Cervical sagittal range-of-motion analysis using three methods. Cervical range-of-motion device, 3space, and radiography. Spine (Phila Pa 1976). 1997;22:501-508.
Ordway NR, Seymour RJ, Donelson RG, Hojnowski LS, Edwards WT. Cervical flexion, extension, protrusion, and retraction. A radiographic segmental analysis. Spine (Phila Pa 1976). 1999;24:240-247.
Portney LG, Watkins MP. Foundations of clinical research: applications to practice: Prentice Hall Health; 2000.
R Development Core Team. R: A language and environment for statistical computing. Vienna, Austria, 2008.
Rudolfsson T, Bjorklund M, Djupsjobacka M. Range of motion in the upper and lower cervical spine in people with chronic neck pain. Man Ther. 2012;17:53-59.
Severinsson Y, Elisson L, Bunketorp O. Reliability of measuring the cervical sagittal translation mobility with a simple method in a clinical setting. Rehabil Res Pract. 2012;2012:629104.
Shrout PE, Fleiss JL. Intraclass correlations: uses in assessing rater reliability. Psychological bulletin. 1979;86:420.
Smith K, Hall T, Robinson K. The influence of age, gender, lifestyle factors and sub-clinical neck pain on the cervical flexion-rotation test and cervical range of motion. Man Ther. 2008;13:552-559.
Swanenburg J, Humphreys K, Langenfeld A, Brunner F, Wirth B. Validity and reliability of a German version of the Neck Disability Index (NDI-G). Manual therapy. 2013.
Takasaki H, Hall T, Kaneko S, Ikemoto Y, Jull G. A radiographic analysis of the influence of initial neck posture on cervical segmental movement at end-range extension in asymptomatic subjects. Man Ther. 2011;16:74-79.
Tousignant M, de Bellefeuille L, O'Donoughue S, Grahovac S. Criterion validity of the cervical range of motion (CROM) goniometer for cervical flexion and extension. Spine (Phila Pa 1976). 2000;25:324-330.
Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther. 1991;14:409-415.

White AA, Panjabi MM. Clinical Biomechanics of the Spine: Lippincott; 1990.

Wu SK, Kuo LC, Lan HC, Tsai SW, Su FC. Segmental percentage contributions of cervical spine during different motion ranges of flexion and extension. J Spinal Disord Tech. 2010;23:278-284.

Wu SK, Lan HH, Kuo LC, Tsai SW, Chen CL, Su FC. The feasibility of a video-based motion analysis system in measuring the segmental movements between upper and lower cervical spine. Gait Posture. 2007;26:161-166.

Zito G, Jull G, Story I. Clinical tests of musculoskeletal dysfunction in the diagnosis of cervicogenic headache. Man Ther. 2006;11:118-129.

**Table 1: Characteristics of included subjects: NDI= Neck disability index, CS= cervical spine, UCS= upper cervical spine, E= extension, F= flexion, CROM™= Cervical Range of Motion device, G4= electromagnetic tracking device. Values are: means (SD; or otherwise indicated).**

**Figure 1: Set-up with neutral upper cervical position,**

**Figure 2: Upper cervical spine extension (UCS-E)**

**Figure 3: Upper cervical spine flexion (UCS-F)**

**Figure 4: Correlation Matrix of ROM (CROM™) and NDI variables: UCS = upper cervical spine, CS= cervical spine, E=Extension, F=Flexion NDI= Neck Disability index, NDI headache= frequency and intensity of headache, NDI pain= neck pain intensity. Values are Pearson's product moment correlations with 95% Confidence intervals in brackets. Extension expressed in negative values; Flexion in positive (Friendly et al. 2002)**

## ACKNOWLEDGMENTS

The authors thank Karen Linwood for proofreading the manuscript and Nicolas Ernst for helping with the measurements.

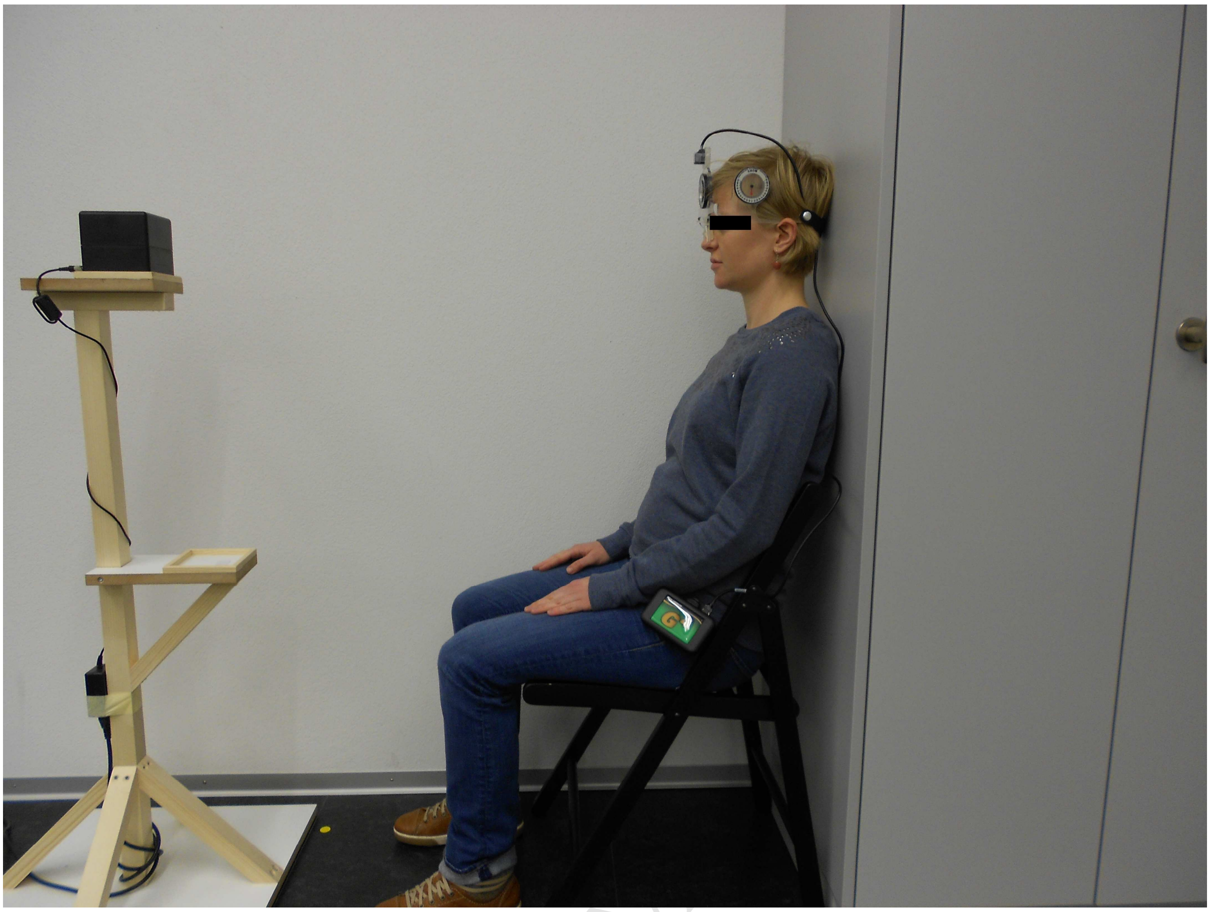
We thank all patients for their participation in the study.

**Table 1**

| Variable | Statistic |
|---|---|
| n | 19 |
| Age (years) | 29.16 (10.26) |
| Duration in years | 3y (1.25-5.5y) median (iqr) |
| Gender | Female: male: 15:4 (proportion) |
| Height (cm) | 170 (8) |
| Weight (kg) | 64 (10) |
| NDI% | 23 (8) |
| NDI pain item (0-5) | 1.5 (0.7) |
| NDI headache item (0-5) | 2.6 (1.4) |
| UCS E (CROM™and G4) | -33° (8.4) and -32° (8.5) |
| UCS F (CROM™ and G4) | 13° (4.5) and 13° (4.5) |
| CS E (CROM™ and G4) | -74° (18.2) and -76° (18.6) |
| CS F (CROM™ and G4) | 60°(10.6) and 60° (9.8) |


G4


CROM
G4



## Correlation Matrix CROM and NDI

| | | | | | | |
|---|---|---|---|---|---|---|
| **UCS-E** | | | | | | |
| -0.53 (-0.79,-0.10) | **UCS-F** | | | | | |
| 0.44 (-0.02,0.74) | -0.31 (-0.67,0.17) | **NDI** | | | | |
| 0.47 (0.02,0.76) | -0.62 (-0.84,-0.23) | 0.84 (0.62,0.94) | **NDI Headache** | | | |
| -0.04 (-0.48,0.42) | 0.25 (-0.23,0.63) | 0.34 (-0.13,0.69) | 0.25 (-0.23,0.63) | **NDI-pain** | | |
| 0.31 (-0.17,0.67) | -0.49 (-0.77,-0.05) | 0.19 (-0.29,0.60) | 0.37 (-0.10,0.71) | 0.01 (-0.45,0.46) | **CS-E** | |
| -0.33 (-0.68,0.15) | 0.21 (-0.27,0.61) | -0.12 (-0.55,0.35) | -0.35 (-0.69,0.13) | -0.01 (-0.46,0.45) | -0.57 (-0.81,-0.16) | **CS-F** |

# Extension and flexion in the upper cervical spine in neck pain patients

## Highlights

- Upper cervical extension-flexion correlates fair to moderate/good to headache intensity/frequency
- The more headache the less upper cervical flexion ROM
- The two measurement instruments (CROM and Polhemus G4) used, achieve similar results

| Test | Trial | ICC2(C,1) 95% CI | ICC2(A,1) 95% CI | Mean Difference (ULA to LLA) |
|---|---|---|---|---|
| UCS Ext. | Trial 1 | 0.95 (0.85-0.98) | 0.95 (0.88-0.98 | 0.58°(6.01° to -4.85°) |
| | Trial 2 | 0.94 (0.79-0.97) | 0.94 (0.83-0.98) | 1.10°(6.91° to -4.70°) |
| | Trial 3 | 0.96 (0.90-0.98) | 0.96 (0.92-0.98) | 1.00°(6.12° to -4.12°) |
| UCS Flex | Trial 1 | 0.75 (0.47-0.95) | 0.74 (0.43-0.94) | -1.21° (5.83° to -8.25°) |
| | Trial 2 | 0.82 (0.60-0.94) | 0.83 (0.58-0.93) | 0.16°(5.42° to -5.10°) |
| | Trial 3 | 0.85 (0.67-0.94) | 0.86 (0.70-0.95) | -0.11°(5.82° to -6.03°) |
| CS Ext | Trial1 | 0.99 (0.95-1) | 0.99 (0.96-1) | -1.26°(4.35° to -6.87°) |
| | Trial 2 | 0.98 (0.91-0.99) | 0.97 (0.93-0.99) | -2.79°(4.41° to -9.99°) |
| | Trial 3 | 0.99 (0.94-0.99) | 0.98 (0.95-0.99) | -2.47°(3.43° to -8.38°) |
| CS Flex | Trial 1 | 0.97 (0.88-0.99) | 0.97 (0.91-0.99) | 0.11°(4.62° to -4.41°) |
| | Trial 2 | 0.97 (0.90-0.98) | 0.97 (0.89-0.98) | -0.05°(5.54° to -5.65°) |
| | Trial 3 | 0.98 (0.95-0.99) | 0.98 (0.96-0.99) | -0.32°(5.48° to -4.85°) |

Appendix A: Validity of measuring with the CROM™ vs. the Polhemus G4 tracking device: ICC= Intra-class correlation coefficient. C= consistency, A= agreement, 95% CI= 95% Confidence interval, UCS= upper cervical spine, CS= cervical spine, Mean Difference: Polhemus G4 – CROM™, ULA= Upper limit of agreement, LLA= Lower limit of agreement

## Correlation Matrix Polhemus G4 and NDI

| | | | | | | |
|---|---|---|---|---|---|---|
| **UCS-E** | | | | | | |
| -0.41 (-0.73,0.05) | **UCS-F** | | | | | |
| 0.50 (0.06,0.78) | -0.44 (-0.75,0.02) | **NDI** | | | | |
| 0.47 (0.01,0.76) | -0.73 (-0.89,-0.41) | 0.84 (0.62,0.94) | **NDI Headache** | | | |
| -0.05 (-0.49,0.42) | 0.12 (-0.35,0.55) | 0.34 (-0.13,0.69) | 0.25 (-0.23,0.63) | **NDI-pain** | | |
| 0.19 (-0.29,0.59) | -0.34 (-0.69,0.14) | 0.20 (-0.28,0.60) | 0.34 (-0.14,0.69) | 0.02 (-0.44,0.47) | **CS-E** | |
| -0.30 (-0.66,0.18) | 0.22 (-0.26,0.61) | -0.18 (-0.58,0.30) | -0.39 (-0.72,0.07) | 0.02 (-0.44,0.47) | -0.55 (-0.80,-0.12) | **CS-F** |

**Appendix B: Correlation Matrix of ROM (G4) and NDI variables: UCS = upper cervical spine, CS= cervical spine, E=Extension, F=Flexion NDI= Neck Disability index, NDI headache= frequency and intensity of headache, NDI pain= neck pain intensity. Values are Pearson's product moment correlations with 95% Confidence intervals in brackets. Extension expressed in negative values; Flexion in positive (Friendly et al. 2002)**