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A Novel Cervical Range of Motion Test to Measure Restricted Combined Movements. Preliminary Pre-Post Intervention Study

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Abstract

Background: Neck stiffness and limited range of motion in the neck can be painful and can impede performing activities of daily living (ADL). General cervical range of motion (CROM) tests are considered accurate assessment of neck movements. However, traditional CROM tests are performed in the sagittal, transverse and frontal planes but neck movements performed in ADL involves mostly combined movements. The CROM-Quarter test is a brand-new test which measure in which of the four quarter(s) or quadrant(s) patient with neck pain has the most restricted movements in 2-dimensional space. Consequently, the clinician can direct the mobilizing treatment more precisely to the movements of the most restricted cervical quadrant(s) and essentially give more effective treatment and potentially shorten the treatment period.

Objective: To ascertain if CROM-Quarter test can be used pre- and post- intervention to document the effects of a single mobilizing treatment session in clinical practice.

Methods: Twenty individuals, ages 18-50 years, with a primary complaint of stiff neck participated. An experienced physical therapist performed the mobilizing treatment for 30 minutes but participants were measured with the CROM-Quarter test immediately before and after treatment of the single most restricted quadrant at the time of the visit. The Oculus Go, a virtual reality headset, was used in this study. The reason was that CROM is too large to perform movements and use a computer screen, therefore the participants had the screen on the head (in front of their eyes) to be able to perform maximal movements of their necks.

Results: Percent increase in area of x and y co-ordinates on the computer screen were calculated, which consists of the total area that an individual could cover within each area (quarter). Paired t-test showed significant difference between pre-post measurements ($p<0.001$) or mean 106% ± 38% improvement. The intra-rater reliability was moderate – excellent.

Conclusion: The results indicated that the CROM-Quarter test can be used to document the effects of a single mobilizing treatment session in clinical practice. Quantifying the progress and outcome of clinical care after each treatment session contributes to value-based health care, which is very much requested in the Western world.

Keywords: Cervical range of motion; Measurement; Neck stiffness; Neck pain; Assessment

Abbreviation: CROM: Cervical Range of Motion; ADL: Activities of Daily Living; ICC: Intraclass Correlation Coefficient; Confidence Interval: CI; SEM: Standard Error of Measurement; VAS: Visual Analogue Scale; IMU: Inertial Measurement Unit

Introduction

Neck pain is a costly and common health problem which can be of insidious onset or can follow a trauma [1,2]. In the adult general population, which peak incidence coincided with middle-age groups peaking at ages 40-49 and ages 35-44, respectively, with typical 12-month prevalence estimates from 30-50% having neck pain [3]. Incidence of self-reported neck pain in the general population is 213 per 1000 persons [3]. The annual incidence of whiplash-associated disorders in North-America and Western Europe is estimated to be at least 300 per 100,000 inhabitants [4]. The number of individuals who seek emergency room treatment for traffic-related whiplash disorders has been on the rise over the past 30 years [5]. In 2015 more than 330 million people in the world had neck pain that lasted longer than 3 months [6]. Neck pain and low back pain combined are the fourth leading cause to years lived with disability in the world just after ischemic heart disease, cerebrovascular disease, and lower respiratory infection [6]. The financial burden that follows disability due to neck pain urges the need to develop outcome measures when assessing clinical progress [7]. Neck pain resulting in limited range of motion, can affect normal activities of the individual patient and lower quality of life [8,9]. Traditional cervical range of motion (CROM) tests are performed in the sagittal, transverse and frontal planes but neck movements performed in ADL involve mostly combined movements. Clinical experience indicates that patients with neck pain usually have restricted movements in combined planes. Until now, CROM tests that measures movements in combined planes has not existed.

In clinical practice there are several methods used to measure CROM in straight planes, including visual estimation, CROM-device, universal goniometer, tape measure assessment and others [10]. It has been demonstrated that a universal goniometer and visual estimation show poor-to-fair inter-tester reliability in repeated measurements while the CROM device was the most reliable testing instrument of

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those three methods [11]. A simple CROM device consists of 3 fluid-dampened inclinometers, one for each plane of motion, transverse, sagittal and frontal plane [8,12]. The inclinometers, two gravitational and the third magnetic are secured to a lightweight, plastic frame which fits on the head. To avoid accessory movements of the trunk and shoulder girdle, verbal instructions are given, however those may not be adequate. The examiner reads off the inclinometer and writes the results down. This may be considered too cumbersome in use, which is the problem with current devices that measure CROM. There are several sophisticated electronic devices that are being tested and used at research-based university clinics, but have not been incorporated into clinical practice as these electronic devices, for example Fastrack, are too expensive and too cumbersome to use [13]. The CROM-Quarter test is a new instrument that gives additional information about in which quarter(s) the movements are most restricted in 2-dimensional space. Accordingly, the clinician can direct the mobilizing treatment more specifically to the most restricted cervical movements. The results can guide clinicians to implement more successful interventions in clinical practice at each visit and therefore potentially shorten the treatment period. CROM Quarter test gives the patients a visual feedback of the results of the effects of the mobilizing treatments after each treatment session. This is also important to motivate patients to maintain the obtained increased mobility after each treatment session through prescribed exercises performed outside of the clinic. The objective of this study was to ascertain if the CROM-Quarter test can be used pre- and post- intervention to document the effects of a single mobilizing treatment session in clinical practice.

Methodology

Participants

Twenty participants, with a main complaint related to stiff neck of various causes, (e.g. heavy work load, after performing unusual activities, sleeping in awkward positions etc.), were asked to participate. The duration of neck pain among the participants was between 3-12 weeks. The participants were recruited from physical therapists working in private practices. The inclusion criteria included men and women, ages 18-50 years, presenting with stiff neck but otherwise healthy, with the minimum score of 3 in pain intensity on a visual analogue scale (VAS). This age group was selected to avoid possible confounding effects of extensive degenerative changes that would impede the mobilizing treatment. Additionally, individuals who had neck stiffness because of trauma, had neurological symptoms, various rheumatologic and inner ear diseases, were excluded from participation. The participants were assured that confidentiality would be maintained. Ethical clearance for the study was obtained from the National Bioethics Committee in Iceland (License no. VSN-19-137) and all subjects gave informed consent to participate in the study.

Measurement tools

Data was collected regarding the length of history of neck pain and participants rated their pain intensity on a VAS that included scores from 'no pain' and to 'the worst pain imaginable'. Pain bothersomeness was also rated on a scale from 0-10. It included scores from 'not at all bothersome' (0) and to 'extremely bothersome' (10). The participants also answered the Neck Disability Index questionnaire which includes ten questions, based on the Oswestry Low Back Pain Index, that assesses disability associated with neck pain [14]. The questions are related to subjective symptomology and ADL. It includes scores from 'no disability (0) to 'full disability' (5). These pain measurements gave clinical characteristics of the participants at baseline. The primary outcome measure in the study, the CROM-Quarter test, was obtained through the NeckSmart software, in the ownership of NeckCare Holding ehf. The Oculus Go, a virtual reality headset, was used in this study. The reason was that the cervical range of motion is too large to perform movements and use a computer screen, therefore the participants had the screen on the head (in front of their eyes) to be able to perform maximal movements of their necks. An Inertial measurement unit (IMU sensor) was placed on the head and secured by a headgear. The IMU sensor is wireless and connected to NeckSmart software via Bluetooth and measures the various movements of the neck during the test in real time. This test measures the quantity of range of motion (ROM) in each of the four (4) quarters of total ROM in – 2-dimensional space: Upper Quarter Left; Upper Quarter Right; Lower Quarter Left: Lower Quarter Right. The outcome was calculated as percentage increase in area of x and y co-ordinates on the computer screen, representing the total area the patient could cover in each quarter/quadrant.

Procedure

Participants received written and verbal information about test procedures and informed consent was obtained. The participants were asked to answer pain and disability questionnaires before the test. The same research assistant performed the testing pre-post intervention. The patient was seated in a chair and strapped to the chair to avoid accessory movements of the trunk and shoulder girdle during the test. The Oculus Go headset and IMU sensor was placed on the participants' head and instructions on how to perform the test were given. The headset provided visual feedback and guided the patient through predefined randomized movement quadrants on the screen (Figure 1). The participants were encouraged to perform as big movement as possible, close to induction of more pain when necessary. To familiarize the participants with the test sequences, they performed 1 trial prior to the test, which data was not used in the analysis. Each patient then performed 6 trials in random order where each trial, measured the area the patient could cover within each of the four quarters, representing the outcome measure for each quarter (Figure 1). There was a 3 second

Figure 1: Experimental set up.

pause between each trial but altogether 24 trials (4 quarters x 6 trials) were performed for each patient pre-post intervention, respectively. The results were downloaded into a report immediately after the test was completed and saved on the computer. After the test, the patient received one mobilizing treatment session by an experienced physical therapist/manual therapist (EK), after receiving information from the tester about which quarter was most restricted. Only this quarter was targeted in the treatment session. The duration of each treatment session, including a short history taken, was approximately 30-minute of mobilizing treatment to increase the restricted cervical movements focusing on that particular quarter. The mobilizing treatment included various modalities, such as soft tissue mobilization e.g. "pump" massage and muscle energy techniques as well as various manual joint treatments, e.g. specific joint mobilization, including high velocity, short amplitude thrust (manipulation). The manual therapist decided what mobilizing treatment suited each patient, i.e. pragmatic approach. The participants were then re-tested immediately after the mobilizing treatment to ascertain the effect of the mobilizing treatment and to document its effect.

Data Analysis

There were no existing data on healthy individuals or pre-treatment versus post-treatment values of patients, which made it impossible to calculate the power of the study. Using trigonometry functions, the 3D angles were projected onto the two-dimensional screen as described when converting spherical coordinates into Cartesian coordinates. Flexion/extension and rotation angles were used to position the cursor in the plane. The raw data from x and y co-ordinates that the patient could cover in each quarter/quadrant was calculated as percentage increase from pre-intervention and post-intervention. The mean of 6 trials for each quarter was calculated and used for data analysis. The pre-post differences were analyzed using a paired t-test, with a single-tail analysis to increase the power of the test. The raw data was drawn from the database (Server) and the mean area covered by the patient in each of the 4 quarters selected for treatment was calculated by a custom-made software. Intraclass Correlation Coefficient, model 3.1 (single measures – mixed model) analyzed the intra-rater pre measurements in each quarter, respectively. Analyses were performed with the procedures implemented by Jamovi®-software (9th edition). Number, subjects, means and standard deviation (SD) were used for description of data. The significance level was set at $p<0.05$.

Results

Participants demographics

Twenty participants (9 males and 11 females) completed the CROM-Quarter test and were included in the analysis. The mean age of the participants was 33 years (± 10). Pain characteristics among participants at the time of visit for the mobilizing treatment are shown in Table 1.

CROM-Quarter test

The post treatment scores were significantly higher than the pre-treatment scores ($p<0.001$). (Figure 2). The mean of the participants' score for the x-y co-ordinates pre-treatment was 386 ± 130 (Table 2) (SEM 29.1) and post-treatment score was 794 ± 216 (Table 2) (SEM 48.3). The mean difference for the x-y co-ordinates was 409 ± 143 (Table 2). The average overall improvement from baseline was 106% ± 38% (Table 2). The measurement on the quarters that were not treated are shown in Table 3. All the participants' individual results are shown in Table 3. Figure 3 shows pre-post results for subject 1 in Upper Quarter Right, but subject 1 showed the greatest improvement of all participants in this study. Figure 4 shows each participant performance clustered pre-treatment versus post- treatment. The intra- rater reliability was moderate-excellent for the upper quarters and the lower quarters, respectively (Table 4).

Variable	Mean ± SD	Range
Duration in weeks	6.5 ± 2.78	3-12
Visual Analogue Scale (0=no pain, 10=the worst pain imaginable)	5.15 ± 1.42	3-8
Pain Bothersomeness (0=not at all bothersome, 10=extremely bothersome)	4.55 ± 1.64	2-9
Neck Disability Index (NDI) (Percentage scores 0-100) *	38.7 ± 13.72	22-68
Abbreviations: SD: Standard deviation *Higher scores indicate more disability		

Table 1: Participants' pain characteristics.

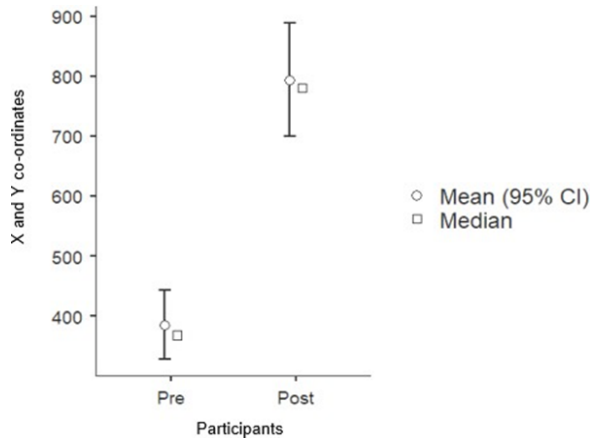

Figure 2: CROM-Quarter test results: Mean and Median with 95% Confidence Intervals pre-post intervention. The post treatment scores were significantly higher than the pre-treatment scores ($p<0.001$). Cohen's d was 2.85. Anything larger than 2, indicates that the difference is larger than two standard deviations.

ID	Most restricted quarter	Pre	Post	Differences	Change in %
Subject 1	Upper right	397.9	1310.4	912.5	229.33%
Subject 2	Lower left	291	684.6	393.6	135.25%
Subject 3	Upper right	369.9	803.5	433.6	117.22%
Subject 4	Lower left	239.6	512.3	272.7	113.81%
Subject 5	Lower right	408.9	757.3	348.4	85.30%
Subject 6	Upper right	419.9	803.9	384	91.45%
Subject 7	Lower right	195.3	482.4	287.1	147%
Subject 8	Upper left	514	1069.4	555.4	108.05%
Subject 9	Lower left	263.6	571.9	308.3	116.96%
Subject 10	Upper left	436.1	905.9	469.8	107.73%
Subject 11	Lower right	301.2	608.5	307.3	102.03%
Subject 12	Lower left	344.2	734.9	390.7	113.51%
Subject 13	Upper right	550.7	961.6	410.9	74.61%
Subject 14	Upper right	365.3	819.8	454.5	124.42%
Subject 15	Lower right	191.1	510.8	319.7	167.29%
Subject 16	Upper left	585.8	1064.5	478.7	81.72%
Subject 17	Upper left	678.7	924.6	245.9	36.23%
Subject 18	Lower left	359.4	693.2	333.8	92.88%
Subject 19	Upper right	492.1	973.7	481.6	97.87%
Subject 20	Lower left	306.5	689.7	383.2	125.02%
Overall	Mean ± SD	386 ± 130	794 ± 216	409 ± 143	106% ± 38%

Table 2: Measurements of the most restricted quarters among all individual participants.

	Student's t	Df	P	Mean differences	SE differences
Upper quarter left	0.429	15	0.674	26.2	61.1
Upper quarter right	-0.338	13	0.741	-14.9	44
Lower quarter right	-4.716	15	**<0.001**	-118.3	25.1
Lower quarter left	-1.536	13	0.149	-61.8	40.3
Abbreviations: Df; Differences; SE: Standard Error					

Table 3: Paired samples test-Quarters not treated.

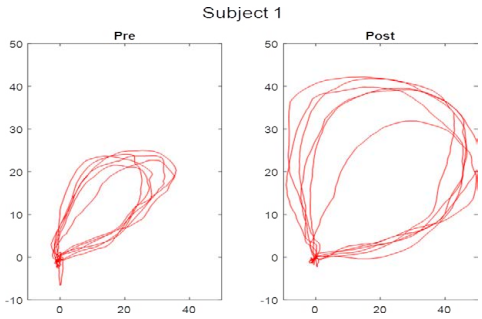

Figure 3: Pre-post results for subject 1 in CROM-Quarter test: Upper Quarter Right. The numbers on the x and y axes are in degrees for visual feedback for the patients.

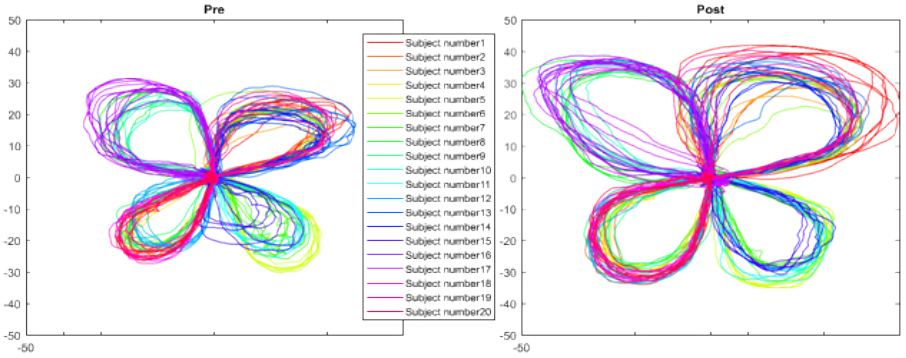

Figure 4: Clustered performance of all participants pre-and post-treatment in all quarters–treated and not treated.

Quarter	$ICC_{3.1}$	95% Confidence interval	
		Lower	Upper
Upper Left	0.789	0.66	0.9
Upper Right	0.781	0.65	0.89
Lower Left	0.939	0.89	0.97
Lower Right	0.932	0.88	0.97

Table 4: Intra-rater reliability for each quarter.

Discussion

The purpose of this study was to examine if the CROM-Quarter test could be used pre- and post- intervention to document the effects of a single mobilizing treatment session of the cervical spine in clinical practice. There was a significant difference between CROM-Quarter test measurements pre versus post–treatment ($p<0.001$) (Figure 2) with mean 106% ± 38% increase in the movements post- treatment (Table 2). The results demonstrate that all participants showed improvement in range of motion after the mobilizing treatment (Table 2). This indicates that the CROM-Quarter test can be used as a measurement tool after a single mobilization treatment session. The measurements for the quarters that were not treated did not show significant difference except for Lower Quarter Right (Table 3). Usually there is less movement in the lower quarters (Figure 4) which means that it takes less to influence the movements there after a mobilization treatment on other quarters. CROM-Quarter test measures restricted combined movements in the 3 cardinal planes at the same time i.e. sagittal, frontal and transverse planes. The intra-rater reliability was moderate-excellent (Table 4), which show that CROM-Quarter can be used by a single therapist.

The results showed that the new CROM test could contribute to value-based therapy when treating people with stiff uncomplicated neck of relatively moderate-severe intensity and recent duration. Value- based healthcare focuses on ideas how to solve problems of quality and economy in healthcare [15]. The aim is first of all creating value to the patients, reducing patients' suffering, developing high quality healthcare and to accomplish better cost-effectiveness. However, there has been difficulty seeking consensus about how to precisely define value-based healthcare [16]. Value-based system gives the patient a chance to be more involved in their health and health care [17]. The outcome measurement is as crucial to patient management as establishing a diagnosis and developing a treatment plan. Demonstrating the progress of the treatment gives the patients motivation to do their part of the therapy. It can inspire them to be responsible for their own health. Achieving and maintaining good health is undeniably less costly than dealing with poor health [18]. It is important for health care professionals, including physical therapists, to be able to quantify the value they bring to the health care, because in the near future payment for services may depend on performance [17]. In order to achieve this, consistent measuring and reporting of clinical outcomes that use quantifiable validated measures are essential [18]. Data show that neck pain is an issue worldwide and seems to be increasing in both the general population and specific occupational groups [4]. Neck pain can have consequences related to the physical, psychological and social aspects of the individual [19]. All of these factors contribute to the increase in costs in society and demonstrate the importance of improving the effectiveness of interventions to reduce disability related to neck pain. There is evidence in the literature that a relationship exists between range of motion and impairment in patients with neck pain [8]. Cervical range of motion is often measured to assess, document treatment effects and to readjust treatment plan as needed in physical therapy [20-21]. Existing research with randomized controlled trials (RCTs) with CROM as an outcome measure have focused on the effects of longer-term therapy (2-4 weeks) [22-29]. However, none of the existing RCTs studies documented the effects of a single treatment session.

There is a need for inexpensive electronic devices to use in clinical practice which would encourage physical therapists to document the effect of a single treatment session, enhancing value-based therapy. Therefore, IMU sensor has been developed by NeckCare to measure various movements of the neck, including CROM in 3-dimensional space with highly accurate data [30]. It is placed on the head and secured by a headgear. The IMU sensor is wireless and connected to the software program via Bluetooth. The software program has a secure web-based database. Another technological way is with oculus goggles that are an inexpensive virtual reality head-mounted display. It can be used for research or rehabilitation [31]. The patient can also use these types of goggles at home and do personalized therapist-prescribed exercises. This gives the patient motivation to do exercises along with manual therapy, given the patient a feedback on the pre versus post treatment results (Figure 3). Using virtual reality glasses is fun and easy; it can make patients feel more positive and motivated about their treatment, increasing the patient's treatment compliance. Performing exercises inside and/or outside the clinic, instructed by the clinician, to maintain the obtained results of each mobilizing treatment session is an important course of action towards persistent improvement, and prevention of pain and disability of each individual patient.

Greater standard error of measurement (SEM) post-treatment indicates that the measurements post- treatment is less reliable i.e. SEM=48.3 post-treatment versus SEM=29.1 pre-treatment. This may include that the post- treatment results are not becoming well established, which in turn emphasizes that each patient does his/her homework.

Substantial amount of neck movement is required of the cervical spine in daily activities [32]. It is important to consider that neck movements are coupled, meaning that neck motions take place in relation to the main motion planes [33]. None of these existing CROM devices take into account that the neck movements are combined. The CROM-Quarter test was developed to meet this need and give clinicians the arsenal needed to discover in which movement quarter(s), each individual patient has the most restricted cervical movement(s). Consequently, it can give the clinician a clearer picture of where the restriction is so they can direct mobilizing treatment more precisely to the most restricted cervical movements at each visit, where mobilization is involved, and essentially give more effective mobilizing treatment. What differentiates this test from other CROM tests is that the CROM-Quarter test measures total ROM in 2-dimensional space, in area of x and y co-ordinates on the computer screen instead of measuring the outcome in degrees. The CROM-Quarter test is fast and easy to use and fits well into busy clinical practices and therefore integrates well into the clinicians existing patient flow. Clinicians can choose whether they use the clinical version of CROM-Quarter test with 3 repetitions of each quarter (altogether 12 trials) to save time, or 6 repetitions as used in the research version of the test.

Strengths and limitations

The present study has several strengths and limitations. The main limitations of this study are twofold: Firstly the inter-rater reliability of the CROM-Quarter test has not yet been established, but reliability is a prerequisite for validity, and secondly no normal reference values exist that are specific for each age group, but it is known that CROM decreases with increasing age [34]. However, this is the first study to use CROM-Quarter test and these preliminary results are promising confirming its construct validity. The study cohort were participants with recent onset neck pain of relatively uncomplicated nature. It remains to be investigated whether other subgroups with neck pain will benefit likewise as demonstrated by the cohort in this study. The participants got the mobilizing treatment from an experienced physical therapist/manual therapist (EK). It remains to be demonstrated whether novice therapists will obtain the same results. The reliability issue and reference normal database are currently being addressed in research in progress. Future studies on different subgroups of neck pain and its related disorders will address how the CROM-Quarter test can be of use over the course of the rehabilitation period in a longitudinal design.

Conclusion

The preliminary results of this study indicate that CROM-Quarter test can be used pre- and post- intervention to document the effects of a single mobilizing treatment session of the cervical spine in clinical practice. There was significant increase in range of motion ($p<0.001$) with mean 106% ± 38% increase in the movements post-treatment. All participants showed improved CROM. This is a great step towards value-based physical therapy. CROM-Quarter test is fast and easy to use and fits well into busy clinical practices and therefore integrates well into the clinicians existing patient flow. The clinician can use the CROM-Quarter test pre- and post-treatment and document the treatment effects in each mobilizing treatment session and consequently direct the treatment to the most restricted movement quadrant at each visit. However, further studies with CROM-Quarter test are needed to confirm the inter- rater reliability of the measurements and its applicability for other subgroups of patients with neck pain.

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