

FUNCTION IN PATIENTS WITH CERVICAL RADICULOPATHY OR CHRONIC WHIPLASH-ASSOCIATED DISORDERS COMPARED WITH HEALTHY VOLUNTEERS



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ABSTRACT

Objective: The purposes of this study were to examine whether any differences in function and health exist between patients with cervical radiculopathy (CR) due to disk disease scheduled for surgery and patients with chronic whiplash-associated disorders (WADs) and to compare measures of patients' physical function with those obtained from healthy volunteers.

Methods: This is a cross-sectional study of patients with CR (n = 198) and patients with chronic WAD (n = 215). Patient data were compared with raw data previously obtained from healthy people. Physical measures included cervical active range of motion, neck muscle endurance, and hand grip strength. Self-rated measures included pain intensity (visual analog scale), neck disability (Neck Disability Index), self-efficacy (Self-Efficacy Scale), and health-related quality of life (EuroQol 5-dimensional self-classifier).

Results: Patient groups exhibited significantly lower performance than the healthy group in all physical measures ($P < .0005$) except for neck muscle endurance in flexion for women ($P > .09$). There was a general trend toward worse results in the CR group than the WAD group, with significant differences in neck active range of motion, left hand strength for women, pain intensity, Neck Disability Index, EuroQol 5-dimensional self-classifier, and Self-Efficacy Scale ($P < .0001$).

Conclusions: Patients had worse values than healthy individuals in almost all physical measures. There was a trend toward worse results for CR than WAD patients. (J Manipulative Physiol Ther 2014;37:211-218)

Key Indexing Terms: *Cervical Vertebrae; Neck Pain; Radiculopathy; Whiplash Injuries; Outcome Measures*

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Longstanding problems of cervical radiculopathy (CR) and indirect neck trauma (whiplash-associated disorder [WAD]) are common, with CR incidence of 83/100000¹ and WAD incidence of 235 to 300/100000.² In recent studies, up to 50% of WAD patients^{3,4} and 30% to 100% of postsurgical CR patients⁴⁻⁹ report personal suffering from prolonged symptoms, with persistent pain, disability, and reduced health-related quality of life (HRQoL). Physical function and treatment have been severely understudied both for CR patients scheduled for surgery^{9,10} and for chronic WAD patients,¹¹ particularly for patients with verified neurological and musculoskeletal findings (WAD Grade III).¹¹ Evidence of effective physiotherapy is inconclusive because there have been few randomized controlled trials involving these specific groups of patients.¹²⁻¹⁵ There is an urgent need for increased knowledge of both groups' function and health to better understand how to tailor successful exercise regimens.

Patients with CR scheduled for surgery have specific magnetic resonance imaging (MRI)-verified pathology of cervical disk disease consistent with clinical findings. It is, therefore, of interest to compare CR patients with WAD

patients, whose diagnosis often persists with clinical signs but without radiologic findings,¹⁶ with respect to self-reporting questionnaires and physiotherapist-obtained measures of function. Active cervical range of motion (AROM), neck muscle endurance (NME), and hand strength are all factors of importance for activities of daily living; they are reduced in other neck pain populations^{8,17} and should be addressed in rehabilitation programs.¹⁸ For patients with chronic WAD^{19,20} or CR,⁵⁻⁹ these factors have been insufficiently evaluated in relatively small samples that exhibit reduced function.^{5-9,19-22}

It is important to investigate whether and to what extent these patient groups differ from a healthy population and whether there are differences in CR patients regarding the onset of symptoms (suddenly after a special occasion, or slowly progressing) and in WAD patients regarding Quebec classification.²³ Information is contradictory regarding whether WAD Grade is related to outcome,^{24,25} and to our knowledge, the literature lacks studies investigating whether the type of symptom onset in CR patients is related to functional outcome.

This study primarily aimed to examine whether any differences in pain intensity, physical function, or HRQoL exist between patients with CR and patients with chronic WAD and to compare these measures of physical function in these patient groups with measures obtained from healthy volunteers. Secondary goals were to investigate whether there were any differences between patients classified as WAD Grade II and Grade III, to determine whether symptoms of CR appeared after a specific occasion, and to investigate correlations between physical measures and self-reported ones.

METHODS

Participants

This study included 198 patients with MRI-verified CR due to cervical disk disease who were scheduled for surgery the following day (mean age 50 years \pm SD 8.5 years, 104 men and 94 women; Fig 1) and 215 patients with chronic WAD (6 months to 3 years since accident) classified as Grade II ($n = 122$) or Grade III ($n = 93$)²³ (mean age, 40 \pm 11.4 years; 78 men and 137 women; Fig 2). Patients' data were compared with data obtained previously from healthy volunteers (for hand strength and neck AROM: $n = 101$; mean age, 43 \pm 10.5 years; 50 men and 51 women^{24,25}; for NME: $n = 116$, mean age 45 \pm 11.7 years, 60 men and 56 women).²⁸

Patients with CR (recruited from neurosurgical clinics) and WAD (identified through electronic medical records from county councils and recruited after inquiries by mail including a short questionnaire) were participants in ongoing randomized clinical trials. Their baseline values were used in the present study. For inclusion criteria, please

Surgical inclusion criteria

- Cervical disk disease verified by MRI and compatible with clinical findings (examined by a neurosurgeon) showing cervical nerve root compression
- Radiculopathy
- Persistent neurologic deficit from a cervical nerve root (duration ≥ 2 mo)

Study inclusion criteria

- Scheduled for surgery for cervical disk disease (with either an anterior approach with fusion or a posterior approach) in 1-3 segmental levels
- Age 18-70 y

Study exclusion criteria

- Myelopathy
- Earlier fracture or luxation of the cervical column
- Malignancy, spinal tumor, spinal infection, or previous surgery in the cervical column
- Systemic disease or a trauma that contraindicates the treatment program or the study measurements/assessments
- Diagnosed severe psychiatric disorder, such as schizophrenia or psychosis
- Known drug abuse
- Lack of familiarity with the Swedish language

Fig 1. Inclusion and exclusion criteria for patients with cervical radiculopathy. MRI, magnetic resonance imaging.

see Figures 1 and 2. For both patient groups, eligibility criteria were verified through telephone interviews, medical files when indicated, and physical examination by an experienced physiotherapist.

Volunteers with healthy necks were randomly selected from computerized employee records from a university hospital and a university by an independent researcher and were stratified with respect to sex and age.²⁶⁻²⁸ Individuals claiming to be healthy without recurrent neck pain, earlier neck trauma, or neck surgery and without any recent neck treatment were included. Individuals with upper extremity problems were excluded from the hand strength measurements. Pregnant women were also excluded. Raw data from these earlier published normative data of healthy controls²⁶⁻²⁸ were used for comparisons between healthy volunteers and patients.

All different parts of the study received approval from the Regional Medical Research Ethics Committee at Linköping University in Sweden, and the study was conducted in accordance with the Declaration of Helsinki. All participants received verbal and written information about the study as well as practical demonstration of the measurements.

Measurements

All measurements were obtained from WAD and CR patients. Only physical measures were obtained from the healthy volunteers.

Background Data. Background data included age, sex, and WAD Grade (II or III)²³ for WAD patients and whether the onset of symptoms was associated with a specific occasion in CR patients.

Study inclusion criteria

- Age 18-63 y
- Grade II or III WAD
- Continuing problems (>20 mm on 100 mm VAS and >20% on NDI) at least 6 mo after a whiplash injury, but not for >3 y.

Study exclusion criteria

- Known or suspected serious physical pathology (eg, myelopathy, spinal tumor, spinal infection or ongoing malignancy, earlier fracture or luxation of the cervical column, earlier neck trauma with persistent injury, or surgery to the cervical column)
 - Neck pain causing absence from work for >1 mo during the year before the trauma
 - Signs of traumatic brain injury at the time of WAD (eg, unconsciousness, retrograde and posttraumatic amnesia, and disorientation/confusion)
 - Generalized or more dominant pain elsewhere in the body
 - Diseases or other injuries that might prevent full participation in the study
 - Diagnosed severe psychiatric disorder
 - Known drug abuse
 - Lack of familiarity with the Swedish language
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Fig 2. Inclusion and exclusion criteria for patients with WAD. NDI, neck disability index; VAS, visual analog scale; WAD, whiplash-associated disorder.

Pain. Current pain intensity in the neck and arms was measured using a visual analog scale (VAS), ranging from 0 to 100 mm (0, no pain; 100, worst imaginable pain).²⁹

Neck-Specific Function. Perceived neck disability was quantified using the Neck Disability Index (NDI). The 10 sections of the NDI (pain intensity, personal care, lifting, reading, headaches, concentration, work, driving, sleeping, and recreation) were scored from 0 to 5 in order of increasing severity, added together, and transformed into percentages (0%, no pain or difficulties; 100%, highest score for pain and difficulty).³⁰

Self-Efficacy Scale. Confidence in the ability to perform 20 individual physical and psychosocial activities despite pain was evaluated using the 10-point Self-Efficacy Scale (SES)³¹ (0, not confident; 10, completely confident). The total score was summarized (0, not confident; 200, completely confident).²⁹ Good measurement properties have been reported for the SES.³¹

Health-Related Quality of Life. We used the EuroQol 5-dimensional self-classifier (EQ-5D), which addresses mobility, self-care, everyday activities, pain, and anxiety/depression, to assess HRQoL. For each dimension, 1 of 3 hierarchical levels was chosen (1, no problem; 2, mild problem; 3, severe problem) and converted to a score (<0, worse than death; 0, death; 1, perfect health).³² Current health state was also measured using the EuroQol vertical VAS (0, worst imaginable; 100, best imaginable).³²

Neck AROM. The neck AROM (in sagittal, frontal, and transverse planes) was measured using the plastic helmet cervical range of motion device (Performance Attainment Associates, Roseville, MN) in the sitting position in a reliable (intraclass correlation coefficient >0.80) and standardized way.²⁶

Neck Muscle Endurance. The endurance tests were measured in a prone position for dorsal neck muscles and a supine

position for ventral neck muscles. Maximum duration of a smaller head lift was measured in seconds with a stopwatch. The upper cervical spine was in a flexed position when ventral muscles were tested and in an extended position during dorsal testing. In the dorsal position, a load of 2 kg for women and 4 kg for men was applied around the head. Patients were instructed to “maintain the head lift for as long as possible, stopping at exhaustion or radiating pain into the arms.” The standardized test position was carefully monitored by the test leader and immediately corrected if not maintained. The physiotherapist interrupted the test if the patient was unable to maintain the position despite 2 reminders.²⁸ Reliability of these procedures has been reported previously as good (ICC >0.80).²⁸

Hand Strength. The test was performed in a standardized way using an isometric hydraulic hand dynamometer “Jamar” (Sammons Preston, Inc, Bolingbrook, IL) in the standing position with a straight back, shoulder adducted and in a relaxed position, elbow flexed to 90°, and the lower arm and wrist in neutral position. Men used grip breadth 3 and women used grip breadth 2. This test was always performed with the right hand first. After a maximal squeeze duration of 8 seconds, the peak value was registered in kilograms.²⁷ Reliability of this procedure has been reported previously as good (ICC >0.80).²⁷

Statistical Analysis

For descriptive statistics, mean ± SDs is presented. For unpaired group comparisons, Student 2-tailed *t* test was used for 2-group comparisons, and factorial analysis of variance followed by the Bonferroni post hoc test was used for unpaired three group comparisons with *P* < .0167 considered statistically significant. For 2-group comparison and correlation, statistical significance was set at *P* > .05. Bivariate correlations were studied using Pearson’s correlation coefficient. Because biological sex has been demonstrated as a factor of importance when interpreting the results of hand strength and NME data^{28,27} and because different loading and grip size were used for men and women during these measurements, the analysis of hand strength and NME data was split by sex owing to the unequal distribution of men and women between patient groups. Effect size (ES) was calculated³³ as the mean value number 1 minus mean value number 2, divided with the pooled SD of the 2 groups. Effect size of 0.40 or higher was set as clinical relevance.³³

RESULTS

Comparisons Between CR Patients, WAD Patients, and Healthy Volunteers

Patients with CR or WAD exhibited significantly lower performance than the healthy group in all physical measures (*P* < .0005; ES, 0.41-1.84), except for NME flexion for women (*P* > .09; ES, 0.23; Table 1). The physical function

Table 1. Comparison Between WAD Patients, CR Patients, and Healthy Volunteers

	WAD	CR	Hy	WAD vs CR	WAD vs Hy	CR vs Hy
	Mean ± SD	Mean ± SD	Mean ± SD	<i>P</i> ; ES	<i>P</i> ; ES	<i>P</i> ; ES
Physical measures						
Sagittal AROM ^a	96 ± 26.1	83 ± 26.7	142 ± 22.1	<.0001; 0.68	<.0001; 1.84	<.0001; 2.33
Frontal AROM	66 ± 17.9	54 ± 17.8	83 ± 19.9	<.0001; 0.91	<.0001; 0.91	<.0001; 1.57
Transverse AROM	111 ± 26.8	100 ± 25.5	154 ± 22.6	<.0001; 0.42	<.0001; 1.68	<.0001; 2.19
Hand right men	41 ± 13.3	38 ± 11.7	51 ± 6.0	.08; 0.24	<.0001; 0.91	<.0001; 1.16
Hand right women	24 ± 7.5	22 ± 8.3	34 ± 4.4	.05; 0.25	<.0001; 1.62	<.0001; 1.93
Hand left men	38 ± 13.4	37 ± 13.0	50 ± 7.2	.43; 0.08	<.0001; 1.05	<.0001; 1.17
Hand left women	23 ± 7.0	20 ± 8.0	32 ± 4.6	<.0001; 0.40	.0004; 1.55	<.0001; 1.98
NME flex men	50 ± 48.5	63 ± 62.8	153 ± 103.2	.25; 0.23	<.0001; 1.32	<.0001; 1.12
NME flex women	29 ± 41.4	28 ± 26.1	37 ± 11.0	.78; 0.03	.13; 0.23	.10; 0.41
NME ext men	108 ± 118.5	106 ± 129.8	417 ± 309.9	.93; 0.02	<.0001; 1.38	<.0001; 1.45
NME ext women	89 ± 123.4	61 ± 84.6	507 ± 386.4	.41; 0.35	<.0001; 1.79	<.0001; 1.81
Self-reported measures ^a						
Neck pain VAS	42 ± 24.3	56 ± 24.0		>.0001; 0.58		
Arm pain VAS	16 ± 22.7	51 ± 28.0		<.0001; 1.38		
NDI%	33 ± 13.3	43 ± 14.7		<.0001; 0.72		
Self-efficacy	150 ± 36.8	127 ± 39.7		<.0001; 0.84		
EQ-5D	0.62 ± 0.26	0.39 ± 0.32		<.0001; 0.79		

Data are presented as mean ± SD with *P* values for significance set as *P* < .0167. Effect size of 0.40 or higher is regarded as clinically relevant.

AROM, active cervical range of motion; CR, cervical radiculopathy; EQ-5D, EuroQol 5-dimensional self-classifier; ES, effect size; Hy, healthy; NDI, neck disability index; NME, neck muscle endurance; WAD, whiplash-associated disorder.

^a When self-reported data and AROM were stratified by sex, significantly worse values for both patient groups remained vs healthy volunteers (*P* = .0008 to *P* < .0001). Between CR and WAD, significantly worse values were still reported for CR patients (*P* = .002 to *P* < .0001), with the exception that there was no significant difference between the 2 groups regarding AROM in the transverse plane for men (*P* = .03).

results for both patient groups were approximately 60% to 80% of the function results of the healthy group, except for NME flexion and extension. Regarding NME flexion, male patients had approximately 40% of function compared with healthy volunteers. Regarding NME extension, male patients had approximately 25% of function, and female patients had approximately 20% of function compared with healthy volunteers.

There was a general trend toward lower/worse values in CR patients than WAD patients regarding both physical and self-reported measures. Significant differences were observed in neck AROM, women's left hand strength, pain intensity, NDI, EQ-5D, and SES (*P* < .0001; ES, 0.40-1.38; Table 1).

Within the CR Group

In the CR group, there were no significant differences among patients who reported that their problems had started after a specific occasion and those who did not (*P* = .10 to .90). Neck muscle endurance correlated significantly with all self-reported measures (*r* = -0.15 to 0.32, *P* < .05). Sagittal plane neck AROM correlated significantly with NDI, SES, and neck pain intensity (*r* = -0.15 to -0.25, *P* < .05). Transverse plane neck AROM correlated significantly with NDI (*r* = -0.20, *P* = .008) and EQ-5D (*r* = 0.16, *P* = .03).

Within the WAD Group

Patients with Grade II WAD trended toward better results on both physical and self-reported measures than patients with

Grade III WAD. Statistical significant differences was observed for neck AROM in the sagittal and transverse planes, hand strength, NME extension, pain ratings, NDI, and self-efficacy (*P* < .05; Table 2) with clinically relevant differences for arm pain (ES, 0.69) and self-efficacy (ES, 0.47) only (Table 2). When patients were stratified by sex, the significances between Grades II and III disappeared regarding men's hand strength and men's NME extension.

All physical measures correlated significantly with NDI (*r* = -0.14 to -0.42, *P* = .04 to <.0001) and self-efficacy (*r* = 0.17 to 0.40, *P* < .02). Neck muscle endurance extension and flexion correlated significantly with arm pain (*r* = -0.15 to -0.19, *P* < .04) and NME extension to EQ-5D (*r* = 0.39, *P* < .0001).

DISCUSSION

Comparisons Between Patients and Healthy Participants and CR and WAD Patients

Both patient groups exhibited results that were approximately 20% to 80% of healthy volunteers' results in nearly all physical measures, suggesting the importance of physical rehabilitation aimed at gaining function. This finding was particularly pronounced for NME extension. The nonsignificant difference between female patients and healthy women regarding NME flexion may indicate that even healthy women have relatively low muscle endurance compared with men (*P* < .0001)²⁸; this may be an important factor regarding the higher prevalence of neck pain among women than

Table 2. Comparison Between Patients With Grade II and Grade III WAD

	Grade II	Grade III	P; ES
	Mean ± SD	Mean ± SD	
Sagittal AROM	100 ± 22.2	91 ± 30.0	.02; 0.35
Frontal AROM	67 ± 15.0	63 ± 21.0	.11; 0.22
Transverse AROM	116 ± 21.3	106 ± 32	.01; 0.38
Hand right	32 ± 12.5	27 ± 12.8	.005 ^a ; 0.39
Hand left	30 ± 11.9	26 ± 12.6	.009 ^a ; 0.33
NME flex	41 ± 47.2	31 ± 41.6	.11; 0.22
NME ext	112 ± 126.5	75 ± 112.2	.03 ^a ; 0.34
Neck pain VAS	39 ± 23.9	47 ± 24.2	.02; 0.33
Arm pain VAS	10 ± 16.9	25 ± 26.5	<.0001; 0.69
NDI%	31 ± 12.2	36 ± 14.1	.004; 0.38
Self-efficacy	157 ± 34.3	140 ± 38.0	.0007; 0.47
EQ-5D	0.63 ± 0.26	0.59 ± 0.26	.24; 0.15

Statistical significance is set as $P < .05$; ES of 0.40 or higher is regarded as clinically relevant.

AROM, active cervical range of motion; EQ-5D, EuroQol 5-dimensional self-classifier; ES, effect size; ext, extension; flex, flexion; NDI, neck disability index; NME, neck muscle endurance; VAS, visual analog scale; WAD, whiplash-associated disorder.

^a Only significant for women when the groups were stratified by sex.

among men.³⁴ To compare the 3 groups properly, it was necessary to standardize the assessments performed in all three groups as well as the ability to use raw data.

The physical disability results confirm results from earlier small studies involving CR patients^{5,8-10} as well as earlier small studies of AROM in patients with chronic WAD.^{18,19} Mean values of neck AROM data for the CR group are comparable with earlier studies of CR patients with relatively few participants^{5,9} and were lower for both patient groups than those obtained in young adults being treated for radiating neck pain.³⁵ Regarding hand strength, CR patients in the present study fared worse than in earlier studies, and WAD patients exhibited results similar to those of CR patients in previous studies.^{5,9} The lower hand strength among CR patients in the present study may be explained by more generous inclusion criteria for surgery in studies that were initiated more than a decade ago but may also be a reflection of the small study samples in the older studies.^{5,9} Neck muscle endurance flexion values in the present WAD patients were comparable with those of previous nonspecific neck pain patients⁸; however, the NME extension values among the present female WAD patients were worse.⁸ The NME values for CR patients in the present study were both slightly better and worse than reported in earlier studies of CR patients.^{5,8,9}

All measurements were worse for the CR group; to our knowledge, no such comparison between the groups has been presented before.

Whiplash-Associated Disorder Grade

Whiplash-associated disorder grade was important regarding both physical measures and self-reported data;

although this finding was not unexpected, it was debatable.^{24,25} To our knowledge, only 1 previous randomized controlled trial¹¹ of patients with chronic WAD included Grade III patients. The results of the present study show that there is an urgent need for increased knowledge of the best way to treat this subgroup of WAD patients, suggesting that future randomized controlled trials should also include patients with Grade III WAD.

Correlation Between Measures

Although significant, the correlations between the physical measures and the self-reported pain, function, and health data were relatively low, indicating that physical rehabilitation must be combined with treatments that aim to improve other important factors, such as psychosocial factors. Psychosocial factors have shown to be important predictors of treatment outcome in both CR and WAD patients.^{16,36,37} Apart from neck-specific exercises,^{38,39} cognitive behavioral intervention has been suggested to be effective in neck pain patients.^{18,40} Health-related quality of life measurements with EQ-5D were worse in both groups of patients in the present study than among previous patients with, for example, low back pain and asthma,⁴¹ demonstrating the frailty that can follow neck pain problems and the interference of such problems with patients' daily lives. The low EQ-5D value for CR patients of only 0.39 is noteworthy. The SES results in the present study are in agreement with the previous results of patients with subacute WAD⁴²; however, to our knowledge, such results in patients with MRI-verified CR scheduled for surgery have never been presented before. Although the CR patients were scheduled for surgery, surgery cannot be expected to solve more than the segmental dysfunction and factors related to nerve encroachment in the particular segmental area. Additional studies about the role of physiotherapy in preoperative and postoperative neck surgery are, therefore, needed in light of the results of the present study and owing to the lack of NDI improvement reported in a long-term follow-up study of the effects of surgery.⁴³

Study Limitations

One limitation of the present study is the difference in sex distribution between the 2 patient groups: the CR patient group was 47% women and the WAD patient group was 64% women. This variation was expected from other studies^{1,44} and can be considered representative for each group. Especially when measuring hand strength and NME, biological sex has been shown to be important to consider when interpreting the results.^{28,27} Women with chronic pain also tend to give up physical activity to a greater extent than men,⁴⁵ which can further influence the physical measures. To be able to compare these patient groups with healthy volunteers and to limit the effect of different levels

of representation, hand strength and NME were stratified by biological sex in the analysis. Alternative analysis was also performed for the other variables, leading to a nonsignificant difference between CR and WAD for men in the transverse plane, but no other changes in the results (Table 1). Nevertheless, sex distribution may influence the results of the present study. Despite this possibility, the present study demonstrated worse results for CR patients than WAD patients. If the sex distribution had been equal, there may have been an even greater difference between the groups, as female sex has been shown correlate with worse outcome.^{36,37,46} We, therefore, argue that a more equal sex distribution would not alter the conclusions of the study.

For security reasons and owing to the risk of confounding factors, CR patients with myelopathy and WAD patients with head injuries were excluded. Therefore, the results may underestimate the severity of problems in these patient groups overall. Nevertheless, our findings undoubtedly demonstrate the existence of disability in these patient groups compared with a healthy population as well as the potential for treatment to be improved.

In the present study, ventral and dorsal NME was investigated as a result of united neck muscle performance. However, for a deeper understanding of muscle function, the coordination between different muscle layers needs to be examined in future studies.⁴⁷

Clinical Application

The present study reported patients to have low physical function and high disability in the investigated measures that also were related to self-evaluated function and health, showing the potential of training these functions in rehabilitation and especially for those patients with neurologic deficits.

CONCLUSIONS

Both WAD and CR patients generally exhibited worse results than healthy volunteers. Patients with CR appeared to be worse than the WAD group. Patients with Grade III

WAD exhibited worse results than those with Grade II WAD. Further studies are needed to investigate whether training of neck function aiming to improve AROM and NME may improve outcome in these patients.

FUNDING SOURCES AND POTENTIAL CONFLICTS OF INTEREST

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Concept development (provided idea for the research): AP, GP, MLL

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Practical Applications

- Both WAD and CR patients generally exhibited worse results than healthy volunteers.
- Patients with CR appeared to be worse than the WAD group, with the exception of self-rated neck disability, in which the WAD group was worse.
- Further studies are needed to investigate whether training of neck function aiming to improve AROM and NME may improve outcome in these patients.

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