Technical Report Chapter 2: Assessment

Australian Clinical Guidelines for Health Professionals Managing People with Whiplash-Associated Disorders, Fourth Edition

State Insurance
Regulatory Authority

NSW GOVERNMENT

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2. Abstract

Background: Whiplash-associated-disorders (WAD) are the most common outcome for Australians involved in non-catastrophic motor vehicle collisions (MVC), where half have persisting problems. Despite three iterations of Australian acute whiplash guidelines, implementation of evidence-based care can be inconsistent and little guidance has been provided on managing people with chronic WAD.

Objective: The objective of these evidence reviews, and recommendation development procedures was to identify clinical presentation features of people with acute and chronic WAD from observational studies and recommend factors that could be assessed by healthcare professionals to determine impairment and inform treatment direction.

Methods: A multidisciplinary panel (n=18) was convened comprising key stakeholders. Observational clinical studies comparing people with acute or chronic WAD to a control group or subgroup of WAD were identified by systematic review and the previous Australian whiplash guidelines. Studies were classified into 7 main categories: physical/musculoskeletal impairment, sensorimotor, pain sensitivity, additional psychological factors, additional symptoms, advanced medical testing, and imaging. Studies were then subcategorised further into assessment types (e.g., range of motion for physical/musculoskeletal impairment). The panel voted on twenty-one clinical questions based on the consistency of findings across the extant literature and current practice to provide consensus recommendations on whether healthcare professionals should assess each factor. The Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) Evidence to Decision Framework was modified for the purpose of developing guideline panel consensus recommendations for assessment of people with WAD. It is to be noted that certainty of evidence ratings and risk of bias were not evaluated in this section of the guidelines and the recommendations are therefore deemed as “guideline panel consensus recommendations”. Implementation considerations assessing these factors were developed in accordance with the included studies (e.g., the assessment tool used, relevant clinical thresholds), feasibility (i.e., whether it can be implemented in a clinical setting) and input from the guideline panel (e.g., subject matter experts, healthcare professionals, consumers).

Results: 29 observational studies for acute and 135 observational studies for chronic WAD were included. Guideline panel consensus recommendations FOR measuring the factors included range of motion, cervical muscle function, cervical joint position error, balance, and thermal hyperalgesia. NEUTRAL consensus recommendations with more stringent implementation considerations were specific to clinical presentation features such as muscle performance, coordination, and proprioception. Consensus recommendations were made AGAINST imaging or advanced testing (e.g., nociceptive flexion, inflammatory biomarkers, fat infiltration).

Conclusions: We have provided healthcare professionals with recommendations for assessing people with whiplash, in addition to the Diagnosis and Prognostic assessments detailed in the guidelines. Assessing neck range of motion assists healthcare professionals in determining the WAD grade. The need to assess physical impairment, pain sensitivity, sensorimotor, additional

psychological factors, and other factors will vary based on the person's clinical presentation. Although some imaging techniques (i.e., measuring muscle fat infiltration) showed evidence of differences in people with WAD and can assist in the understanding of the WAD mechanism, consensus recommendations were made against assessing these factors mainly as they are not feasible to implement in clinical settings. Assessment should be based on risk stratification, clinical presentation features of the person with WAD, and whether assessing the factors assist in treatment direction.

3. Suggested citation

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4. Introduction

Whiplash-associated-disorders are the most common injury for the ~2.6 million Australians involved in a non-catastrophic MVC and are characterised by symptoms following whiplash trauma to the neck (MAA, 2009). Whilst half of those Australians injured should see rapid recovery following a MVC, the clinical course is not so clear for the remaining 50% who may develop chronic pain, disability, psychological disorders (e.g., posttraumatic stress, depression, and anxiety) and continue to report long-term interference in daily life (Campbell et al., 2018; Sterling et al., 2010).

The 2014 NSW SIRA "Guidelines for the Management of Acute Whiplash Associated Disorders for Health Professionals" (SIRA, 2014) covers management of people with WAD in the first 12 weeks following an MVC. The 2008 Trauma and Injury Recovery "Clinical Guidelines for Best Practice Management of Acute and Chronic Whiplash-Associated Disorders" (TRACsa, 2008) provides some guidance on management of people with chronic WAD. However, a considerable number of studies have been published since these two guidelines, and at present, the acute guidelines are mostly used across Australia. As per the Australian National Health and Medical Research Council (NHMRC) Standards for Guidelines, recommendations within clinical guidelines need to be based on current evidence to ensure ongoing relevance and reliability. There is a need for systematic review and collation of current evidence to update the existing Australian WAD guidelines and bridge the gap between research and clinical practice. Since the previous guidelines the GRADE process for evaluating certainty of evidence and developing recommendations is being increasingly used and is now a requirement of new Australian guidelines. The overall aim of developing these guidelines is to improve health and social outcomes of people with acute and chronic WAD by providing best practice consensus recommendations for health professionals managing these people. This technical report details the evidence review, guideline consensus recommendation procedures, and recommended outcomes for assessing people with acute and chronic WAD.

5. Abbreviations

BPPT = Brachial Plexus Provocation Test
BPNN = Back Propagation Neural Network
COMT = Genetic marker
CPM = Conditioned Pain modulation
CPT = Cold pain thresholds
CT = Computed tomography
DASS = Depression Anxiety Stress Scale
EDT = Electrical Detection Thresholds
EMG = Electromyography

EPT = Electrical Pain Thresholds
GP = General Practitioners
GRADE = Grading of Recommendations, Assessment, Development, and Evaluations
HCP = Healthcare Professional
HPT = Heat Pain Thresholds
MFI = Muscle Fat Infiltration
MRI = Magnetic Resonance Imaging
MRS = Magnetic Resonance Spectroscopy
MSK = Musculoskeletal
MVC = Motor vehicle collision
MVIF = Maximal voluntary isometric force
NFR = Nociceptive Flexion Reflex
NHMRC = National Health and Medical Research Council
NTNP = Non-Traumatic Neck Pain
PDQ = Perceived Deficits Questionnaire
PET = Positron Emission Tomography
PPT = Pressure Pain Threshold
PSD = Positive Symptom Distress
QST = Quantitative Sensory Testing
ROM = Cervical Range of Motion
SD = Standard Deviation
SES = Self-Efficacy Scale
SPECT = Single Photon Emission Computed Tomography
SPNT = Pursuit Neck Torsion Test
US = Ultrasound
WAD = Whiplash-associated disorders

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6. Technical Report Chapter 2: Assessment of acute and chronic whiplash-associated disorders

6.1. Review of evidence

6.1.1. Objectives

Objectives of this systematic review and recommendation development procedures were to identify evidence of the clinical features of WAD and evaluate the feasibility of their assessment methods to inform what factors healthcare professionals (HCP) should assess in people with whiplash-associated disorders (WAD). The process included evaluating what assessment methods assist in: i) classifying the grade of whiplash associated disorders (WAD); ii) determining dysfunction in people with acute or chronic whiplash-associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); iii) determining the direction of treatment(s); or iv) evaluating the effectiveness of treatment intervention(s). These data were used to develop clinical consensus recommendations and implementation considerations for healthcare professionals managing people with acute and chronic WAD in Australia.

6.1.2. Systematic review

Systematic review methods used in the 2014 NSW SIRA "Guidelines for the Management of Acute Whiplash Associated Disorders for Health Professionals" (SIRA, 2014) and 2008 Trauma and Injury Recovery "Clinical Guidelines for Best Practice Management of Acute and Chronic Whiplash-Associated Disorders" (TRACsa, 2008) were adapted for this review to ensure a consistent methodological approach and synthesis of current evidence with that of the existing guidelines.

6.1.3. Search strategy

Database searches were performed specific to the population group (whiplash injury) and study design criteria (observational studies). A single search strategy was used to capture original research articles pertaining to assessment for acute or chronic WAD. The search strategy was developed in the Ovid Medline database (Table 1) and adapted for database specific medical subject headings.

Table 1: Management of whiplash-associated-disorders database search strategy

Characteristics	Search strategy
Whiplash injury	1. whiplash* 2. whiplash injuries/ 3. neck pain* adj4 whiplash 4. neck injur* adj4 whiplash 5. traumatic neck injur* 6. traumatic neck pain*
Assessment	7. diagnosis/ 8. diagnosis*. mp. 9. assessment*.mp. 10. evaluation study/ 11. evaluat*.mp. 12. analy*.mp.
Whiplash injury And Assessment	1 OR 2 OR 3 OR 4 OR 5 OR 6 AND 7 OR 8 OR 9 OR 10 OR 11 OR 12
Subclassification	Sub?classif* Sub?group*
Filters	Publication date: 2007-current

/ = medical subject heading; * = truncation of keyword; adj4 = adjunct within 4 words keyword; mp. = multi-purpose

Searches were performed using eight electronic databases covering the period of 2007 (end of the TRACsa guidelines search) to 1 June 2022: Allied and Complementary Medicine Database (Amed), CINAHL, Cochrane (Systematic Reviews Database), Embase, Medline, PsycINFO, and Web of Science Core Collection. Articles were screened for eligibility using the online software Covidence (Covidence.org: Melbourne, Australia). Clinical observational studies included in the previous Australian guidelines were identified. Reference lists of review articles that were specific to whiplash injury were screened.

6.1.4. Inclusion criteria

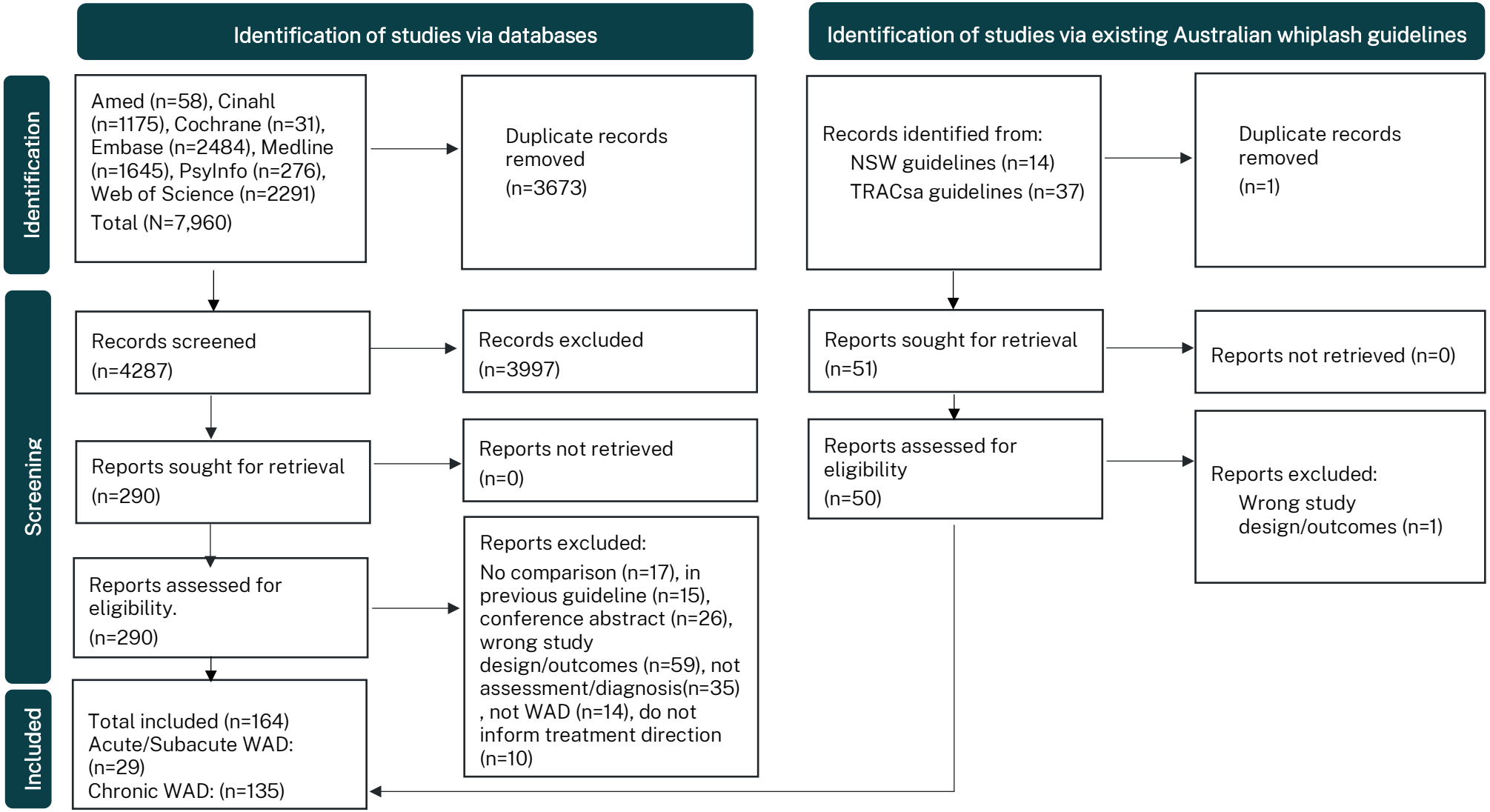
Articles from the database searches and those included in the existing guidelines were screened against the population, study design, and whiplash injury grade inclusion criterion (Table 2). Conflicts in the title and abstract screening were resolved via consensus by the two reviewers. Full-text screening of articles was performed by APCS. Members of the research team were consulted on studies whose eligibility was unable to be determined by the reviewers, and a decision was made by consensus.

Table 2: Inclusion criterion for whiplash-associated-disorders assessment studies

Characteristics	Inclusion criterion
Population	• Human study • Participants were of driving age ≥16 years. • Motor vehicle accident resulting in WAD grade I-III (Spitzer, 1995). • Study includes an identifiable and separately analysed subgroup of people suffering from whiplash, that comprise ≥50% of the total sample size.
Study design	• Observational studies • Participants with acute or chronic WAD were compared to other populations (e.g., cohort with idiopathic neck pain) • Study includes an identifiable and separately analysed subgroup of participants suffering from whiplash. • Available in English.
Outcomes	Clinical assessment techniques, functional tests, imaging, or radiological tests that were used to: ○ (Assessment) assessment methods assist in classifying the grade of acute and subacute. ○ (Dysfunction) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations. ○ (Informing treatment) informing treatment direction of responsiveness, e.g., pain sensitivity, muscle function.
Acute	• Manuscript published between January 2007 - June 2022. • Participants were recruited with acute/subacute WAD (<3months post whiplash injury).
Chronic	• Manuscript published between January 2007 – June 2022. • Participants were recruited with chronic WAD (≥3months post whiplash injury).

A PRISMA flow chart (Page et al., 2021) of the study selection pertaining to the clinical assessment with acute and chronic WAD is shown in Figure 1. There were 290 full text articles screened from those identified in the databases and a further 50 articles from the existing Australian guidelines. There were 29 and 135 studies included that related to clinical studies assessing people with acute and chronic WAD, respectively. Further information on the process of identifying clinical questions relevant to identify clinical features of WAD an Australian context is outlined in 2.1.5 Selection of clinical question.

Figure 1 Assessment of whiplash-associated disorders search results.



6.1.5. Selection of clinical question

Clinical presentation features (e.g., impaired neck range of motion) and their assessment methods were identified from the previous Australian whiplash guidelines and from the systematic review. The research team categorised studies according to the primary factor investigated (i.e., if the authors defined the factor as the primary aim). Seven assessment categories were developed: physical/musculoskeletal impairment, sensorimotor, pain sensitivity, additional psychological factors, other symptoms, advanced medical testing, and imaging. Evidence summaries and recommendations were based on the following clinical research question: What assessments assist in a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s)? This question was applied to each assessment category (Table 3).

Table 3: Clinical questions related to the assessment section of whiplash-associated disorders

Assessment categories	Clinical question
Physical Musculoskeletal Impairment	What physical and/or musculoskeletal clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).
Sensorimotor	What sensorimotor clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).
Pain sensitivity	What pain sensitivity clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).
Additional Psychological Factors	What psychological clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).
Additional Symptoms	What clinical assessments of additional symptoms assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

Advanced medical testing	What advanced medical testing methods assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).
Imaging	What imaging methods assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

Studies in each category were then sub-categorised according to the factors assessed, test performance, or the technique used. For example, studies under the physical/musculoskeletal impairment category were grouped into trigger points, cervical range of motion, muscle performance/postural changes, or muscle function (Table 4). These sub-categories were developed to facilitate panel consensus recommendations (see 6.2 Consensus recommendation development).

Table 4: Assessment of whiplash-associated disorders subcategories

Assessment domain	Subcategories
Physical Musculoskeletal Impairment	Trigger points, Cervical Range of Motion (ROM) Muscle performance/postural changes Muscle function
Sensorimotor	Cervical joint position error Cervical movement sense Oculomotor disturbance Balance Coordination Test Others – Proprioception
Pain sensitivity	Pressure hyperalgesia Thermal hyperalgesia Dynamic pain sensitivity testing Quantitative Sensory Testing (QST) (vibration) Brachial Plexus Provocation Test (BPPT) Nociceptive Flexion Reflex (NFR) Others
Additional Psychological Factors	Fear avoidance Self-efficacy Mental disorder Psychological distress Cognitive deficits
Additional Symptoms	Additional symptoms Sleep disturbance Jaw symptoms Disability
Advanced medical testing	Stress hormone Inflammatory biomarkers Cerebral blood flow Others
Imaging	Morphology Structure changes Morphology Muscle Fat Infiltration

	Morphology Muscle Size Metabolites measure by Magnetic resonance spectroscopy Brain characteristics Nerve Mobility Others

6.1.6. Data extraction and evidence synthesis

Data extraction was performed by two members of the research team (APCS and LC). The following information was extracted for each study: first-author, year of publication, study title, study aim, study design (longitudinal, cross-sectional), setting, country, classification of acute or chronic WAD population, number of participants and % of female participants, age (mean, SD) for WAD group and comparison group (e.g. healthy control, idiopathic neck pain), study type (diagnostic or clinical assessment studies), factors type(s) assessed and the outcome measured for each factor, main primary factors and outcome assessed, primary factor assessment/diagnostic technique, main outcome, significant differences between groups (yes or no) and comments (author's conclusion) into a custom spreadsheet in Microsoft Excel. If the study assessed multiple factors; the main factor was determined according to the primary aim and results. If this was not possible, a consensus on the main outcome was achieved among the research team. The main outcome and statistical differences between groups (i.e., WAD group versus healthy control) were extracted for the primary factor.

Each included study belonged to one category and its subcategory only; the exception was for pain sensitivity, where studies were classified into more than one subcategory. This decision was based on a pragmatic approach by the research team as pain sensitivity was evaluated using several assessment methods that are applied in clinical practice (e.g., thermal hyperalgesia, brachial plexus provocation test, conditioned pain modulation). Evidence summaries for each category detailed the number of studies and whether there were statistically significant differences between WAD and control groups.

6.2. Consensus recommendation development

For each category, an evidence summary and draft of the modified GRADE Evidence to Decision Framework (Alonso-Coello et al., 2016) was provided to the guideline panel for review prior to meeting, consistent with the format detailed in this technical report. The research team summarised the evidence in lay language (suitable for non-research guideline panel members) during a whole day working group workshop; held via face-to-face meeting and simultaneously in Microsoft Teams for those who could not attend physically.

The GRADE Evidence to Decision Framework was modified to discuss and develop a panel consensus recommendation for factors, assessment methods, and test/techniques healthcare professionals should use when assessing people with WAD. The clinical feasibility of assessing or performing the test, strength of association (number and proportion of participants/studies finding significant differences between groups), and undesirable effects (e.g., possible exacerbation of symptoms by provocative tests) were considered critical outcomes by the panel when developing consensus recommendations. Different studies that used the same population cohort had their results (significant or not significant) counted once to not overestimate the strength of association evidence. Resources, equity, and acceptability framework elements received input from healthcare professionals, consumers, and insurers on the guideline panel. Consensus recommendations were developed separately for acute and chronic WAD.

Following review and panel agreement on content presented in the framework (the panel was asked to comment on each item), the panel used an anonymous online voting system (Menti.com) to reach a consensus on a recommendation classification. The voting question "Are you for or against healthcare professionals assessing the following factors in people with acute/chronic WAD" was

adapted for each category and sub-category. One voting question could contain one or more subcategories. Grouping more than one subcategory in those questions was performed pragmatically based on the strength of the evidence and likely recommendation classification. The clinical voting questions proposed to the panel are outlined in Table 5.

Table 5: Clinical question for panel to vote on consensus recommendation

Assessment domain	Clinical question for voting
Physical musculoskeletal impairment	
Acute	Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with acute WAD: Cervical ROM
Acute	Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with acute WAD: Cervical muscle function and cervical muscle performance.
Chronic	Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with chronic WAD: Cervical ROM
Chronic	Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with chronic WAD: Cervical muscle function?
Chronic	Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with chronic WAD: Cervical muscle performance?
Sensorimotor	
Acute	Are you for or against healthcare professionals assessing the following sensorimotor factors in people with acute WAD: cervical joint position error, cervical movement sense, oculomotor disturbance, balance, and coordination test?
Chronic	Are you for or against healthcare professionals assessing the following sensorimotor factors in people with chronic WAD: cervical joint position error, cervical movement sense, oculomotor disturbance, balance?
Chronic	Are you for or against healthcare professionals assessing the following sensorimotor factors in people with chronic WAD coordination and proprioception (others)?
Pain sensitivity	
Acute	Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with acute whiplash: thermal hyperalgesia, pressure hyperalgesia, dynamic pain sensitivity, brachial plexus provocation test?
Acute	Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with acute whiplash: vibration hyperalgesia, nociceptive flexion reflex?
Chronic	Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with chronic whiplash: thermal hyperalgesia, pressure hyperalgesia, brachial plexus provocation test?
Chronic	Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with chronic whiplash: dynamic pain sensitivity test?

Chronic	Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with chronic whiplash: Nociceptive Flexion Reflex (NFR) and vibration hyperalgesia?
Additional psychological factors	
Acute	Are you for or against healthcare professionals assessing the following additional psychological factors in people with acute WAD: fear avoidance and self-efficacy?
Chronic	Are you for or against healthcare professionals assessing the following psychological factors in people with chronic WAD: depression?
Chronic	Are you for or against healthcare professionals assessing the following psychological factors in people with chronic WAD: psychological distress symptoms and perceived cognitive deficits?
Additional symptoms	
Acute Chronic	Are you for or against healthcare professionals assessing the following additional symptoms in people with acute and chronic WAD: jaw symptoms, upper limb disabilities, sleep quality?
Advanced medical testing	
Acute	Are you for or against healthcare professionals assessing the following advanced medical testing in people with acute WAD: stress hormone and inflammatory biomarkers?
Chronic	Are you for or against healthcare professionals assessing the following advanced medical testing in people with chronic WAD: stress hormone and inflammatory biomarkers, blood flow, skin biopsy and genetic markers?
Imaging	
Acute	Are you for or against healthcare professionals assessing the following imaging technique in people with acute WAD: magnetic resonance imaging (MRI) and Ultrasound (US) to assess changes in Morphology – structure changes, muscle fat infiltration and muscle size- and muscle stiffness?
Chronic	Are you for or against healthcare professionals assessing the following imaging techniques in people with chronic WAD: Magnetic resonance imaging (MRI) and Ultrasound (US) to assess changes in WAD Morphology – structure changes, muscle fat infiltration, muscle size, muscle morphology, metabolites measured by MRS, Brain, and nerve mobility and others?

Consensus recommendation classifications and their interpretations are outlined in Table 6. More than 50% of votes were required to reach consensus, with a quorum of eight panel members. However, 50% was not considered sufficient to be a consensus if there is strong opposition to the result. If there is no clear consensus after the first vote, the working group would critically discuss the outcome and rationale before proceeding to a second vote. Where a consensus cannot be reached, the Chair could choose to have the casting vote.

Clinical implementation considerations were developed for all recommendations that were neutral, conditional for, or strong for. These considerations were informed by the extant literature presented in the evidence summary (e.g., clinical test to measure the factor) and from input by the guideline panel (e.g., subject matter experts' healthcare professionals, consumers).

Table 6: Assessment recommendation classifications and their interpretation

Recommendation classification	Interpretation
Strong consensus for	Healthcare professionals should assess the factor in all or almost all people, in all or almost all circumstances, in accordance with the implementation considerations. "There was strong guideline panel consensus that healthcare professionals assess the following (factor, perform test, technique, or imaging) in people with (acute/chronic) WAD"
Conditional consensus for	Healthcare professionals should assess the factor in most people, but not all, in accordance with the implementation considerations. "There was guideline panel consensus to suggest that healthcare professionals assess the following (factor, perform test, technique, or imaging) in people with (acute/chronic) WAD"
Neutral	Neither for nor against assessing the factor. In some instances, healthcare professionals could assess the factor in accordance with the implementation considerations, such as people who present impairment for the factor or assessing the factor may assist in guiding treatment direction. "The guideline panel cannot reach consensus for or against assessing the following (factor, perform test, technique, or imaging) in people with (acute/chronic) WAD"
Conditional consensus against	Healthcare professionals should not assess the factor in most people. "There was guideline panel consensus to suggest that healthcare professionals do not assess the following (factor, perform test, technique, or imaging) in people with (acute/chronic) WAD"
Strong consensus against	Healthcare professionals should not assess the factor in all or almost all people, in all or almost all circumstances. "There was strong guideline panel consensus that primary healthcare professionals do not assess the following (factor, perform test, technique, or imaging) in people with acute/chronic WAD"

Consensus recommendations were developed separately for managing acute and chronic WAD, except for the additional symptom category. In some circumstances, consistent significant findings were present for a factor, and the finding was of interest to investigate the mechanisms of the

clinical feature of WAD; however, the technique or test was not feasible in a clinical setting. It was unlikely that assessment of these factors could have a 'consensus recommendation for'.

6.3. Method limitations

The evidence synthesis and recommendation development procedures are potentially limited by the following factors:

- Studies included in the assessment section are low quality observational studies comparing a WAD group to a control group and risk of bias evaluation was not performed.
- Extent of heterogeneity in what studies assessed technique or test used. A more narrative approach to summarising the finding was used as statistical analysis and performing the magnitude of evidence for pooled analyses were not feasible for these guidelines.
- The certainty of evidence was not evaluated as part of this section of the guidelines. The evidence synthesis was based on consistency of findings and the number of studies and participants.
- The GRADE Evidence to Decision Framework (Alonso-Coello et al., 2016) was adapted to develop recommendations. The recommendation is not based on a method as robust as the other portions of these guidelines, and therefore we noted that recommendations were a "panel consensus recommendation".

7. Assessment consensus recommendations

A.1 Physical Musculoskeletal Impairment

What physical and/or musculoskeletal clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.1.1. Executive summary

What Physical/Musculoskeletal Impairment Factors should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: Two cross-sectional studies evaluated physical musculoskeletal (MSK) impairment in people with whiplash compared with controls or other pain conditions. Two studies evaluated physical MSK impairments in sub-groups of people with WAD. Summary of findings there:

- Muscle function: 1/1 study found isometric muscle fatigue in paravertebral and upper extremity muscles in people with WAD.
- Muscle Performance: 1/1 study suggests overactivity in superficial neck flexor muscles in people with acute WAD.

Chronic whiplash: 22 studies evaluated physical MSK impairment in people with whiplash compared with controls or other pain conditions. Eighteen independent studies evaluated physical MSK impairments in sub-groups of people with WAD. Summary of findings here:

- Trigger point: 1/1 study found a higher prevalence of trigger points in neck muscles in people with WAD.
- Cervical range of motion (ROM): 6/6 studies found a significant reduction in ROM in people with WAD.
- Muscle performance/Postural changes: 5/6 studies found muscle performance impairment in people with WAD (e.g., the increased elevation of the clavicle.
- Muscle function: 6/6 significant studies reduction in muscle function in people with WAD (e.g., lower cervical strength, poor cervical flexor endurance) than control.

A.1.2. Acute physical musculoskeletal impairment

Muscle Function

Category: Physical Musculoskeletal Impairment

Sub-category: Muscle Function- Acute and Subacute WAD studies (n=1)

Table 7: Summary of included studies (acute muscle function)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Rastovic et al., 2017) Isometric muscle fatigue of the paravertebral and upper extremity muscles after whiplash injury	To determine muscle fatigue in people with whiplash injury in six body positions	75 people with acute (within 6hr) WAD	75 healthy controls	Muscle Function Endurance Neck and upper extremities isometric muscle endurance tests	In all six positions, people with whiplash had faster fatigue than controls ls (P<.05). Assignment to the person or control group and injury grade could be predicted with more than 90% accuracy based on time to muscle fatigue.	Muscle endurance and the appearance of isometric muscle fatigue during testing can be useful indicators of whiplash injury and grade.	Significant Fatigue WAD>C

Muscle Performance

Category: Physical Musculoskeletal Impairment

Sub-category: Muscle Performance - Acute WAD studies (n=1)

Table 8: Summary of included studies (acute muscle performance)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Sterling, Jull, Vicenzino, Kenardy, et al., 2003) Development of motor system dysfunction following whiplash injury	To determine if motor system dysfunction exists in people with acute WAD compared to asymptomatic controls	66 people with acute WAD (<3mo) (68% female)	20 asymptomatic controls (60% female)	Muscle Performance EMG activity during a craniocervical flexion test	Overactivity on EMG measurements of superficial neck flexors remained elevated in all whiplash groups compared to controls ($p<0.01$). This was greatest in the moderate /severe group ($p<0.01$).	Suggestive of overactivity in superficial neck flexors in people with acute WAD.	Significant Muscle activity WAD>C

EMG = electromyography

A.1.3. Acute physical musculoskeletal impairment evidence summary

Table 9: Summary of evidence for included studies in acute physical musculoskeletal impairment.

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Muscle Function (Independent cohorts n=1)	(Rastovic et al., 2017)	75 people WAD 75 controls	Isometric muscle fatigue clinical test	Isometric muscle fatigue during testing can be a useful indicator.	1 –Sig

Muscle Performance (Independent cohorts n=1)	(Sterling, Jull, Vicenzino, Kenardy, et al., 2003)	66 acute WAD 20 controls	Electromyography	Overactivity in superficial neck flexors in people with acute WAD.	1 –Sig

A.1.4. Chronic physical musculoskeletal impairment

Trigger point

Category: Physical Musculoskeletal Impairment

Sub-category: Trigger point - Chronic and mixed WAD studies (>3mon) (n=1)

Table 10: Summary of included studies (chronic trigger point)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Comparison Population	Comments	Significant
(Ettlin et al., 2008) A distinct pattern of myofascial findings in people after whiplash injury	Prevalence and distribution of trigger points in the neck and shoulder musculature in WAD, fibromyalgia, nontraumatic chronic cervical syndrome, endogenous depression, and healthy controls	47 WAD (>6mo)	21 fibromyalgia (>6mo) 17 people with chronic cervical syndrome (>6mo) 15 people with endogenous depression (>6mo) 24 healthy control group	Trigger points	People with WAD had significantly higher prevalence of positive trigger points in the semispinalis capitis muscle than any of the control groups (P<.05). For all other muscles, no difference between groups.	People with whiplash showed a distinct pattern of trigger point distribution that differed significantly from other groups and healthy subjects. The semispinalis capitis muscle was more frequently affected by trigger points in people with WAD.	Significant Prevalence WAD> C

Cervical range of motion

Category: Physical Musculoskeletal Impairment

Sub-category: Cervical range of motion - Chronic and mixed WAD studies (>3mon) (n=7)

Table 11: Summary of included studies (chronic cervical range of motion)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Antonaci et al., 2002) 3D kinematic analysis and clinical evaluation of neck movements in people with whiplash injury	To compare accuracy of computerised ROM vs clinical evaluation in WAD and healthy controls	70 acute and chronic WAD Grade II and III people	46 healthy volunteers	Cervical Range of Motion Computerised ROM	Cervical ROM significantly reduced in people with whiplash compared with vs controls ($p<0.05$). Left rotation $p<0.005$.	Reduced ROM in people with acute and chronic WAD	Significant ROM WAD<C
(Grip et al., 2003)* Classification of neck movement patterns related to WAD using neural networks	To determine the predictive value of a 3-D computerised neck movement analyser for WAD	59 people with chronic WAD (>3mo) (51% female)	56 healthy controls (48% female)	Cervical Range of Motion 3D -motion capture	Computerised BPNN (back propagation neural network) ROM analysis of people with chronic WAD had a sensitivity of 0.90 and specificity of 0.88 in identifying people with WAD from controls.	Computerised BPNN movement analysis may be useful in classifying people with chronic WAD.	Significant ROM WAD<C

(Ohberg et al., 2003)* Chronic WAD and neck movement measurements: an instantaneous helical axis approach	To determine whether neck movement analysis can distinguish between people with chronic WAD and healthy controls	59 people with chronic WAD (>3mo) (51% female)	56 healthy controls (48% female)	Cervical Range of Motion	Neck movement analysis was able to distinguish people with chronic WAD from controls in terms of reduced speed of movement and reduced range of movement in all directions ($p<0.001$)	Neck movement analysis distinguished people with chronic WAD from healthy controls regarding speed of movement and range of movement in all directions.	
(Armstrong et al., 2005) Head and neck position sense in whiplash patients and healthy individuals and the effect of the cranio-cervical flexion action	To examine ROM and position sense impairment in people with WAD vs healthy controls	23 people with chronic WAD (57% female)	23 healthy controls (65% female)	Cervical Range of Motion 3-Space Fastrak	Significant reduction in ROM ($p<0.05$) in WAD.	Reduced ROM in people with chronic WAD	Significant ROM WAD<C
(Dall'Alba et al., 2001) Cervical range of motion discriminates between asymptomatic persons and those with whiplash	Comparative study of cervical ROM in asymptomatic vs whiplash subjects	114 people with chronic WAD (>3mo) (82% female)	89 asymptomatic volunteers (54% female)	Cervical Range of Motion Computerized, electromagnetic, motion-tracking device	ROM measures combined with age, sex data correctly categorized 90.3% of subjects (sensitivity 86.2%, specificity 95.3%)	Reduced cervical ROM is a characteristic of chronic WAD	Significant ROM WAD<C

(Kaale et al., 2007) Active range of motion as an indicator for ligament and membrane lesions in the upper cervical spine after a whiplash trauma	Active range of motion as an indicator for ligament and membrane lesions in the upper cervical spine after a whiplash trauma	87 participants with WAD II (65.5% female)	29 control participants (65.5% female)	Cervical Range of Motion CROM goniometer	Significant differences for all ranges of motion except side bending to the left. Adjusted differences in mean values were 10° (extension), 7° (rotation right) and 7° (rotation left), 7° (flexion), 4° (side-bending, right) and 3° (side-bending, left), respectively.	Soft tissue lesions may affect neck motion as reflected by AROM. However, since lesions to different structures seem to affect the same movement, AROM alone is not a sufficient indicator for soft-tissue lesions to a specific structure in the upper cervical spine.	Significant ROM WAD<C
(Malik et al., 2017) Assessment of Range of Movement, Pain and Disability Following a Whiplash Injury	To assess long term function after whiplash injury	28 symptomatic WAD and long-standing neck pain (Group B) (46% female) 27 symptomatic WAD and no neck symptoms (Group C) (52% female)	24 no WAD but long-standing neck pain (Group A) (63% female) 85 control people (Group D) (69% female)	Cervical Range of Motion Goniometry	Comparing the four groups using a one-way ANOVA showed a significant difference between the groups ($p<0.001$). There is Significant difference in ROM between symptomatic WAD and control groups. No difference between idiopathic neck pain and controls.	Whiplash injury with chronic problems cause a significantly decreased cervical range of movement with a higher pain score. People with shorter duration of whiplash symptoms appear to do better in the long-term	Significant ROM WAD<C

2 papers reported same cohort – Grip 2003, and Ohberg 2003

Muscle Performance/Postural Changes

Category: Physical Musculoskeletal Impairment

Sub-category: Muscle performance/ Postural Changes (Electromyography, Kinematic) - Chronic and mixed WAD studies (>3mon) (n=7)

Table 12: Summary of included studies (chronic muscle performance)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Descarreaux et al., 2007) Neuromuscular control of the head in an isometric force reproduction task: comparison of whiplash subjects and healthy controls	To establish if subjects with WAD can produce isometric neck extension and flexion forces with precision and to evaluate if different neuromuscular control strategies can be observed between healthy and WAD subjects	17 participants with WAD I-II	14 healthy subjects	Muscle activation/ Postural changes Electromyographic (EMG) Surface Isometric neck extension and flexion	The average time to peak force was significantly longer for WAD [110.93 (13.20)] N than for the healthy controls [169.83 (14.54)]. A significant increase in peak force variability was also observed in the WAD group, and no group differences were noted for absolute error	Indicate that WAD subjects, when attempting to reproduce isometric force, have longer time to peak force than normal subjects	Significant Impairment WAD>C

(Helgadottir et al., 2010)* Altered scapular orientation during arm elevation in people with insidious onset neck pain and whiplash-associated disorder.	Whether there is a pattern of altered scapular orientation during arm elevation in people with insidious onset neck pain (IONP) and WAD compared to asymptomatic people	23 participants with WAD II (>6 mo) (87% female)	22 insidious onset neck pain (IONP) (>6 months) (90% female) 20 control subjects (85% female)	Muscle activation/ Postural changes Kinematic EMG surface	WAD group demonstrated an increased elevation of the clavicle compared to the asymptomatic group and the IONP group (P<.05), and reduced scapular posterior tilt on the nondominant side compared to the IONP group (P<.05)	Suggests that differences may exist in the nature of the impairments between these groups of people.	Significant Impairment WAD>C
Helgadottir, Kristjansson, Einarsson, et al. (2011)* Altered activity of the serratus anterior during unilateral arm elevation in patients with cervical disorders.	To investigate whether there is a pattern of altered activity in the serratus anterior (SA) and trapezius in people with insidious onset neck pain (IONP) and WAD	27 participants with WAD II (>6 mo) (89% female)	22 insidious onset neck pain (IONP) (>6 months) (90% female) 23 symptomatic subjects (78% female)		Significantly delayed onset of serratus anterior muscle activation and less duration of muscle activity in the IONP group (P< .05), and in the WAD group (P< .01) compared to the asymptomatic group. No statistical difference was found between the symptomatic groups. There were no group main effects or interaction effects for the upper, middle and lower trapezius.	Suggest that the disturbance in the onset of muscle activation of the serratus anterior muscle may occur as a general response to chronic neck pain	

(Helgadottir, Kristjansson, Mottram, et al., 2011)* Altered Alignment of the Shoulder Girdle and Cervical Spine in Patients With Insidious Onset Neck Pain and Whiplash-Associated Disorder	Whether there is a pattern of altered alignment of the shoulder girdle and the cervical and thoracic spine in people with neck pain.	23 participants with WAD II (>6 months) (87% female)	21 insidious onset neck pain (IONP) (>6 months) (90% female) 20 symptomatic subjects (85% female)		A difference was found between the symptomatic groups on the left side. In contrast, the WAD group revealed an increased scapular anterior tilt ($p < .03$) and the IONP group showed a decreased clavicle elevation ($p = .02$).	A different manifestation was observed between people with IONP and WAD on the left side in clavicle elevation and scapular anterior tilt, suggesting that a difference may exist impairments between these groups	

(Voerman et al., 2007) Upper trapezius muscle activation patterns in neck-shoulder pain patients and healthy controls	Investigating whether people with neck–shoulder complaints from different aetiologies show comparable muscle activation patterns, characterised by higher activation and lower relaxation levels of the trapezius muscles compared to healthy controls	20 participants with WAD (>3 months) (60 % female)	21 with work-related musculoskeletal disorders (WMSD) (10% female) 20control subjects (60% female)	Muscle activation/ Postural changes EMG surface Upper trapezius	No clear evidence for abnormal muscle activation patterns in people with WMSD and people with WAD compared to healthy controls	No convincing evidence was found for comparable muscle activation patterns between people with WMSD and people with WAD	NS
(Nederhand et al., 2000) Cervical muscle dysfunction in the chronic WAD grade II	To determine whether surface EMG of the upper trapezius can distinguish people with chronic WAD II from healthy controls	18 people with chronic WAD (>6mo) (83% female)	19 healthy controls (78% female)	Muscle activation/ Postural changes EMG surface Upper trapezius	Surface EMG of the upper trapezius showed decreased ability to relax these muscles after exercise in people with chronic grade II WAD. No significance data provided.	EMG shows decreased relaxation of trapezius muscles after exercise for people with chronic WAD vs controls.	Significant Ability to relax muscle WAD <C
(Vikne et al., 2013) Muscle activity and head	Compared head kinematics and muscle activation in relatively	15 participants with chronic WAD (>6mo) (60% female)	15 heathy controls (60% female)	Muscle activation/ Postural changes	The findings in the present study of generally reduced displacement, peak acceleration, deceleration and	Simple, unconstrained head movements in participants with chronic WAD are accomplished with reduced velocity and	Significant

kinematics in unconstrained movements in subjects with chronic neck pain; cervical motor dysfunction or low	unconstrained neck movements at three different speeds in participants with and without chronic WAD. In addition, comparisons were made taking both movement velocity and displacement into consideration.			Head kinematic EMG surface Sternocleido mastoid and splenius muscles	velocity at the maximum (M) speed conditions for the WAD group compared to controls	displacement but with normal muscle activation levels and movement patterns for a given velocity and displacement.	
(Kristjansson & Jonsson, 2002) Is the sagittal configuration of the cervical spine changed in women with chronic whiplash syndrome? A comparative computer assisted radiographic assessment, 2002	To compare cervical lordosis in people with normal and chronic whiplash	41 chronic WAD (100% female)	39 with chronic neck pain (100% female) 39 asymptomatic controls (100% female)	Postural changes Cervical lordosis	Non-significant difference in ratio of lower to upper cervical lordosis in WAD group. Significant difference for C4-5 level (3 degrees, 95%CI 0.8-5.2, p=0.007)	Cervical lordosis may be greater in people with chronic WAD	Significant

* 3 papers reported on the same cohort - Helgadottir 2010, Helgadottir, Kristjansson, Einarsson, et al. (2011) and Helgadottir, Kristjansson, Mottram, et al., 2011

Muscle Function

Category: Physical Musculoskeletal Impairment

Sub-category: Muscle Function (endurance, strength) - Chronic and mixed WAD studies (>3mon) (n=6)

Table 13: Summary of included studies (chronic muscle function)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Woodhouse, Liljeback, et al., 2010) Reduced head steadiness in whiplash compared with non-traumatic neck pain	Investigate head steadiness during isometric neck flexion in subjects with chronic whiplash-associated disorders (WAD), those with chronic non-traumatic neck pain and healthy subjects.	56 participants with WAD I-II (>6 months). (60% female)	57 with chronic nontraumatic neck pain (>6 months) (68% female) 57 asymptomatic subjects (49% female)	Muscle Function EMG surface Isometric neck flexion fatigue	Significantly decreased head steadiness (low load task) WAD compared with in the other 2 groups. The difference was explained largely by severe levels of neck pain and dizziness. No group differences in the high-load task.	Reduced head steadiness during an isometric holding test was observed in a group of WAD.	Significant
(Kumbhare et al., 2005) Measurement of cervical flexor endurance following whiplash	To assess discriminant validity of cervical flexor endurance test between people with WAD and controls	71 people with acute/chronic WAD (69% female)	160 normal controls (56% female)	Muscle Function Cervical flexor endurance test	People with WAD demonstrated significantly poorer neck flexor endurance ($p<0.001$).	People with acute and chronic WAD demonstrated significantly poorer cervical flexor endurance than normal controls.	Significant

(Stenneberg et al., 2022) Clinical characteristics differ between patients with non-traumatic neck pain, patients with whiplash-associated disorders, and pain-free individuals	To compare clinical characteristics between people with WAD, with NTNP, and pain-free individuals in primary care physiotherapy	168 people acute and chronic (73.8% female)	336 pain-free people (73.8% female) 336 people with non-traumatic neck pain (NTNP) (73.8% female)	Muscle Function Endurance clinical test	Both groups scored significantly worse than pain-free individuals on all characteristics. People with WAD had less muscle endurance (-5.5 seconds) than those with NTNP. Acute versus chronic Neck flexor muscle endurance, a statistically significant difference between the groups.	WAD is a more severe condition than NTNP and should be considered a separate subgroup. A different approach in clinical practice and research is required for WAD and NTNP.	Significant Muscle endurance WAD<C
(Baydal-Bertomeu et al., 2011) Neck motion patterns in whiplash-associated disorders: quantifying variability and spontaneity of movement	Quantify some of the features of neck motion patterns and analyse the differences between healthy and WAD neck motion patterns	30 participants with WAD - (50%female)	29 controls (52% female)	Muscle Function Endurance video-photogramm etry.	WAD group showed significant reductions in the range of motion and both the maximum angular velocity and acceleration compared to the control group (p<0.001).	Reduction in amplitude and speed of flexion-extension motion in WAD	Significant
(Pearson et al., 2009) Maximal voluntary isometric neck strength	To quantify maximal voluntary o isometric neck forces in healthy subjects and individuals	14 participants with WAD I-II. (42% female)	healthy group28 (43% female)	Muscle Function Maximal voluntary isometric force (MVIF)	Extension (P<.0001), retraction (P<.0001), and left lateral flexion (P = .03) forces were significantly lower for the WAD group compared to the	Cervical strength was lower in individuals with WAD. Particularly in extension, retraction and left lateral flexion.	Significant Strength WAD <C

deficits in adults with whiplash-associated disorders and association with pain and fear of movement	with whiplash-associated disorder (WAD)			Multi-Cervical Unit (MCU)	healthy group. Group differences for other directions were not statistically significant.	Strength deficits were not clearly linked to psychological factors.	
(Peolsson et al., 2014) Function in patients with cervical radiculopathy or chronic whiplash-associated disorders compared with healthy volunteers	To examine whether any differences in function and health exist between people with cervical radiculopathy (CR) due to disk disease scheduled for surgery and people with chronic whiplash-associated disorders (WADs) and to compare measures of persons' physical function with those obtained from healthy volunteers	215 people with chronic WAD (64% female)	101 healthy controls (50% female)	Muscle Function General performance Endurance test	Patient groups exhibited significantly lower performance than the healthy group in all physical measures (Sagittal and frontal AROM, Hand strength, neck muscle endurance flexion and extension, P <.0005). Exception for neck muscle endurance in flexion for women (P > .09).	Patients had worse values than healthy individuals in almost all physical measures. There was a trend toward worse results for people with CR than people with WAD.	Significant Muscle endurance WAD<C

EMG = Electromyography

A.1.5. Chronic physical musculoskeletal impairment evidence summary

Table 14: Summary of evidence for included studies in chronic physical musculoskeletal impairment

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Trigger points (Independent cohort n=1)	(Ettlin et al., 2008)	47 WAD; 21 fibromyalgi; 17 chronic cervical syndromes 15 endogenous depressions 24 controls	Prevalence of trigger points	Trigger point distribution differed significantly in QAD from other patient groups.	1 - Sig
Cervical Range of Motion (Independent cohorts n=6)	(Antonaci et al., 2002)	70 acute and chronic WAD Grade II-III 46 controls	Computerised ROM	Reduced ROM in acute and chronic WAD.	6 - Sig
	(Grip et al., 2003) (Ohberg et al., 2003)*	59 WAD 56 controls	3D -motion capture	Neck movement analysis was able to distinguish people with chronic WAD from controls.	
	(Armstrong et al., 2005)	23 WAD 23 controls	3-Space Fastrak	Reduced ROM in people with chronic WAD.	
	(Dall'Alba et al., 2001)	114 WAD 89 controls	Computerized electromagnetic, motion-tracking device	Reduced cervical ROM is a characteristic of chronic WAD.	
	(Kaale et al., 2007)	87 WAD II 29 controls	CROM goniometer	Differences in neck motion in all directions.	

	(Malik et al., 2017)	28 WAD and long-standing neck pain 27 WAD and no neck 24 no WAD and neck pain 85 controls	Goniometer	Mean ranges of movement reduced in WAD.	
Muscle performance /postural changes (Independent cohorts n=6)	(Descarreaux et al., 2007)	17 WAD I-II; 14 controls	EMG surface	A significant increase in peak force variability was observed in the WAD group.	5 - Sig 1 - NS
	(Helgadottir et al., 2010) (Helgadottir, Kristjansson, Einarsson, et al., 2011) (Helgadottir, Kristjansson, Mottram, et al., 2011)	27 WAD II 22 insidious onset neck pain; 20 controls	Kinematic EMG surface	Increased elevation of the clavicle reduced scapular tilt in WAD. Disturbance in the onset of muscle activation	
	(Voerman et al., 2007)	20 WAD 21 work-related musculoskeletal disorders 20 control	EMG surface Upper trapezius	No clear evidence for abnormal muscle activation patterns in WAD	
	(Nederhand et al., 2000)	18 chronic WAD 19 controls	EMG surface Upper trapezius	Decreased relaxation of trapezius muscles after exercise for chronic WAD	

	(Vikne et al., 2013)	15 chronic WAD 15 controls	EMG surface Sternocleidomastoid and splenius muscles	Chronic WAD move with less velocity and displacement compared with healthy controls	
	(Kristjansson & Jonsson, 2002)	41 chronic WAD 39 with chronic neck pain 39 symptomatic controls	Postural changes	Cervical lordosis may be greater in people with chronic WAD	
Muscle Function (Independent cohorts n=6)	(Woodhouse, Liljeback, et al., 2010)	56 WAD I-II 57 chronic nontraumatic neck pain. 57 asymptomatic subjects	Isometric neck flexion fatigue EMG surface	Reduced head steadiness during an isometric holding test was observed in a group of WAD.	6 - Sig
	(Kumbhare et al., 2005)	71 mixed WAD 160 controls	Cervical flexor endurance test	People with acute and chronic WAD demonstrated significantly poorer cervical flexor endurance than normal controls.	
	(Stenneberg et al., 2022)	124 mixed WAD; 336 controls	Endurance clinical test	People with WAD had less muscle endurance compared to people with NTNP.	
	(Baydal-Bertomeu et al., 2011)	30 WAD III; 29 controls	Endurance video-photogrammetry.	Reduction in amplitude and speed of flexion-extension motion in WAD	
	(Pearson et al., 2009)	14 WAD I-II 28 controls	Maximal voluntary isometric force Multi-Cervical Unit (MCU)	Cervical strength was lower WAD. Particularly in extension, retraction and left lateral flexion.	
	(Peolsson et al., 2014)	215 WAD 101 controls	Neck muscle endurance test	WAD group exhibited lower performance in neck muscle endurance for neck and extension test, expect in flexion for women	

Table 15: Evidence to decision framework (physical musculoskeletal impairment in acute WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○ Trivial ● Small ○ Moderate ○ Large ○ Varies ○ Don't know	Consistent findings across the included studies that suggest impairment in muscle function and performance. Although two studies showed significance when comparing WAD to control groups, there is only one study for each category and the findings are overall inconclusive.	The results are consistent with the previous guideline and literature.
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported.	Some people may have a temporary increase in symptoms when performing higher load tests.
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ● Varies ○ Don't know	Strong recommendation for measuring the factor: assessing ROM. Although there is no study in ROM for acute WAD, assessing ROM is a key component to determine the WAD grade. Does not favour either assessing or not assessing: muscle function and performance.	Reduction in ROM is an adverse prognostic indicator (see Prognostic Section in the Guideline) and hence should be assessed. It is also assessed as part of the Canadian C-spine rule. For the other measurements, they could be performed if clinically indicated. This is consistent with other guidelines and musculoskeletal conditions where muscle function and performance can be impaired following injury.
Resources required How large are the resource requirements (costs)?		

Judgement	Research evidence	Additional considerations
○ Large costs ○ Moderate costs ○ Negligible costs and savings ○ Moderate savings ○ Large savings ● Varies ○ Don't know	One study used the clinical fatigue test, which does not involve cost. Moderate cost associated with assessing neck muscle activation using EMG.	Overall, most of the factors can be assessed in clinical settings using lower cost equipment or clinical tests. ROM is commonly assessed in clinical practice using inclinometers, which are easily available. Muscle endurance can be assessed using a clinical test. Resources on how to perform these tests are in My Whiplash Navigator. https://mywhiplash.com.au/ Strength can be assessed using a hand-dynamometer and the cost will vary depending on the dynamometer. Muscle performance can be assessed using EMG which may have a moderate cost
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	No evidence.	HCP's can easily perform ROM and the clinical versions of muscle assessment tests (e.g., endurance) as part of routine consultation and with no additional costs.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Not reported.	After explaining how to perform the tests, most tests are acceptable to people with WAD. People expect physical assessments as part of routine consultation with HCPs.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations

○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Not reported.	Most of the test/assessment can be easily performed in the clinical setting using simple equipment. Allied health professionals are trained to perform most of the tests, while GP's may lack time to perform additional tests (other than ROM).

A.1.6. Conclusions (physical musculoskeletal impairment in acute WAD)

VOTE 1: Assessment of range of motion (ROM) in people with acute WAD

Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with acute WAD: Cervical ROM

Type of recommendation (cervical ROM in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	○	●

Recommendations
There was strong guideline panel consensus that healthcare professionals assess the following: range of motion in people with acute WAD. *(Panel vote summary: 12/12 100% strong for)* **Justification** *Evidence* • No evidence in assessment studies for ROM. *Consistency* • Strong evidence in prognostic studies that poor cervical ROM is associated with poor prognosis, hence assessment is recommended to determine prognosis.

- Cervical ROM assessment is also important to classify the Grade of WAD.

Subgroups considerations

n/a

Implementation considerations

Indications:

- Assessing Cervical ROM is required to determine WAD Grade and inform treatment direction.

How to assess:

- ROM can be measured in clinical settings using an inclinometer. Most reliable method is positioned in the midline of the forehead for lateral flexion or in the vortex of the head in the line with the nose for flexion and extension.
- Resources on how to perform CROM are freely available from Whiplash Navigator https://mywhiplash.com.au/
- Normative age-related values are found on MyWhiplashNavigator

  https://www.mywhiplash.com.au/node/160/#standard-assessment

VOTE 2: Assessment of muscle function and performance in people with acute WAD

Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with acute WAD: cervical muscle function and cervical muscle performance.

Type of recommendation (muscle function and performance in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	●	○	○

Recommendations
The guideline panel cannot reach consensus for or against assessing the following the following: cervical muscle function and performance in people with acute WAD.

(Panel vote summary: 10/11 (91%) neutral), 1/1 (9%) conditional for).

Justification

Evidence

There were two studies (hence inconclusive), however both found an impairment in people with WAD (in muscle performance and endurance respectively).

Acceptability and feasibility

Assessment of muscle function/performance is commonly performed by HCPs and is expected by people as part of routine consultation.

- People at low risk of poor recovery do not need to have a complicated assessment as they are expected to recover well.
- HCPs could consider assessing these factors in people at medium/ high risk of poor recovery if clinically indicated.
- HCPs could consider assessing these factors when clinically indicated (e.g., person reports difficulty performing functional tasks requiring neck endurance (lifting head off bed, holding head up).

Implementation considerations

Indications:

Do not assess these in people at low risk (of poor recovery) as they will recover well without these assessments. Consider assessing these factors in people at medium/ high risk of poor recovery if clinically indicated.

- Clinical indications for assessing cervical muscle function may include when the person reports difficulty performing functional tasks requiring neck endurance (lifting head off bed, holding head up). "*Head feels heavy" (consumer quote)*
- Clinical indications for assessing cervical (or axio-scapula) muscle performance may include when people report "muscle tightness or tension" in neck or axio-scapula muscles that require re-training. *"Tight feeling in muscle in front of neck" (consumer quote)*

How to assess:

- Healthcare professionals should explain the purpose of these assessments to the person.
- Consider muscle performance tests before function (lower load before endurance) as it could be provocative.
- Examples of how to assess muscle performance and muscle endurance are provided in (Whiplash Navigator https://mywhiplash.com.au/).

What to do:

• If assessed to be impaired, this may require rehabilitation (see neck-specific exercises in treatment recommendations).

Table 16: Evidence to decision framework (physical musculoskeletal impairment in chronic WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○ Trivial ○ Small ● Moderate ○ Large ○ Varies ○ Don't know	Moderate and consistent evidence for physical musculoskeletal impairments in people with chronic WAD compared with controls or other pain groups in the following: • Cervical range of motion (ROM): 6/6 studies found reduced ROM in people with chronic WAD. • Muscle function: 6/6 studies showed a reduction in muscle function. Measured as strength and endurance. • Muscle performance/postural changes: 5/6 studies showed impaired in chronic WAD were significant. The assessment methods varied among studies.	These findings are consistent with previous guidelines and literature. HCP's also need to consider that ROM and muscle function can vary depending on the person and their symptoms.
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported.	Some people may have a temporary increase in symptoms when performing higher load tests.
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations

○ Favours not assessing ○ Probably favours not assessing ● Does not favour either assessing or not assessing ● Probably favours assessing ● Favours assessing ○ Varies ○ Don't know	Favours assessing: Cervical ROM. Probably favours assessing: Muscle function Does not favour assessing or not-assessing (neutral): Muscle performance	Consistent with previous guideline and literature.
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ● Moderate costs ● Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	Studies used equipment such as goniometers, 3-D Motion Fastrack, EMG surface, kinematic analysis methods - video-photogrammetry, hand-dynamometer.	Overall, most of the factors can be assessed in clinical settings using lower cost equipment or clinical tests. ROM is commonly assessed in clinical practice using inclinometers, which are easily available. Muscle endurance can be assessed using a clinical muscle endurance test. Resources how to perform the test can be found here. https://mywhiplash.com.au/ Strength can be assessed using a hand-dynamometer. Cost will vary depending on the dynamometer. Muscle performance can be assessed using various methods including surface EMG, incurring moderate cost. https://mywhiplash.com.au/ Strength can be assessed using a hand-dynamometer and the cost will vary depending on the dynamometer. Muscle performance can be assessed using EMG which may have a moderate cost
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations

○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	No evidence.	HCP's can easily perform ROM as part of routine consultation and with no additional costs. Muscle function and performance testing may require additional training by HCPs to implement these tests and effectively interpret their results.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Not reported.	After explaining how to perform the test, most people with whiplash expect and accept these tests as part of routine consultation.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Not reported	Most of the assessments can be easily performed in the clinical setting using simple equipment. Allied health professionals are trained to perform most of the tests, while GP's might lack time to complete muscle tests, however, would routinely perform cervical ROM assessment.

A.1.7. Conclusions (physical musculoskeletal impairment in chronic WAD)

VOTE 1: Assessment of range of motion in people with chronic WAD

Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with chronic WAD: Cervical ROM?

Type of recommendation (cervical range of motion in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	○	●

Recommendations

There was strong guideline panel consensus that healthcare professionals assess the following: cervical range of motion in people with chronic WAD.

(Panel vote summary: 11/11 100% strong for)

Justification

- There is strong evidence that people with chronic WAD have poorer (significantly less) cervical ROM than controls or people with other neck pain conditions.
- Findings are consistent with previous guidelines.
- Assessing Cervical ROM is feasible to be performed by in a clinical setting by all primary HCP's.
- Cervical ROM assessment is also important to determine the grade of WAD and to evaluate treatment effectiveness.
- Trivial adverse effects with ROM assessment.

Subgroup considerations

n/a

Implementation considerations

Indications:

- Assessing CROM is required to determine WAD Grade and inform treatment direction.

How to assess:

- ROM can be measured in clinical settings using an inclinometer. Most reliable method is positioned in the midline of the forehead for lateral flexion or in the vertex of the head in the line with the nose for flexion and extension.

- Normative age-related values are found on MyWhiplashNavigator
- Resources on how to perform Cervical ROM are freely available from Whiplash Navigator

https://www.mywhiplash.com.au/node/160/#standard-assessment

VOTE 2: Assessment for muscle function in people with chronic WAD

Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with chronic WAD: cervical muscle function?

Type of recommendation (cervical muscle function in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	●	○

Recommendations

There was guideline panel consensus to suggest that healthcare professionals assess the following: cervical muscle function in people with chronic WAD.

(Panel vote summary: 12/12 100% conditional for)

Justification

- Moderate evidence for muscle function impairment in people with chronic WAD compared to the control groups.
- More common for muscle function to be impaired in the chronic phase of people with WAD.
- Assessment of muscle function can be used to evaluate the effectiveness of treatment.

Subgroups considerations

- HCPs could consider assessing these factors when clinically indicated (e.g., person reports difficulty performing functional tasks requiring neck endurance (lifting head off bed, holding head up).

Implementation considerations

Indications:

- HCPs indications for assessing cervical muscle function may include when the person reports difficulty performing functional tasks requiring neck endurance (lifting head off bed, holding head up).

How to assess:

- Examples of how to assess muscle performance and muscle endurance are provided.

https://www.mywhiplash.com.au/content/higher-risk-assessments#motor-assessment

What to do:

- If assessed to be impaired, this may require rehabilitation (see neck-specific exercises in treatment recommendations).

VOTE 3: Assessment for muscle performance in people with chronic WAD

Are you for or against healthcare professionals assessing the following physical musculoskeletal impairment factors in people with chronic WAD: Cervical muscle performance?

Type of recommendation (muscle performance in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	●	○	○

Recommendations
The guideline panel cannot reach consensus for or against assessing the following: cervical muscle performance in people with chronic WAD. *(Panel vote summary: 10/11 91% neutral; 1/11 9% conditional for)* **Justification** • The evidence for impairments in muscle performance is inconclusive. • There are different tests evaluated, hence heterogeneity in studies (e.g., scapular tilt, onset of muscle activation, abnormal trapezius activation pattern).

Subgroup considerations

n/a

Implementation considerations

Indications:

- People with chronic whiplash may require an assessment of muscle performance if clinically indicated. For example, report of “muscle tightness or tension” in neck or axio-scapula muscles that require re-training. Muscle performance may vary in people with chronic WAD.

How to assess:

- Examples of how to assess muscle performance (e.g., cranio-cervical flexion test) are provided in Whiplash Navigator

https://www.mywhiplash.com.au/content/higher-risk-assessments#motor-assessment

What to do:

- If assessed to be impaired, this may require rehabilitation (see neck-specific exercise in treatment recommendations).

A.2. Sensorimotor

What sensorimotor clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.2.1. Executive summary

What Sensorimotor test/function should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: 6 studies evaluated sensorimotor function in people with whiplash compared with controls or other pain conditions.
Five cross-sectional studies and one longitudinal study evaluated sensorimotor function in sub-groups of people with WAD. Summary of findings here:

- Cervical joint position error: 1/1 study found increased joint position error in people with acute WAD.
- Cervical movement sense: 1/1 study showed no differences in cervical movement sense in people with acute WAD.
- Oculomotor disturbance: 2/2 studies found oculomotor disturbance in people with acute WAD.
- Balance: 1/1 study found reduced balanced control in people with acute WAD

Chronic whiplash: 37 studies evaluated sensorimotor function in people with whiplash compared with controls or other pain conditions.
Thirty-seven cross-sectional studies evaluated sensorimotor function in sub-groups of people with WAD. Summary of findings here:

- Cervical joint position error: 6/8 studies found increased joint position error in people with chronic WAD.
- Cervical movement sense: 4/5 study suggests that cervical movement sense is affected in people with chronic WAD.
- Oculomotor disturbance: 8/9 studies found oculomotor disturbance in people with chronic WAD.
- Balance: 10/10 studies found reduced balanced control in people with chronic WAD.
- Coordination test (Bimanual coordination test) 2/2 studies found people with chronic WAD are more susceptible to sensory disturbances.
- Others – proprioception: 2/3 studies found proprioception is different in people with chronic WAD (e.g., shoulder proprioception)

A.2.2. Acute sensorimotor

Cervical joint position error

Category: Sensorimotor

Sub-category: Cervical joint position error - Acute and Subacute WAD (n= 1 study)

Table 17: Summary of included studies (acute cervical joint position error)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Sterling et al., 2004) Characterization of acute whiplash-associated disorders,	To characterize acute whiplash injury in terms of motor and sensory dysfunction and psychological distress and compare subjects with higher and lesser levels of pain and disability	80 acute (<1 month) WAD graded II -III (WAD grouped into mild, moderate or severe symptoms based on NDI scores)	20 healthy controls (WAD grouped into mild, moderate, or severe symptoms based on NDI scores)	Cervical joint position error	The groups with severe or moderate symptoms demonstrated JPEs right rotation (P <0.01). No difference between the mild and control groups. The group with severe symptoms also showed greater JPE in extension (P <0.01) than the other two WAD groups (moderate and mild) and the control group.	Increased joint position error in acute WAD subjects with moderate/severe symptoms	Significant JPE Severe WAD> mild, moderate and Control

Cervical movement sense

Category: Sensorimotor

Sub-category: Cervical movement sense - Acute and Subacute WAD (n=1 study)

Table 18: Summary of included studies (acute cervical movement sense)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Eklund et al., 2020) Jaw-neck motor function in the acute	To determine how jaw and head movement amplitudes and movement cycle times	23 people with acute WAD) (83% females)	27 healthy controls without neck trauma (56% female)	Cervical movement sense Jaw and head movements during jaw	Compared with controls, cases showed smaller jaw movement amplitudes (P = .006) but no difference in head movement	Suggest jaw-neck motor function may be affected in the acute stage after a whiplash trauma although the effects were minor.	NS

stage after whiplash trauma	correlate with jaw and neck pain and neck disability in the acute stage after whiplash trauma.			opening-closing were recorded with. an optoelectronic system.	amplitudes, head/jaw ratios or movement cycle times.		

Oculomotor disturbance

Category: Sensorimotor

Sub-category: Oculomotor disturbance - Acute and Subacute WAD (n=2 studies)

Table 19: Summary of included studies (acute oculomotor disturbance)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Solarino et al., 2009) Vestibular evoked myogenic potentials (VEMPs) in whiplash injury: a prospective study	To prospective study was to evaluate the changes in Vestibular-evoked myogenic potentials - mVEMPs in people affected by whiplash injury.	14 with WAD Acute (baseline)	15 healthy volunteers	Oculomotor disturbance Electromyographic activity VEMPs are biphasic myogenic potentials recorded on the tonically contracted sternocleidomastoid (SMS).	At time 0 (baseline) and at time 90 days, p1 latency was significantly higher in people with whiplash compared with healthy subjects on both sides (p <0.002). The amplitude of p1-n1 was significantly lower in people with whiplash at time 0 (p=0.003 on the right and p=0.018 on the left), but not at 90 days.	People with acute WAD may have alterations of vestibular evoked myogenic potentials.	Significant VEMPS Latency WAD >C

(Stiebel-Kalish et al., 2018) The Discrepancy between Subjective and Objective Measures of Convergence Insufficiency in Whiplash-Associated Disorder versus Control Participants	Examined the incidence of symptoms and findings consistent with CI in a cohort of people after MVA-related WAD compared with age-matched control participants.	57 people with acute WAD (56% female)	39 controls with no pre-existing lack of binocular vision or neurologic illness. (66% female)	Oculomotor disturbance Questionnaire, vision tests	The absolute CISS score was higher in the WAD group compared with the control group (15.310.0 vs. 7.77.7; P < 0.001). Findings consistent with Convergence insufficiency (CI) occurred in 7.0% of people with WAD and 7.7% of control participants (P = 0.90).	Visual symptoms suggestive of CI were reported more frequently among people with WAD than control.	Significant Visual symptoms WAD > C

Balance

Category: Sensorimotor

Sub-category: Balance - Acute and Subacute WAD (n=1 study)

Table 20: Summary of included studies (acute balance)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Dehner et al., 2008) Postural control deficit in acute QTF grade II whiplash injuries	To investigate balance control in people with acute WAD grade II.	40 people with acute WAD (35% female)	40 controls	Balance Posturography platform. 8 position tests were performed	People with acute whiplash injuries of the cervical spine achieved significantly poorer results for both ST(Sigma) and FA(Sigma) than the healthy controls(p<0.001)	People with acute WAD may have disturbed balance control	Significant Balance control WAD < C

Coordination test

Category: Sensorimotor

Sub-category: Coordination test- Acute and Subacute WAD (n=1 study)

Table 21: Summary of included studies (acute coordination test)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Daenen, Nijs, Roussel, Wouters, & Cras, 2012) Altered perception of distorted visual feedback occurs soon after whiplash injury: an experimental study of central nervous system processing	To investigate whether the pattern of sensations in response to sensorimotor incongruence differs between people suffering from acute and chronic WAD and healthy controls.	30 participants with acute WAD (47% female) 35 participants with chronic WAD (> 3 months) (74% female)	31 healthy controls (77% female)	Coordination Bimanual	Significantly more sensations were reported during the incongruent mirror stage compared to the incongruent control stage (P < .05). No significant difference was observed between the acute and chronic WAD groups (P > .05).	Altered perception of distorted visual feedback and suggest altered central sensorimotor nervous system. processing in people with acute WAD.	Significant Visual responses WAD > C

A.2.4. Acute sensorimotor evidence summary

Table 22: Summary of evidence for included studies in acute sensorimotor

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Cervical joint position error (Independent cohort n=1)	(Sterling et al., 2004)	80 acute WAD II-III 20 controls	Joint position error Fastrak system	Increased joint position error in acute WAD subjects with moderate/severe symptoms	1 – Sig
Cervical movement sense (Independent cohort n=1)	(Eklund et al., 2020)	23 acute WAD 27 controls	Jaw and head movements during jaw opening-closing - optoelectronic system	No significant differences in head movement amplitudes in WAD compared to control.	1 – NS
Oculomotor disturbance (Independent studies n=2)	(Solarino et al., 2009) (Stiebel-Kalish et al., 2018)	14 acute WAD 15 controls 57 acute WAD 39 controls	Electromyographic activity VEMPs Visual tests and questionnaire	WAD may have alterations of vestibular evoked myogenic potentials (VEMPs) Visual symptoms were reported more frequently among people with WAD than control.	2 – Sig
Balance (Independent cohort n=1)	(Dehner et al., 2008)	40 acute WAD 40 controls	Platform – 8 tasks	Acute WAD reduced balance control	1 – Sig
Coordination test (Independent cohort n=1)	(Daenen, Nijs, Roussel, Wouters, & Cras, 2012)	30 acute WAD 35 chronic WAD 31 controls	Bimanual Coordination Test	Indicate an altered perception of distorted visual feedback in WAD	1 – Sig

A.2.5. Chronic sensorimotor

Cervical joint position error

Category: Sensorimotor

Sub-category: Cervical joint position error - Chronic and mixed WAD studies (>3mon) (n=8 studies)

Table 23: Summary of included studies (chronic cervical joint position error)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(De Pauw et al., 2018) Motor impairment in patients with chronic neck pain: does the traumatic event play a significant role? A case-control study	To analyze differences in motor impairment between both groups, and assess the association with self-reported symptoms	35 people with chronic WAD (100% female)	38 people with chronic idiopathic neck pain. (100% female) 30 healthy controls (100% female)	Cervical joint position error A laser helmet. Rotations left/right, flexion/extension	Repositioning accuracy, measured via joint position. error, in WAD was significant. higher on the horizontal axis after performing flexion extensions compared with control.	WAD showing an increase error in the horizontal plane after extension and flexion	Significant JPE WAD >C
(Frydas et al., 2014) Discriminative validity of sensory evaluation in a whiplash-associated disorder II population	To determine whether differences in sensory evaluation occur post whiplash injury.	20 people with chronic WAD (65% female)	22 control participants with no history of whiplash/neck injury (41% female)	Cervical joint position error Helmet with mounted laser for CPE	Discrimination between groups was not identified using separate logistic regressions on vibration or cold pain thresholds (thenar eminence) or on global flexion/extension/right rotation. position errors (p>0.01).	Does not support the use. of vibration, CPT or JPE to distinguish individuals with CWADII with relatively mild levels of g self-report disability from control participants	NS discrimination between groups
(Grip et al., 2007) Variations in the axis of	To measure variations in the axis of motion (together with	22 subjects with WAD (> 3 months) (77%female)	21 with non-specific neck pain (< 3 months) (75% female)	Cervical joint position error Head relocation test	During flexion, the whiplash group had a larger constant repositioning error than the control	Measuring variation in the axis of motion together with target performance gives	Significant Flexion JPE WAD >C

motion during head repositioning --a comparison of subjects with whiplash-associated disorders or non-specific neck pain and healthy controls	target performance) as a new approach to estimate proprioceptive ability for two groups of people with neck pain and one group of controls.		24 control subjects (75% female)	Rotation, flexion, extension	group (-1.8(2.9) ° vs. 0.1(2.4) °, P = 0.04). During axial rotation to the left, there was more variation in axis direction for neck pain groups as compared with controls (4.0(1.7)° and3.7(2.4)° vs. 2.3(1.9)°, P = 0.01 and 0.05).	objective measures on proprioceptive. ability that are difficult to quantify by visual inspection. Repositioning errors were in general small, suggesting it is not sufficient as a single measurement variable in a clinical situation	
(Feipel et al., 2006) Head repositioning accuracy in patients with WAD	To compare head repositioning error (HRE) in people with WAD and healthy controls	29 people with acute and chronic WAD (Grade I-III (62% female)	26 healthy controls (54% female)	Cervical joint position error electro goniometric device using helmet Axial rotation; flexion-extension and lateral bending	Greater HRE in people with WAD in a variety of tasks (p=0.009) However, differences were small and of questionable clinical significance (e.g. neutral blindfolded repositioning task – difference between groups)	Greater HRE in people with WAD in a variety of tasks (p=0.009)	Significant HRE WAD>control
(Sjolander et al., 2008) Sensorimotor disturbances in chronic neck pain--range of motion, peak velocity, smoothness of movement,	To evaluate sensorimotor functions in people with chronic neck pain	7 participants with WAD II-III (71% female)	9 with insidious neck pain (10% female) 16 control subjects (81% female)	Cervical joint position error Rotation task measured with electromagnetic tracking system - repositioning acuity (VE) and bias (CE) and	WAD showed the poorest repositioning acuity and the largest ROM Variability	Concluded that jerky and irregular cervical movements and poor position sense acuity are characteristic sensorimotor symptoms in chronic neck pain	Significant variable error (VE). WAD>control

and repositioning acuity				the variability of ROM.			
(Treleaven et al., 2003) Dizziness and unsteadiness following whiplash injury: characteristic features and relationship with cervical joint position error	To compare dizziness and unsteadiness symptoms with cervical joint position error (JPE) in a group of people with chronic WAD and healthy controls.	102 people with chronic WAD (>3mo) (72% female)	44 healthy controls (66% female)	Cervical joint position error Fastrak electromagnetic device	WAD subjects had significantly greater JPE's than controls ($p<0.02$).	WAD subjects demonstrated significant JPE compared to normal controls.	Significant JPE WAD> C
(Woodhouse & Vasseljen, 2008) Altered motor control patterns in whiplash and chronic neck pain	Investigate motor control deficits in WAD compared to chronic non-traumatic neck pain and healthy controls in relation to the cervical range of motion (ROM), conjunct motion, joint position error and ROM-variability	56 participants with WAD I-II (>6 months). (60% female)	57 with chronic nontraumatic neck pain (>6 months) (68% female) 57 asymptomatic subjects (49% female)	Cervical joint position error Laser head and Fastrak sensor Cervical Rotation	There were no significant group differences in ROM-variability (SDmean) or JPE.	No group differences for JPE	NS
(Uremovic et al., 2007)	To examine the loss of proprioception	60 participants with WAD (50% female)	60 control subjects (50% female)	Cervical joint position error	People with neck injuries were not able to return the	Subjects with recent cervical spine injuries	Significant JPE

Impairment of proprioception after whiplash injury	in people who had a whiplash injury.			Cervical Measurement System (CMS) assessed after 3months	head to the neutral position of 0° after 30° rotation, unlike 93.3% of the control were able to do it. People with a cervical spine injury showed significant impairment of proprioception in comparison with healthy subjects (P<0.001)	incorrectly perceive their head position.	WAD> control

Cervical movement sense

Category: Sensorimotor

Sub-category: Cervical movement sense - Chronic and mixed WAD studies (>3mon) (n=6 studies)

Table 24: Summary of included studies (chronic cervical movement sense)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Astrup et al., 2021) Impaired neck motor control in chronic whiplash and tension-type headache	1) Present a new method based on head laser tracking designed to measure head or hand movements, and 2) further investigate if people suffering from	22 people with chronic (>12mo) WAD (18% female)	19 people with chronic tension-type headache 37 symptomatic controls (27% female)	Cervical movement sense Laser tracking device To track a reference point moving on the wall by a laser	In the different runs (circle, square, different speeds), the mean distances between the reference point and the laser tracking point were larger in both patients' groups compared to controls.	Motor control of head movements is impaired in both chronic whiplash and tension-type headache and in whiplash also of the hand.	Significant Movement sense WAD> Control

	chronic whiplash or tension-type headache have impaired motor control of neck muscles			fixed to the forehead or held in the hand. Tracked moves in runs of a circle or a square at three different speeds 10, 20, or 30 cm/s.			
(Ernst et al., 2019) Clinical assessment of cervical movement sense in those with neck pain compared to asymptomatic individuals	Examine differences in CMS between age- and gender-matched individuals with NP and asymptomatic controls to determine suitable cut-off measures for clinical interpretation. We also examined subgroup differences between people with idiopathic neck pain (INP) and WAD.	13 people with chronic WAD (>3mo) (54% female)	25 people with chronic idiopathic neck pain (56% female)	Cervical movement sense Clinical tests using head mounted laser device - F8 or ZZ pattern	WAD subjects performed the ZZ pattern significantly. faster, and generated on average 5.8 more errors than INP. subjects, a non-significant trend (p=0.11). and non-significant for F8 (p=0.02)	People with whiplash performed the ZZ task faster with similar errors to those with idiopathic neck pain, but not significant	NS F8 and ZZ WAD = Idiopathic neck pain

(Grip et al., 2008) Cervical helical axis characteristics and its center of rotation during active head and upper arm movements-comparisons of whiplash-associated disorders, non-specific neck pain and asymptomatic individuals (same cohort as above Grip 2007)	to investigate the helical axis and its centre of rotation in people with non-specific neck pain or pain due to whiplash injury as compared with matched controls.	22 subjects with WAD (>3months) (77% female)	21 with non-specific neck pain (<3months) (75% female) 24 control subjects (75% female)	Cervical movement sense Motion capture system Helical axis and its center of rotation during fast head movements (side rotation and flexion/extension) and ball catching	Upper body movements were more restricted in WAD and NP groups, even though the NP group showed the largest average head rotation. A small but significant anterior displacement of CR and a tendency to a downward displacement was observed in the WAD group	An increased number of irregularities in axis movement among people with neck pain implied disturbances in the sensorimotor control	Significant Movement sense WAD> Control
(Sandlund et al., 2008) Acuity of goal-directed arm movements to visible targets in chronic neck pain (same as Roijezon 2011)	To evaluate end-point acuity in goal-directed arm movements in subjects with chronic neck pain,	21 participants with WAD (>3 months) (52% female)	24 with non-specific neck pain (>3 months) (58% female) 22 pain-free subjects (59% female)	Cervical movement sense Test of end-point acuity in goal-directed pointing. Electromagnetic tracking system Fastrack	End-point acuity, controlled for peak velocity, was reduced for both neck-pain groups. Similar spatial error patterns across all groups indicated no direction-specific reduction.	Acuity of goal-directed arm movements can be reduced in chronic neck pain	Significant Movement sense WAD < C

(Vangronsveld et al., 2007) An experimental investigation on attentional interference by threatening fixations of the neck in patients with chronic whiplash syndrome	To investigated attentional disruption in people with chronic whiplash syndrome using the primary task paradigm.	40 with WAD (65% females)	40 healthy controls (65% females)	Cervical movement sense task performance (neck fixation)	Patients showed increased RTs during both threat conditions compared to the previous baseline condition, controls did not show this delay	The patients showed a more pronounced deterioration of performance compared to controls when the neck rotation and extension fixations were introduced. Within the groups, neither catastrophic thinking nor fear predicted the magnitude of the performance deterioration	Significant
(Woodhouse, Stavdahl, et al., 2010) Irregular head movement patterns in whiplash patients during a trajectory task (same cohort as Myran et al. 2008)	To investigate whether a trajectory head movement task can differ between people with WAD, people with chronic non-traumatic neck pain (CNP) and asymptomatic controls	35 participants with WAD I-II (>6 months). (66% female)	45 with chronic nontraumatic neck pain (>6 months) (71% female) 49 asymptomatic subjects (50% female)	Cervical movement sense Electromagnetic tracking system Fastrack Figure of eight	Significantly higher angular RMS velocity was found in the WAD group compared to the two other groups for the slow-paced test (3–4 and 4–5 Hz frequency bands) and the moderate paced test (3–4 Hz frequency band) indicating irregular and uncoordinated movements.	People with whiplash showed a consistent lack of movement smoothness when compared to people with CNP and asymptomatic controls.	Significant Angular Velocity WAD> C &CPN

(Vangronsveld et al., 2007) not added in the summary voting count.

Oculomotor disturbance

Category: Sensorimotor

Sub-category: Oculomotor disturbance- Chronic and mixed WAD studies (>3mon) (n=9 studies)

Table 25: Summary of included studies (chronic oculomotor disturbance)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Bexander & Hodges, 2012) Cervico-ocular coordination during neck rotation is distorted in people with whiplash-associated disorders	To investigate intricate coordination between eye and neck/movement and compare the relationship between eye position/movement and neck muscle activity with pain-free control	8 participants with WAD II (89% female)	11 pain-free control (63% female)	Oculomotor disturbance Electromyography Electro-oculography Cervical rotation was performed with five gaze conditions involving different gaze directions relative to cervical rotation	The superficial muscle splenius capitis (SC) was active in both directions of cervical rotation in contrast to activity only with right rotation in pain-free controls ($p < 0.001$). The activity of obliquus capitis inferior (O) and Multifidus (MF) varied between directions of cervical rotation, unlike the non-direction-specific activity in controls ($p < 0.01$). The effect of horizontal gaze direction on neck muscle EMG was augmented compared to controls	Redistribution of activity between neck muscles during cervical rotation and increased interaction between eye and neck muscle activity in people with WAD.	Significant Oculomotor Disturbance WAD>C
(Kelders et al., 2005) The cervico-ocular reflex is increased	To determine whether the cervico-ocular reflex may permit an objective	8 people with WAD (mixed duration) (75% female)	8 healthy controls (25% female)	Oculomotor disturbance Infrared eye-tracking device to	Significant difference in cervico-ocular reflex between people with WAD and controls ($p=0.037$).	Significant difference in cervico-ocular reflex between people with WAD and controls	Significant cervico-ocular reflex WAD> control

in whiplash injury patients	diagnosis of WAD			track both horizontal and vertical eye movements			
(Kongsted et al., 2007) Are smooth pursuit eye movements altered in chronic whiplash-associated disorders? A cross-sectional study	To evaluate whether smooth pursuit eye movements differed between people with long-lasting whiplash-associated disorders and controls	34 participants with WAD (82% female)	60 control participants (55% female)	Oculomotor disturbance smooth pursuit neck torsion (SPNT) electrooculography	Eye movements were no different in people with WAD than in our controls, regardless of neck position (P <0.06)	Disturbed smooth pursuit eye movements do not appear to be a distinct feature in people with chronic WAD	NS
(Janssen et al., 2015) Smooth Pursuit Eye Movement Deficits in Patients with Whiplash and Neck Pain are Modulated by Target Predictability	Investigating the effect of static neck torsion on smooth pursuit in response to both predictably and unpredictably moving targets using video-oculography	11 people with chronic WAD	20 healthy controls	Oculomotor disturbance Video-oculography 9 runs in which the chair was positioned in a specific rotation (e.g., 0°, 15° 30°, 45°)	WAD had reduced smooth pursuit gains and smooth pursuit gain decreased due to neck torsion P < 0.00. Healthy controls showed higher gains for predictably moving targets compared with unpredictably moving targets, whereas people with neck pain had similar gains in response to both types of target movements.	Smooth pursuit of WAD is affected.	Significant Smooth pursuit gains WAD<C

(Prushansky et al., 2004) Electro-oculographic (EOG) measures in patients with chronic whiplash and healthy subjects a comparative study	To examine the value of EOG measures in differentiating people with WAD from controls	26 people (with chronic WAD (>6mo) (62% female)	23 healthy controls (70% female)	Oculomotor disturbance Chart ENG for Windows Eye Movement Test System	Neck torsion did not influence eye movement performance of either the WAD or healthy groups. However, compared with the healthy group, people with WAD had significantly lower smooth pursuit velocity gain (SPVG) (p = 0.01) and prolonged saccadic latency(p = 0.001), irrespective of neck position	Despite scattered differences that reached significance, the electro-oculographic measures used in this study do not seem to offer a clinically relevant method for differentiating between people with WAD and normal subjects.	Significant smooth pursuit velocity gain WAD<C
(Tjell et al., 2002) Smooth pursuit neck torsion test (SPNT) – a specific test for WAD	To determine if the SPNT can differentiate between WAD and alternative diagnoses (non-traumatic neck pain)	75 people with chronic WAD (>6mo); 50 with dizziness (62% female) and 25 without dizziness (68% female)	30 healthy controls (50% female) 20 controls with vertigo (55% female) 20 controls with meniere (60% female)	Oculomotor disturbance Corneoretinal potential recorded binocularly by surface Ag/AgCl electrodes during a smooth pursuit neck torsion (SPNT) test	The validity of the SPNT test for diagnosing WAD was Sensitivity 72% and specificity 92%. Healthy volunteers used to determine normal values.	SPNT was useful in differentiating people with WAD from controls.	Significant
(Treleaven et al., 2008) Comparison of sensorimotor	To determine if differences exist in reported symptoms and in outcomes of	20 participants with WAD (>3 months) (75% female)	20 (female) vestibular subjects (45% female	Oculomotor disturbance Smooth pursuit neck	Subjects with whiplash had significantly higher SPNT test scores than both control and subjects with	Differences in sensorimotor disturbances between subjects with discreet whiplash and those	Significant SPTN score WAD>C

disturbance between subjects with persistent whiplash-associated disorder and subjects with vestibular pathology associated with acoustic neuroma	sensorimotor tests (cervical joint position error [JPE], neck-influenced eye movement control, postural stability) between subjects with persistent whiplash and subjects with unilateral vestibular pathology associated with acoustic neuroma.		20 control subjects (70% female)	torsion (SPNT) test	acoustic neuroma (P<.01)	with vestibular pathology associated with acoustic neuroma. The results support the SPNT test as a test of cervical afferent dysfunction.	
(Treleaven et al., 2005a) Smooth pursuit neck torsion test in WAD: relationship to self-reports of neck pain and disability, dizziness and anxiety	To determine if the SPNT can differentiate between people with WAD and healthy controls and examine the relationship between SPNT values pain, dizziness and anxiety in people with WAD	100 chronic WAD (50 with dizziness, 50 without) and 50 healthy controls (76% female)	50 healthy controls (60% women)	Oculomotor disturbance Electro-oculography (EOG) used to measure and record eye movement during the smooth pursuit neck torsion test	Significant differences in SPNT between dizzy and non-dizzy WAD groups and between both those groups and healthy controls (p<0.01).	The SPNT test was useful in differentiating people with chronic WAD from controls.	Significant
(Treleaven et al., 2011)	Investigated eye, head co-	20 participants with WAD	20 control subjects	Oculomotor disturbance	WAD had significantly less	Deficits in gaze stability and head	Significant

Head eye co-ordination and gaze stability in subjects with persistent whiplash associated disorders	ordination and gaze stability in subjects with persistent whiplash and asymptomatic controls	(75% female)	(65% female)	Gaze stability task, Sequential head eye movement task	maximal eye angle to the left, range of head movement during the gaze stability task and decreased velocity of head movement in head eye co-ordination and gaze stability tasks compared to the control group ($p < 0.01$).	eye co-ordination may be related to disturbed reflex activity associated with decreased head range of motion and/or neck pain	gaze stability tasks WAD < C

Balance

Category: Sensorimotor

Sub-category: Balance- Chronic and mixed WAD studies (>3mon) (10 studies)

Table 26: Summary of included studies (chronic balance)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Cote et al., 2009) Whiplash-associated disorders affect postural reactions to antero-posterior support surface	Quantify the biomechanical characteristics of the postural response during sitting to sudden support surface translations in a WAD group, and to compare these	10 participants with chronic grade II WAD (50% female)	10 age-and-gender matched healthy group. (50% female)	Balance Kinematic and EMG postural stabilization Postural reactions to anteroposterior support surface	The displacement onset of the combined head, arms and trunk centres of mass was significantly delayed in persons with WAD. In the WAD group, the activation onset of the lumbar erector spinae were less affected by	Suggest that individuals with WAD may alter stretch reflex threshold and/or elicit a learned response for pain avoidance that may be direction specific.	Significant

translations during sitting	patterns with those of healthy individuals control group			translations during sitting.	perturbation direction and the sternocleidomastoid muscle, a neck flexor, showed a trend towards being activated later, compared to the healthy group.		
(Field et al., 2008) Standing balance: A comparison between idiopathic and whiplash-induced neck pain	directly compared balance between these groups to determine if neck pain precipitated by trauma resulted in greater or different balance impairments	30 WAD II (77% female)	30 with idiopathic neck pain and (>3 months) (77% female) 30 healthy controls (80% female)	Balance Clinical Test of Sensory Integration and Balance (CTSIB) during comfortable stance — standing on a firm surface and on a soft surface	WAD had significantly greater sway energy and RMS amplitude than the idiopathic group in comfortable stance tests on a soft surface ($F>4.4$, $p<0.04$). WAD had greater RMS, but significantly less sway energy than the idiopathic group in most narrow stance tests in the anterior posterior direction $F>5.8$, $p<0.02$).	Balance deficits exist in both subjects with WAD and idiopathic neck pain compared to controls; however, differences in balance strategies may exist between the neck pain groups	Significant Balance deficits WAD>C
(Findling et al., 2011) Trunk sway in patients with and without, mild traumatic brain injury after whiplash injury	Assessed the addition effect of mild traumatic brain injury (MTBI) on the balance control of people who simultaneously suffered a whiplash	44 people with WAD and MTBI 36 people with WAD without MTB	7 healthy controls	Balance Trunk sway for a battery of stance and gait tests	Sway measures for standing in one leg and two-legged stance tasks were not significant between WAD groups, but were increased in both groups compared to control ($P>0.05$)	A similar pattern of balance impairment was present in people with whiplash injury with and without MTBI. However, the impairment was greater for stance and complex gait tasks in people with WAD with MTBI.	Significant Postural Sway WAD>C

	associated disorder (WAD).				Greater trunk sway than people with WAD without MTBI for stance tasks and complex gait tasks		
(Juul-Kristensen et al., 2013) Increased neck muscle activity and impaired balance among females with whiplash-related chronic neck pain: a cross s-sectional study	To investigate neck muscle activity and postural control in people with whiplash-associated disorder compared with healthy controls.	10 people with chronic WAD (100% female)	10 healthy controls (100% female)	Balance Three balance tasks (Romberg stance with open and closed eyes, and a one-legged stance) and an arm perturbation task EMG activity of the anterior scalene, sternocleidomastoid, neck extensors and upper trapezius muscles	During balance tasks with closed eyes and one-legged stance, the relative mean activity of all 4 muscles was significantly increased in WAD compared with healthy controls. Postural sway was also significantly increased (P <0.001)	WAD had higher relative neck muscle activity and larger postural sway during normal balance tasks compared with control subjects.	Significant Postural Sway WAD> Control
(Madeleine et al., 2011) Characterization of postural control deficit	To characterize the variability of postural control in people with	11 participants with WAD I-II (>6 months). (46% female)	11 asymptomatic healthy subjects (46% female)	Balance Force Platform	The amplitude of variability of the centre of pressure was larger among people with whiplash compared with	The analysis of postural control dynamics revealed increased amplitude of postural variability.	Significant Postural instability WAD> C

in whiplash patients by means of linear and nonlinear analyses - A pilot study	chronic whiplash injury			Static postural tasks with eyes open, eyes closed and eyes open and speaking.	controls (P < 0.001) while fractal dimension was lower (P < 0.001). The sample entropy increased during both eyes closed and a simple dual task compared with eyes open (P < 0.05).	and decreased signal dimensionality related to the deficit in postural stability found in WAD	
(Roijezon et al., 2011) The slow and fast components of postural sway in chronic neck pain	To understand of the nature of altered postural control in neck pain by studying the slow and fast components of body sway.	21 participants with WAD (>3 months) (52% female)	24 with non-specific neck pain (>3 months) (58% female) 21 pain-free subjects (61% female)	Balance Force plate Barefooted in the Romberg position; with feet together, heel-to-heel and toe-to-toe, with closed eyes and arms crossed over the chest.	Increased magnitude of the slow sway component was found in WAD, but not in NS.	Increased magnitude of the slow sway component implies an aberration in sensory feedback or processing of sensory information in WAD.	Significant slow sway WAD> C & NS
(Stokell et al., 2011) Dynamic and functional balance tasks in subjects with persistent whiplash: A pilot trial	To determine whether subjects with whiplash had deficits in dynamic and functional balance tasks when compared to a healthy control group	20 participants with WAD (>3 months) (70 %female)	20 healthy participants (85% female)	Balance Clinical tests of balance (Single leg stance, Step test, Fukuda stepping test, Tandem walk test, Singleton test, Stair	Subjects with whiplash demonstrated significant deficits (p < 0.01) in single leg stance with eyes closed, the step test, tandem walk on a firm and soft surface, stair walking, and the timed 10 m walk with	The whiplash subjects demonstrated significant impairment in selected clinical measures in comparison with healthy control subjects.	Significant Deficits WAD>C

				walking test, Timed 10 m walk)	and without head movement when compared to the control subjects		
(Gandelman-Marton et al., 2016) Postural stability in patients with different types of head and neck trauma in comparison to healthy subjects	Compare postural control in people with different types of head and neck trauma to healthy subjects.	11 people with WAD 12 WAD mild head trauma without loss of consciousness (WHTNLC)	14 healthy controls	Balance 5 tests using eyes open and closed with stable and moving platform	Compared to healthy subject's sway index (SI) was significantly higher in people with WHTNLC in three of the tests. There were no significant differences within the patient group according to type of injury. When time following the injury was considered, the SI was non-significantly higher within the first week after trauma compared to other time intervals.	The severity of the postural abnormality in people with head and/or neck trauma is not uniform and is influenced by the type of trauma.	Significant Sway index WHTNLC> C
(Treleaven et al., 2005b) Standing balance in persistent whiplash: a comparison between subjects with and without dizziness	To assess balance responses in subjects with chronic WAD with and without dizziness versus healthy controls	101 people with chronic WAD (>3mo)(50 with dizziness (76% women), 50 without (76% women)	51 healthy controls (60% women)	Balance Clinical Test for Sensory Interaction in Balance over the 6 conditions was performed in comfortable stance	Significant difference in balance in chronic WAD subjects with and without dizziness versus controls ($p<0.05$). Greater balance deficits noted in people with WAD with dizziness.	People with chronic WAD with dizziness demonstrated poorer balance than those without dizziness and healthy controls.	Significant Poor balance WAD > C
(Yu et al., 2011) The effect of	To determine whether the neck torsion positions	20 participants with WAD II (>3 months) with a score of at least	20 control subjects	Balance Computerise d force plate	The whiplash group had significantly greater rms amplitude in the AP	Neck torsion manoeuvre may lead to greater postural deficits in individuals	Significant Postural deficits

neck torsion on postural stability in subjects with persistent whiplash	change balance responses in the WAD population when compared to asymptomatic individuals	10 out of 100 on the Neck Disability Index (NDI)		With eyes closed in comfortable stance under 5 conditions: neutral head, head turned to left and right and neck torsion to left and right	direction following neck torsion compared to the control group (p < 0.03)	with persistent WAD and provides further. evidence of neck torsion to identify abnormal cervical afferent input, as an underlying cause of balance disturbances in WAD.	WAD>C

Coordination test

Category: Sensorimotor

Sub-category: Coordination test - Chronic and mixed WAD studies (>3mon) (n=2)

Table 27: Summary of included studies (chronic coordination test)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Daenen, Nijs, Roussel, Wouters, Van, et al., 2012) Sensorimotor incongruence exacerbates symptoms in patients with chronic whiplash	To evaluate whether a visually mediated incongruence between motor output and sensory input aggravates symptoms and triggers additional sensations in	35 people with chronic WAD (74% female)	31 healthy controls (77% female)	Bimanual coordination test	The pattern of reported sensory changes during the congruent and incongruent stages significantly differed between both groups (P < 0.05).	Exacerbation of symptoms and/or additional sensations due to reducing/disturbing the visual input during action in people with chronic WAD.	Significant Altered perception WAD>C

associated disorders: An experimental study	people with chronic WAD.						
(Don et al., 2017) The effect of visual feedback of the neck during movement in people with, chronic whiplash-associated disorders: An experimental study	To determine whether SMI causes sensory disturbances or pain in people with chronic WAD and healthy controls.	30 people with chronic WAD (67% female)	34 healthy controls (68% female)	Bimanual Coordination Test	A statistically significant difference in a perceived sensory disturbance between conditions was found in the WAD group (P<.001).	Chronic WAD are more susceptible to sensory disturbances owing to Sensorimotor incongruence (SMI)	Altered perception WAD>C

Other proprioception

Category Sensorimotor

Sub-category: Others Proprioception - Chronic and mixed WAD studies (>3mon) (n=3)

Table 28: Summary of included studies (chronic others proprioception)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Sandlund et al., 2006) Predictive and discriminative value of	To determine the predictive and discriminative value of shoulder	37 people with chronic WAD II and III (>6mo) (54% female)	41 healthy controls (63% female)	Proprioception shoulder proprioception test involving active	Subjects with WAD demonstrated reduced shoulder position sense when compared to controls (p=0.003)	Shoulder proprioception test able to differentiate chronic WAD group from healthy controls.	Significant WAD> C

shoulder proprioception tests for patients with WAD	proprioception tests for people with WAD			ipsilateral arm position-matching			
(Treleaven & Takasaki, 2015) High variability of the subjective visual vertical test of vertical perception, in some people with neck pain - Should this be a standard measure of cervical proprioception?	To investigate the most sensitive SVV error measurement to detect group differences between no neck pain control, idiopathic neck pain (INP) and WAD subjects.	42 people with chronic WAD (>3mo) (64% female)	48 healthy controls (72% female) 36 people with chronic idiopathic neck pain (>3mo) (55% female)	Proprioception Vertical perception testing	The INP group had significantly ($p < 0.03$) greater VE and RMSE when compared to both the control and WAD groups. There were no differences seen between the WAD and controls.	People with INP (not WAD), had an altered strategy for maintaining the perception of vertical by increasing variability of performance.	NS
(Richter et al., 2010) Long-term adaptation to neck/shoulder pain and perceptual performance in a hand laterality motor imagery test	The effect of neck/shoulder pain on the performance in a hand laterality motor imagery	21 participants with WAD (52% female)	24 (58% female) with non-specific neck pain (58% female) 22 pain-free subjects (58% female)	Laterality Hand laterality test task with digitised right- or left-hand stimuli presented at five different stimulus angles	Main results revealed that the subjects afflicted with whiplash injury on the average exhibited a faster response pattern than symptom-free healthy controls.	Perceptual learning and may reflect different stages of adaptation to neck pain.	Significant

A.2.6. Chronic sensorimotor evidence summary

Table 29: Summary of evidence for included studies in chronic sensorimotor

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Cervical joint position error (Independent cohorts n=8)	(De Pauw et al., 2018)	35 WAD 38 chronic idiopathic 30 controls	Laser helmet Rotations, flexion, and extension	Increased joint position error in flexion and extension in WAD.	6 – Sig 2 – NS
	(Frydas et al., 2014)*	20 WAD 22 controls	Laser Helmet Rotations, flexion, and extension	Does not distinguish individuals with CWADII with relatively mild levels of self-report disability from control	
	(Grip et al., 2007)	22 WAD 21 non-specific neck pain 30 controls	Electric torch in a Helmet Head relocation test	Great JPE in WAD group than control group	
	(Feipel et al., 2006)	29 WAD 26 controls	Electro goniometer Rotation; flexion-extension and lateral bending	Greater HRE in people with WAD in a variety of tasks	
	(Sjolander et al., 2008)	7 WAD 9 insidious neck pain 16 controls	Electromagnetic tracking system Repositioning acuity (VE) and bias (CE) and the variability of ROM	WAD showed the poorest repositioning acuity and the largest ROM Variability	
	(Treleaven et al., 2003)	102 WAD 44 controls	Electromagnetic tracking system	WAD subjects demonstrated significant JPE compared to normal controls.	
	(Woodhouse & Vasseljen, 2008)	56 WAD 57 non-chronic traumatic neck pain 57 controls	Laser head and Fastrak sensor Cervical Rotation	No group differences in ROM-variability (SDmean) or JPE	
	(Uremovic et al., 2007)	60 WAD 60 controls	Cervical Measurement System	Subjects with recent cervical spine injuries incorrectly perceive their head position.	

Cervical movement sense (Independent cohorts n=5)	(Astrup et al., 2021)	22 WAD 19 chronic headaches 37 controls	Laser tracking device Movements of a circle or a square 10, 20, or 30 cm/s.	A small but highly significant dyscoordination of head movements and hand in WAD than control	4 – Sig 1 – NS
	(Ernst et al., 2019)	13 WAD 25 chronic idiopathic neck pain	Head-mounted laser device Figure of 8 (F8) and ZZ pattern.	No significant difference in the clinical test between WAD and idiopathic neck pain	
	(Grip et al., 2008)	22 WAD 21 non-specific neck pain 24 controls	Motion capture system during fast head movement	An increased number of irregularities in axis movement in neck pain	
	(Sandlund et al., 2008)	24 WAD 24 non-specific neck pain 22 controls	Test of end-point acuity in goal-directed pointing	Acuity of goal-directed arm movements can be reduced in chronic neck pain.	
	(Woodhouse, Stavdahl, et al., 2010)	35 WAD 45 non-chronic traumatic neck pain 49 controls	Electromagnetic tracking system Fastrack Figure of 8	People with whiplash showed a consistent lack of movement smoothness when compared to people with CNP and asymptomatic controls.	
Oculomotor disturbance (Independent cohorts n=9)	(Bexander & Hodges, 2012)	8 WAD 11 controls	Electromyography (SC, O and MF) Cervical rotation was performed with five gaze conditions.	Evidence of redistribution of activity between neck muscles during cervical rotation and increased interaction between eye and neck muscle activity in people with WAD.	8 – Sig 1 – NS
	(Kelders et al., 2005)	8 WAD 8 controls	Eye-tracking device to track both horizontal and vertical eye movements.	Altered cervico-ocular reflex in people with WAD.	
	(Kongsted et al., 2007)	34 WAD 60 controls	Smooth pursuit neck torsion (SPNT)	Eye movements were no different in people with WAD.	

			- electrooculography		
	(Janssen et al., 2015)	11 WAD 20 controls	Video-oculography – different rotation chair position	WAD had reduced smooth pursuit gains and smooth. pursuit gain decreased due to neck torsion.	
	(Prushansky et al., 2004)	26 WAD 23 controls	SPNT test	WAD had significantly lower smooth pursuit velocity gain However, electro-oculographic do not seem to offer a clinically relevant method.	
	(Tjell et al., 2002)	100 WAD 73 controls	SPNT test -Electro-oculography	SPNT was useful in differentiating people with WAD from controls.	
	(Treleaven et al., 2008)	20 WAD 20 Vestibular 20 controls	SPNT test	Subjects with whiplash had significantly higher SPNT test scores	
	(Treleaven et al., 2005a)	100 WAD 50 controls	SPNT test Electro-oculography	The SPNT test was useful in differentiating people with chronic WAD from controls.	
	(Treleaven et al., 2011)	20 WAD 20 controls	Gaze stability task	Deficits in gaze stability and head eye coordination	
Balance (Independent cohorts n=10)	(Cote et al., 2009)	10 WAD 10 controls	Postural stability during sitting	Individuals with WAD may alter their stretch reflex threshold.	10 – Sig
	(Field et al., 2008)	30 WAD 20 idiopathic neck pain 30 controls	Clinical Test of Sensory Integration and Balance	Compared to controls, balance disturbance in subjects with WAD and idiopathic neck pain.	
	(Findling et al., 2011)	44 people with WAD and mild traumatic brain injury (MTBI); 36 people with WAD without MTBI	Trunk sway for a battery of stance and gait tests	Balance deficit in WAD compared to control and for complex task higher deficit in WAD with MTBI	
	(Juul-Kristensen et al., 2013)	10 WAD 10 controls	Clinical balance tasks	Postural sway and neck muscle activity increased during balance tasks compared to control.	

	(Madeleine et al., 2011)	11 WAD; 11controls	Static postural with eyes closed and open and speaking	Postural instability found in WAD	
	(Roijezon et al., 2011)	21 WAD 24 non-specific neck pain; 21control	Barefooted in the Romberg position	Increased magnitude of the slow sway component in WAD compared to control group.	
	(Stokell et al., 2011)	20 WAD 20 controls	Several Clinical tests of balance	WAD demonstrated significant impairment in postural stability in comparison to control group.	
	(Gandelman-Marton et al., 2016)	11 WAD 14 controls	Balance states with eyes open and closed and stable and unstable platform	Sway index (SI) was significantly higher in people with WHTNLC in three of the tests.	
	(Treleaven et al., 2005b)	101 WAD 51 controls	Clinical Test for Sensory Interaction in Balance	Greater balance deficits noted in people with WAD with dizziness.	
	(Yu et al., 2011)	20 WAD 20 controls	Balance under 5 different conditions	Neck torsion manoeuvre may lead to greater postural deficits in individuals with persistent WAD.	
Coordination Test (Independent cohorts n=2)	(Daenen, Nijs, Roussel, Wouters, Van, et al., 2012)	35 WAD 31 controls	Bimanual coordination test	WAD present an exacerbation of symptoms and additional sensations in response to visually mediated changes during action.	2 – Sig
	(Don et al., 2017)	30 WAD 34 controls	Bimanual coordination test	Chronic WAD are more susceptible to sensory disturbances owing to sensorimotor incongruence (SMI).	
Others – Proprioception (Independent cohorts n=3)	(Sandlund et al., 2006)	37 WAD 34 controls	Shoulder proprioception	Shoulder proprioception test able to differentiate chronic WAD group from healthy controls.	2 – Sig 1–NS
	(Treleaven & Takasaki, 2015)	42 WAD 36 idiopathic neck pain	Vertical perception testing	People with INP (not WAD), had an altered strategy for maintaining the perception of vertical.	
	(Richter et al., 2010)	21 WAD 24 non-specific neck pain	Hand laterality test	Perceptual learning and may reflect different stages of adaptation to neck pain.	

		22 controls			

***** Discrimination between groups

Table 30: Evidence to decision framework (sensorimotor in acute WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○ Trivial ● Small ○ Moderate ○ Large ○ Varies ○ Don't know	These findings were consistent across all studies. However, only few studies evaluated sensorimotor function in people with acute WAD. Evidence was small for the following sensorimotor test/function assessments in acute WAD: • Cervical joint position error: small association 1/1 study found an increased joint position error in acute WAD subjects with moderate/severe symptoms. • Cervical movement sense: one study found no significant differences in head movement amplitudes in WAD compared to control. • Oculomotor disturbance: small association with 2/2 studies showing ocular disturbance in WAD than control. • Balance: small association with 1/1 study showing reduced balance control in WAD. • Coordination test: 1/1 study indicating an altered perception of distorted visual feedback in WAD.	Consistent with previous guideline and literature with the subgroup consideration (medium/high risk).
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	No evidence of adverse effects reported.	Some tests can provoke some symptoms (e.g., dizziness), and it is important to inform the person that it might occur. Healthcare professionals may select only one or two tests to assess these impairments instead of performing multiple tests on the same day, as adverse effects can be accumulative.

Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ● Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Does not favour either assessing or not assessing: Cervical joint position error, Cervical movement sense, Oculomotor disturbance, Balance, and Coordination tests in acute WAD.	HCP's might assess some factors depending on the person's presentation. More likely to be applicable to medium-high risk subgroups.
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ● Moderate costs ● Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	A few studies used laboratory equipment that is not feasible for healthcare professionals (e.g., kinematic analyses). However, most studies reported clinical equivalent tests that healthcare professionals could use at negligible cost. E.g., smooth pursuit neck torsion test (SPNT); Tandem walk test)	Most factors can be assessed in clinical settings using lower-cost equipment or clinical tests. Cervical joint position error is commonly assessed in clinical practice as a mount, a laser pointer, and a target. Cervical movement sense is commonly assessed in clinical practice using a laser pointer following a pattern, fixed with a light headband. The oculomotor disturbance is clinically assessed (i.e., smooth pursuit neck torsion test) using an object that people must follow with their eyes. The test can assist in differentiate dizziness due to WAD from vestibular symptoms. Balance can be performed using in a clinical setting using example, tandem stance. Available from Whiplash Navigator https://mywhiplash.com.au/
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations

○ Reduced ● Probably reduced ○ Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	Not reported.	All tests can be performed using the clinical equivalent at low cost. However, HCP's will require some training and expertise in performing and interpreting tests as some results/symptoms are not frequently seen in all people (e.g., oculomotor impairment).
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ●Yes ○ Varies ○ Don't know	Not reported.	Clinical versions of tests are considered acceptable.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ● Probably yes ○ Yes ○ Varies ○ Don't know	Not reported	The tests are minimally invasive and do not require specialised equipment. Allied HCPs are more likely to perform the tests. They will require training (not routinely taught in undergraduate programs) and require some expertise to interpret as some results/symptoms are not frequently seen in all people (e.g., oculomotor – impairment). Performing those tests may not be feasible for GP's due to time limitations.

A.2.7. Conclusions (sensorimotor in acute WAD)

VOTE 1: Assessment of cervical joint position error, cervical movement sense, oculomotor disturbance, balance, and coordination test in people with acute WAD

Are you for or against healthcare professionals assessing the following sensorimotor factors in people with acute WAD: cervical joint position error, cervical movement sense, oculomotor disturbance, balance, and coordination test?

Type of recommendation (cervical joint position error, cervical movement sense, oculomotor disturbance, balance, and coordination test in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong recommendation consensus for measuring the factor(s)
○	○	●	○	○

Recommendations
The guideline panel cannot reach consensus for or against assessing the following sensorimotor tests: Cervical joint position error, cervical movement sense, oculomotor disturbance, balance, and coordination test in people with acute WAD. *(Panel vote summary: 11/12 (92%) neutral, 1/12 (8%) conditional for).* **Justification** • Evidence is small with only a few studies for those factors in people with acute WAD. • However, most studies demonstrate a greater impairment for people with acute WAD compared with controls or other pain conditions. **Subgroup considerations** • Do not assess these factors in people who are low risk (of poor outcome) as they will recover well without requiring more complicated assessments. • People at medium/high risk of poor outcome and/or those with dizziness are more likely to present with sensorimotor impairment. **Implementation considerations** *Indications:* • Do not assess these in people at low risk (of poor recovery) as they will recover well without these assessments. • Consider assessing these factors in people at medium/ high risk of poor recovery if clinically indicated, such as when people report dizziness or impairment in balance. *Considerations:*

- Some of the tests can provoke or increase symptoms. Avoid performing multiple tests on the same day to avoid symptom accumulation. HCPs are advised to prioritise the required tests based on clinical presentation.
- Consider differential diagnosis of dizziness when interpreting tests (e.g., concussion, vestibular)
- Training may be required to performing and interpreting tests. It is important to understand normative values and values that indicate impairment (e.g., error of > 4.5 degrees indicates impairment for cervical joint position error test)

How to assess:

- Resources on how to perform, normative values and threshold for cervical joint position error, cervical movement sense (CMS), smooth pursuit neck torsion test (SPNT), Balance – e.g., tandem step test) assessments are freely available from Whiplash Navigator: https://www.mywhiplash.com.au/content/higher-risk-assessments#sensorimotor-assessment

What to do:

- If the persons are impaired – HCPs are recommended to rehabilitate the impairment and may be directed to recommended treatments (e.g., dizziness specific exercise – see guideline treatment section). Note that dizziness specific interventions included balance components.
- Exercise needs to be safely performed (supervised) if at risk of falls (reduced balance).
- Referral to whiplash specialist.

Table 31: Evidence to decision framework (sensorimotor in chronic WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○ Trivial ● Small ● Moderate ○ Large ○ Varies ○ Don't know	Moderate evidence was found between the following sensorimotor assessments in people with chronic WAD. • Cervical joint position error: 6/8 studies found an increased joint position error compared with control group. • Cervical movement sense: 4/5 studies found altered cervical movement sense.	Consistent with previous guidelines and literature.

	• Oculomotor disturbance: 8/9 studies found increased ocular disturbance. • Balance: 10/10 studies reported a reduced/altered balance control Small evidence was found between the following sensorimotor assessments in people with chronic WAD. • Coordination: 2/2 studies found people with chronic WAD are more susceptible to sensory disturbances, evaluated using bimanual coordination test Other proprioception (i.e., shoulder, laterality): 2/3 studies demonstrated differences in people with chronic WAD	
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	No evidence of adverse effects was reported.	Some tests can provoke some symptoms (e.g., dizziness), and it is important to inform the person that it might occur. HCP's may select only one or two tests to assess impairment instead of performing multiple tests on the same day, as adverse effects can be accumulative.
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ● Does not favour either assessing or not assessing ● Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Probably favour assessing: Cervical joint position error, cervical movement sense, oculomotor disturbances and balance. Does not favour either assessing or not assessing: Coordination test and others proprioceptive tests	The adverse effect can be accumulated as the number of tests assessed increases.

Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ● Moderate costs ● Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	A few studies used laboratory equipment that is not feasible for healthcare professionals (e.g., kinematic analyses). However, most studies reported clinical validate tests that healthcare professionals could use at a negligible cost. (i.e., Smooth disturbance neck torsion test; Tandem walk test)	Most factors can be assessed in clinical settings using lower-cost equipment or clinical test. Cervical joint position error is commonly assessed in clinical practice as a mount, a laser pointer, and a target. Cervical movement sense is commonly assessed in clinical practice a laser pointer following a pattern, fixed with a light headband. The oculomotor disturbance is clinically assessed (i.e., smooth pursuit neck torsion test) using an object that people must follow with their eyes. The test can assist in differentiate dizziness due to WAD from vestibular symptoms. Balance assessments can be performed in a clinical setting, e.g., tandem tasks. Available from Whiplash Navigator https://mywhiplash.com.au/
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
○ Reduced ● Probably reduced c Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	Not reported	All tests can be performed using the clinical equivalent at low cost. However, HCP's will require some training and expertise in performing and interpreting tests as some results/symptoms are not frequently seen in all people (e.g., oculomotor impairment).
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations

○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Not reported.	Clinical versions of tests are considered acceptable
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ● Probably yes ○ Yes ○ Varies ○ Don't know	Not reported.	The tests are minimally invasive and do not require specialised equipment. Allied HCPs are more likely to perform the tests. They will require training (not routinely taught in undergraduate programs) and require some expertise to interpret as some results/symptoms are not frequently seen in all people (e.g., oculomotor – impairment). Performing those tests may not be feasible for GP's due to time limitations.

A.2.8. Conclusions (sensorimotor in chronic WAD)

VOTE 1: Assessment of cervical joint position error, cervical movement sense, oculomotor disturbance and balance in people with chronic WAD

Are you for or against healthcare professionals assessing the following sensorimotor factors in people with chronic WAD: cervical joint position error, cervical movement sense, oculomotor disturbance, balance?

Type of recommendation (cervical joint position error, cervical movement sense, oculomotor disturbance, balance in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	●	○

Recommendations

There was guideline panel consensus to suggest that healthcare professionals assess the following: cervical joint position error, cervical movement sense, oculomotor disturbance and balance in people with chronic WAD.

(Panel vote summary: 11/12 conditional for (92%), 1/12 (8%) neutral)

Justification

- Moderate evidence showing that people with chronic WAD have impairments in cervical joint position error, cervical movement sense, oculomotor disturbance and balance.
- Findings are consistent with previous guidelines.
- All factors can be clinically assessed.
- Results of tests can be used to reassess effectiveness of treatment.

Subgroups considerations

n/a

Implementation considerations

Indications:

- Whilst many people with chronic WAD may demonstrate impairment, primary HCPs should consider individual presentation (e.g., people with dizziness).

Considerations:

- Consider these and other tests to differentiate other sources of symptoms (e.g., due to mild traumatic brain injury/ concussion or vestibular causes)
- Be aware that some of the tests can provoke or increase symptoms. Avoid performing multiple tests on the same day to avoid symptom accumulation. Prioritise test based on clinical presentation.

How to assess:

- Training is required to performing and interpret tests. It is important to understand normative values and values that indicate impairment (e.g., error of > 4.5 degrees indicates impairment for cervical joint position error test)
- Resources on how to perform, normative values and threshold for cervical joint position error, cervical movement sense (CMS), smooth pursuit neck torsion test (SPNT), Balance – tandem step test) assessments are freely available from Whiplash Navigator https://www.mywhiplash.com.au/content/higher-risk-assessments#sensorimotor-assessment

What to do:

- If people are impaired primary HCPs are recommended to rehabilitate the impairment and may be directed to recommended treatments (e.g., dizziness specific exercise – see guideline treatment section)
- Referral to whiplash expert +/- psychological (consideration differential diagnoses).

VOTE 2: Assessment of coordination and other proprioception in people with chronic WAD

Are you for or against healthcare professionals assessing the following sensorimotor factors in people with chronic WAD coordination and proprioception (others)?

Type of recommendation (coordination and other proprioception in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong recommendation consensus for measuring the factor(s)
○	○	●	○	○

Recommendations
The guideline panel cannot reach consensus for or against assessing the following: coordination and proprioception in people with chronic WAD. *(Panel vote summary: 10/12 neutral (83%), 2/12 conditional (17%) for).* **Justification** • Only few studies assessing those factors resulting in small evidence.

Subgroup considerations

- n/a

Implementation considerations

Indications:

- We do not recommend as assessing upper limb coordination or other proprioceptive tests routinely. There may however be individual circumstances when assessment is indicated (e.g., person reporting upper limb incoordination or differences in laterality perception.

Considerations:

- Primary HCPs should be aware that some people with WAD may be hypervigilant, hence assessment of laterality may be contraindicated.

What to do:

- If people are impaired primary HCPs are recommended to rehabilitate the impairment

A.3. Pain Sensitivity

What pain sensitivity clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.3.1. Executive summary

What Pain Sensitivity Factors should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: 5 studies evaluated physical pain sensitivity in people with whiplash compared with controls or other pain conditions. 2 longitudinal studies evaluated pain sensitivity in sub-groups of people with WAD. Summary of findings in Table 32

- Pressure hyperalgesia: 4/4 independent cohorts showed lower pressure pain threshold in people with acute WAD.
- Thermal hyperalgesia: 3/3 of independent cohorts showed altered thermal hyperalgesia in people with acute WAD.
- Dynamic pain sensitivity testing: 2/2 independent cohorts reduced conditioned pain modulation (CPM) tolerance in people with acute WAD.
- Other pain sensitivity tests: 2/2 independent cohorts showed a positive sign on the brachial plexus provocation test. The 1/1 study found a lower vibration threshold, and the 1/1 study lower nociceptive flexion reflex (NFR) in people with acute WAD.

Chronic whiplash: 7 studies evaluated physical pain sensitivity in people with whiplash compared with controls or other pain conditions. 5 cross-sectional and two longitudinal studies evaluated pain sensitivity in sub-groups of people with WAD. Summary of findings in Table 34

- Pressure hyperalgesia: 10/11 independent cohorts showed lower pressure pain threshold in people with acute WAD.
- Thermal hyperalgesia: 11/11 independent cohorts showed thermal hyperalgesia in people with chronic WAD.
- Dynamic pain sensitivity testing: 2/4 independent cohorts reduced conditioned pain modulation (CPM) tolerance in people with chronic WAD, and 2/4 showed no differences in people with chronic WAD.
- Quantitative Sensory Testing (vibration): 2/3 independent cohorts showed significant alteration in vibration threshold in people with chronic WAD.
- Brachial plexus provocation test: 3/3 independent cohorts positive for Brachial Plexus Provocation Test in people with WAD.
- Nociceptive flexion reflex (NFR): 1/2 independent cohort showed lower NFR in people with chronic WAD.
- Others (i.e., spinal reflex, photophobia): 4/4 independent cohorts showed a significant difference in people with chronic WAD.

A.3.2. Acute pain sensitivity

Pain sensitivity

Category: Pain sensitivity

Sub-category: Pain sensitivity (pressure hyperalgesia, thermal hyperalgesia, dynamic pain sensitivity test, other pain sensitivity testing - Acute and Subacute WAD studies (n=7))

Table 32: Summary of included studies (acute pain sensitivity)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome(s) assessed	Results	Comments	Significant
(Fernandez-Perez et al., 2012) Muscle trigger points, pressure pain threshold, and cervical range of motion in patients with high level of disability related to acute whiplash injury	To analyse the differences in the prevalence of trigger points (TrPs) between people with WAD and healthy controls	20 participants with acute WAD II and severe disability (mean NDI, 68.5 ± 8.7) (50% female).	20 age-and-gender matched healthy group. (50% female)	TrP manual compression: Temporalis, masseter, upper trapezius, levator scapulae, sternocleido mastoid, suboccipital, and scalene muscles.	TrPs in WAD was 7.3 ± 2.8. In comparison, healthy controls had 1.7 ± 2.2 latent and no active TrPs (P<.01). In people with acute WADs, the most prevalent sites for active TrPs were the levator scapulae and upper trapezius muscles.	The local and referred pain elicited from active TrPs reproduced neck and shoulder pain patterns in individuals with acute WADs with higher levels of disability	Significant
(Chien et al., 2008a)* Hypoesthesia occurs in acute whiplash irrespective	To investigate the presence of sensory hypoaesthesia in acute WAD	52 people with acute WAD (61% female) High-risk (n=17; NDI >30; sensory hypersensitivity)	31 healthy asymptomatic (80% female)	Quantitative Sensory Testing (thermal: cold, heat; vibration) Brachial Plexus	Both the high-risk and low-risk groups exhibited significant elevation in sensory detection when compared with controls (P<0.05).	Hypoaesthesia as well as hypersensitivity may be present in acute WAD.	Significant

of pain and disability levels and the presence of sensory hypersensitivity		Low risk" (n=35; without these signs)		Provocation Test (BPPT)			
(Chien et al., 2010)* The development of sensory hypoesthesia after whiplash injury	To investigate hypoesthesia soon after whiplash injury (within 4 wk) and to 3 and 6 months postinjury and to determine differences in detection thresholds between those with initial features of poor recovery and those without these signs.	52 participants with acute (< 1 month) grade II WAD. (62% female) High-risk (n=17; NDI >30; sensory hypersensitivity) Low risk" (n=35; without these signs)	38 healthy asymptomatic volunteers (73% female)	Quantitative Sensory Testing (thermal: cold, heat; vibration) Brachial Plexus Provocation Test (BPPT)	WAD low and high-risk groups showed hypoesthesia at 1-month postinjury. Vibration and electro cutaneous hypoesthesia persisted only at 3 and 6 months in the high-risk WAD group. Heat detection thresholds continued to be elevated in the high-risk group at 3 and 6 months. Both WAD groups were distressed at 1 month, but this decreased by 3 months in the low-risk group.	Sensory hypoesthesia is a feature of acute WAD but persists only in those at higher risk of poor recovery	
(Kasch et al., 2005) Reduced cold pressor tolerance in non-recovered whiplash patients: a 1-	To compare sensory pain stimuli differences between people with whiplash and ankle injured controls	141 people with acute WAD I-III (<2d) (52% female)	40 people with ankle injuries (53% female)	Conditioned Pain Modulation (CPM) test	People with whiplash who failed to recover at 1 year had less cold pain endurance ($p<0.05$) and shorter time to peak pain ($p<0.01$)	Reduced cold pressor tolerance in non-recovered people with whiplash: a 1-year prospective study	Significant

year prospective study							
(Sterling, 2010) Differential development of sensory hypersensitivity and a measure of spinal cord hyperexcitability following whiplash injury	To compare the temporal development of sensory hypersensitivity and NFR responses from soon after injury to either recovery or to transition to chronicity	62 people with acute WAD sub-grouped based on NDI (58% female)	22 asymptomatic volunteers (63% female)	Pressure and thermal (cold) pain thresholds Nociceptive flexion reflex (NFR)	All whiplash groups demonstrated spinal cord hyperexcitability (lowered NFR thresholds) at 3 weeks post-injury. This hyperexcitability persisted in those with moderate/severe symptoms at 6 months but resolved in those who recovered or reported lesser symptoms at 6 months. In contrast generalized sensory hypersensitivity (pressure and cold) was only ever present in those with persistent moderate/ severe symptoms and remained unchanged throughout the study period.	WAD injury induces spinal cord hyperexcitability. Irrespective of initial symptom levels but this persists only in those with ongoing moderate to severe symptoms. In contrast cold hyperalgesia and widespread pressure hyperalgesia are only ever present in those who develop persistent moderate/severe. symptoms.	Significant
(Sterling & Pedler, 2009) A neuropathic	To investigate the presence of a neuropathic pain	85 people with acute WAD recruited from mixed sources. People sub-	N/A	S- LANSS for classification of neuropathic	Those with a neuropathic component (score >12) showed higher pain/disability,	A predominantly neuropathic pain component is related to a complex presentation of higher pain/disability	Significant

component is common in acute whiplash and associated with a more complex clinical presentation	component in acute whiplash using the Self-reported Leeds Assessment of Neuropathic Signs and Symptoms scale (S-LANSS) and evaluated relationships among S-LANSS responses, pain/disability, sensory characteristics (mechanical, thermal pain thresholds, and Brachial plexus provocation test [BPPT] responses) and psychological distress (General Health Questionnaire-28 [GHQ-28])	grouped based on S-LANSS scores		pain subgroup (Self-reported Leeds Assessment of Neuropathic Signs and Symptoms' scale) Pressure and thermal (cold) pain thresholds Brachial plexus provocation test (BPPT)	hyperalgesia and sensitivity with the BPPT (all p<0.03). There were no differences for pressure pain thresholds	and sensory hypersensitivity	
(Daenen et al., 2014) Changes in Pain Modulation Occur Soon	Evaluate conditioned pain modulation (CPM) in acute WAD and investigate	30 people (with acute WAD (<3mo) 47% female)	31 healthy controls (77% female)	Conditioned Pain Modulation	A significant CPM effect was observed in acute WAD (P = 0.012 and P = 0.006), which was significantly lower than controls (P =	Changes in CPM were observed in acute WAD, suggesting less efficient pain modulation. Suggest that central pain and sensorimotor	Significant

After Whiplash Trauma but are not Related to Altered Perception of Distorted Visual Feedback	whether changes in CPM are associated with altered perception of distorted visual feedback.	35 people with chronic WAD (>3mo) (74% female)			0.004 and P = 0.020). No obvious differences in CPM were found between acute and chronic WAD (P = 0.098 and P = 0.041).	processing underlie distinctive mechanisms	

A.3.3. Acute pain sensitivity evidence summary

Table 33: Summary of evidence for included studies in acute pain sensitivity

Sub-category	Studies	Population	Assessment method	Conclusion	Evidence Summary
Pressure hyperalgesia (Independent cohorts n=4)	(Fernandez-Perez et al., 2012)	20 acute WAD and severe disability. 20 controls	TrP manual compression	Increased of active TrPs in neck and shoulder in individuals with acute WADs.	4 - Sig
	(Chien et al., 2008a) (Chien et al., 2010)	52 acute WAD 31 controls 52 acute WAD 38 controls	Quantitative Sensory Testing Pressure pain threshold (PPT)	Both the high-risk and low-risk groups exhibited significant elevation in sensory detection (lower pressure pain threshold) when compared with controls.	
	(Sterling, 2010)	62 acute WAD 22 controls	PPT	PPT were lower in people with moderate/severe symptoms compared with lower risk groups in acute phase.	
		85 acute WAD (29 with neuropathic pain 56 without defined by S-LANSS)	PPT	PPT were lower in people with neuropathic pain versus non-neuropathic pain in acute WAD.	
Thermal hyperalgesia (Independent	(Chien et al., 2008a)	52 acute WAD 31 controls 52 acute WAD 38 controls	Quantitative Sensory Testing (thermal: heat, cold)	Altered cold and heat thresholds in people with WAD compared with controls.	3 - Sig

cohorts n=3)	(Chien et al., 2010)				
	(Sterling, 2010)	62 acute WAD 22 controls	Cold pain thresholds (CPT)	Cold pain thresholds were higher in people with moderate/severe symptoms compared with lower risk groups in acute phase.	
	(Sterling & Pedler, 2009)	85 acute WAD (29 with neuropathic pain, 56 without defined by S-LANSS)	CPT	Cold pain thresholds were higher in people with neuropathic pain versus non-neuropathic pain in acute WAD.	
Dynamic pain sensitivity testing (Independent cohorts n=2)	(Kasch et al., 2005)	142 acute WAD; 40 with ankle injuries	Conditioned Pain Modulation (CPM) test	Reduced CPM tolerance in WAD compared with control (ankle injury).	2 - Sig
	(Daenen et al., 2014)	30 acute WAD 31 controls	Conditioned Pain Modulation test	Reduced CPM was observed in acute WAD compared with controls, suggesting less efficient pain modulation.	
Other pain sensitivity testing (Independent cohorts n=3)	(Chien et al., 2008a) (Chien et al., 2010)	52 acute WAD 31 controls 52 acute WAD 38 controls	Quantitative Sensory Testing (vibration) Brachial Plexus Provocation Test	Vibration threshold lower and positive sign on BPPT in WAD group compared with controls.	2 - Sig (BPPT), 1 - Sig (vibration hyperalgesia) 1 - Sig (NFR)
	(Sterling, 2010)	62 acute WAD 22 controls	Nociceptive flexion reflex (NFR)	The WAD groups showed significantly lower NFR thresholds compared with controls.	
	(Sterling & Pedler, 2009)	85 acute WAD (29 with neuropathic pain, 56 without defined by S-LANSS)	Brachial Plexus Provocation Test	Significant difference in BPPT test in people with acute WAD and neuropathic pain versus people with acute WAD and no neuropathic pain.	

A.3.4. Chronic pain sensitivity

Pain sensitivity

Category: Pain sensitivity

Sub-category: Pain sensitivity (pressure hyperalgesia, thermal hyperalgesia, dynamic pain sensitivity test, Quantitative Sensory Testing (vibration), Brachial Plexus Provocation Test (BPPT), Nociceptive Flexion Reflex (NFR) other pain sensitivity testing – Chronic WAD studies (n=20))

Table 34: Summary of included studies (chronic pain sensitivity)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Castaldo et al., 2019) Widespread Pressure Pain Hypersensitivity, Health History, and Trigger Points in Patients with Chronic Neck Pain: A Preliminary Study	To investigate the association between pressure pain thresholds, trigger points, and health conditions in people with chronic neck pain	34 people with chronic WAD (76% female)	34 people with mechanical neck pain (MNP) (68% female)	Pressure pain thresholds Upper trapezius, extensor carpi radialis longus, and tibialis anterior muscles	No differences between MNP and WAD (P>0.5) in all muscle	There is no difference in PPT for all muscles between WAD and MNP group	NS
(Chien et al., 2008b)* Whiplash (grade II) and cervical radiculopathy share a similar sensory presentation:	To compare chronic whiplash with a cervical neuropathic condition-cervical radiculopathy, using Quantitative	50 participants with chronic grade II WAD.	38 participants with radiculopathy 31 controls with age and sex-matched to WAD group	Quantitative Sensory Testing (thermal: cold, heat; vibration Pressure Pain thresholds	WAD and cervical radiculopathy groups demonstrated lower pain thresholds to pressure and cold stimuli at all sites than the controls (P<0.01). There was no difference in	Generalized sensory hypersensitivity and hypoesthesia occur in both chronic whiplash and cervical radiculopathy	Significant

an investigation using quantitative sensory testing	Sensory Testing				detection thresholds between the asymptomatic limbs of the radiculopathy group and the whiplash group (P>0.05), but both these groups showed higher detection thresholds than the controls (P<0.05)		
(Chien et al., 2009)* Hypoaesthesia occurs with sensory hypersensitivity in chronic whiplash--further evidence of a neuropathic condition	To investigate the sensory presentation of chronic WAD	31 participants with chronic grade II WAD (80% female)	31 healthy volunteers	Quantitative Sensory Testing (thermal: cold, heat; vibration Electrocutaneous stimulation Pain threshold	WAD group demonstrated elevated vibration, heat and electrical detection thresholds at most hand sites compared to controls ($p < 0.05$). Electrical detection thresholds in the lower limb were no different from controls ($p = 0.83$). Mechanical and cold pain thresholds were altered in the whiplash group ($p < 0.05$) with no group difference in heat pain thresholds ($p > 0.1$).	Sensory hypoaesthesia and hypersensitivity co-exist in the chronic whiplash condition. These findings may indicate peripheral afferent nerve fibre involvement but could be a further manifestation of disordered central pain processing.	
(Chien & Sterling, 2010) Sensory hypoaesthesi	This study compared the somatosensory phenotype of whiplash and	50 participants with chronic grade II WAD (78% female)	28 participants with idiopathic neck pain (71% female)	Quantitative Sensory Testing (thermal: cold, heat; vibration)	WAD group demonstrated lowered pressure pain thresholds (PPTs) at all sites compared to the	PPT is lower in WAD than in control, but no differences between pain groups. WAD has a lower cold pain threshold, detection	Significant

a is a feature of chronic whiplash but not chronic idiopathic neck pain	idiopathic neck pain.		31 healthy volunteers (81% female)	Pressure pain threshold	controls ($p < 0.01$) but there was no difference between the two neck pain groups ($p > 0.05$) except at the tibialis anterior site ($p = 0.02$). The whiplash group demonstrated lowered cold pain thresholds compared to idiopathic and control groups ($p < 0.03$). For detection thresholds, the whiplash group showed elevated vibration ($p < 0.04$), heat ($p < 0.02$) and electrical ($p < 0.04$) thresholds at all upper limb sites compared to the idiopathic neck pain group and the controls ($p < 0.04$).	threshold, elevated vibration, heat and electrical than INP and control. Sensory hypoesthesia whilst present in chronic WAD is not a feature of chronic idiopathic neck pain.	
(Coppieters et al., 2015) Cognitive performance is related to central sensitization and health-related quality of life in patients	Examining the presence of cognitive impairment, CS, and limitations on health related QoL in people with chronic WAD and FM compared to	16 people with chronic WAD (>3mo) (81% female)	21 people with fibromyalgia (FM) (76% female) 22 healthy controls (64% female)	Pressure pain thresholds Temporal summation [TS], and conditioned pain modulation [CPM]).	PPTs at the shoulder and finger were significantly lower in FM people compared to chronic WAD people and controls. TS was significantly higher in both patient groups in comparison with healthy controls, but no difference	TS higher in both pain groups than control. However, FM showed lower PPT than WAD and no differences in CPM for all 3 groups.	Significant

with chronic whiplash-associated disorders and fibromyalgia	healthy controls.				between WAD and FM No significant differences for the efficacy of endogenous pain inhibition (CPM) in all 3 groups		
(Coppieters et al., 2016) Differences Between Women With Traumatic and Idiopathic Chronic Neck Pain and Women Without Neck Pain: Interrelationships Among Disability, Cognitive Deficits, and Central Sensitization	To examine differences in disability, cognitive deficits, and central sensitization between women with traumatic and idiopathic (nontraumatic) chronic neck pain and women who were healthy	32 people with chronic WAD (> 3mon) (100% female)	28 healthy controls (100% female) 35 chronic idiopathic neck pain (CINP) (> 3mon) (100% female)	Pressure pain thresholds and Conditioned pain modulation (CPM using cold pressor test)	Decreased PPTs were demonstrated at the middle trapezius muscle, quadriceps muscle, hand, and lumbar region in participants with CWAD but only at the middle trapezius muscle in participants with CINP, relative to the results for women who were healthy (P<.017). No significant differences between participants with CWAD and participants with CINP were found for PPTs at the 4 locations. were significantly lower in participants with CWAD than in women who were healthy and participants with CINP	Local hyperalgesia was demonstrated in participants with CWAD and CINP but not in women who were healthy. However, distant hyperalgesia and decreased CPM efficacy were shown only in participants with WAD.	Significant

					(P<.017).		
(Banic et al., 2004) Evidence for spinal cord hypersensitivity in chronic pain after whiplash injury and in fibromyalgia	To investigate spinal cord hypersensitivity in people with chronic WAD vs people with fibromyalgia and healthy controls	27 people with whiplash (<6mo duration) (70% female)	22 people with fibromyalgia (82% female) 29 healthy controls (69% female)	Spinal reflex Transcutaneous electrical stimulation of the sural nerve	Reflex thresholds were significantly lower in the whiplash compared with the control group, after both single P= 0.024 and repeated P=0.035 stimulation	Spinal cord hypersensitivity demonstrated in chronic WAD and fibromyalgia compared to healthy controls.	Significant
(Haggman-Henrikson et al., 2013) Altered thermal sensitivity in facial skin in chronic whiplash-associated disorders	To investigate facial thermal thresholds in people with chronic WAD with both a qualitative method and quantitative sensory testing (QST)	10 people with chronic WAD (>6mo) (100% female)	10 healthy controls (100% female)	Quantitative Sensory Testing (thermal: cold, heat)	In WAD QST systematically showed significantly higher detection thresholds (i.e., decreased sensitivity) for both cold and warm stimuli than healthy group.	WAD presented higher detection thresholds for both cold and warm stimuli	Significant
(Lemming et al., 2012) Widespread pain hypersensitivity and facilitated temporal summation of deep tissue pain in whiplash associated disorder: an	Widespread deep tissue pain hyperalgesia was evaluated in women with chronic whiplash associated disorder (n = 25) and controls (n = 10) using computerized cuff pressure	25 people with chronic WAD (>6mo) (100% female)	10 healthy controls (100% female)	Computerized cuff pressure algometry and hypertonic saline infusion. Leg with constant cuff pressure stimulation	Cuff pressure pain thresholds were lower in subjects with WAD compared with controls (p < 0. 05). Tonic pressure stimulation evoked higher maximal VAS and larger areas under the VAS curve in subjects WAD compared with controls (p < 0. 05).	Indicated widespread hyperalgesia in chronic whiplash associated disorder and facilitated temporal summation outside the primary pain area, suggesting involvement of central sensitization.	Significant

explorative study of women	algometry and hypertonic saline infusion.			Hypertonic saline was infused in the tibialis anterior muscle			
(Moog M, 2002) The late whiplash syndrome: a psychophysical study	To examine psychophysical responses to non-noxious stimuli and their relationship to psychological profiles in people with chronic WAD and matched controls	43 people with chronic WAD (>6mo) (65% female)	43 healthy matched controls (65% female)	Quantitative Sensory Testing (thermal: cold, heat; vibration)	28 people with WAD reported vibration induced pain vs no controls (p value not reported). A significantly higher proportion of people with WAD reported cold induced pain ($p<0.0004$) but not heat induced pain when compared to controls. No differences in vibration perception threshold between WAD and control.	Chronic whiplash sufferers have an increased pain response to non-noxious stimulation of healthy tissue implicating a central mechanism of pain sensitisation.	Significant
(Ng et al., 2014) Less efficacious conditioned pain modulation and sensory hypersensitivity in chronic whiplash-associated disorders in Singapore	Investigating neck motion and pain sensitivity in people with chronic WAD in Singapore	30 people with chronic WAD (>13mo) (47% female)	30 healthy and pain free controls (47% female)	Brachial Plexus Provocation Test (BPPT) Quantitative Sensory Testing (thermal: cold, heat; vibration) Conditioned pain modulation (CPM)	Pain thresholds of blunt pressure, BPPT, and cold were significantly lower in participants with WAD. Cold pressor pain tolerance was significantly lower in participants with WAD. A less efficacious CPM was also demonstrated in participants with WAD.	These findings of sensory hypersensitivity in Singaporeans with chronic WAD	Significant

(Scott et al., 2005) Widespread sensory hypersensitivity is a feature of chronic whiplash associated disorder but not chronic idiopathic neck pain	To investigate sensory changes in people with chronic WAD vs people with chronic idiopathic neck pain	29 people with chronic WAD (>3mo) (57% female)	20 people with idiopathic neck pain (INP) (85% women) 20 pain-free people (60% female)	Pressure pain thresholds (PPTs) Quantitative Sensory Testing (thermal: cold, heat)	Pressure pain thresholds were decreased in both subject groups when compared to controls ($p<0.05$). In the WAD group PTT were also decreased at peripheral sites ($p<0.001$). Thermal thresholds (hot and cold) were altered in the WAD group ($p<0.03$) than INP and control.	Both chronic WAD and INP demonstrated mechanical hyperalgesia. Chronic WAD additionally demonstrated widespread hypersensitivity indicating a potential central mechanism of pain processing.	Significant
(Sterling et al., 2008) Psychologic factors are related to some sensory pain thresholds but not nociceptic flexion reflex threshold in chronic whiplash	To investigate relationships between psychologic factors (distress and catastrophisation) and pain threshold responses to sensory stimuli and spinal cord excitability as assessed by the NFR responses.	30 participants with WAD II-III (77% female)	30 healthy asymptomatic (80% female)	Nociceptive flexion reflex (NFR) Pressure pain thresholds Thermal (heat and cold)	Whiplash injured participants demonstrated lowered pain thresholds to pressure and cold ($P<0.05$); lowered NFR thresholds ($P=0.003$), comparable with other musculoskeletal conditions. There were no group differences for heat pain thresholds or pain at NFR threshold.	Decreased pain thresholds present in WAD group compared to control	Significant
(Michele et al., 2002) Pressure pain thresholds in chronic	To investigate pressure pain thresholds (PPT) in people with chronic WAD vs	115 people with chronic WAD (>3mo) (78% female)	95 healthy controls (53% female)	Pressure pain thresholds	People with chronic WAD had significantly lower PPTs than controls in both local and	Results suggest a sensitised central nervous system in people with chronic WAD	Significant

whiplash associated disorder: further evidence of altered central pain processing	healthy controls				remote sites (all p<0.001)		
(Sterling et al., 2002) Responses to a clinical test of mechanical provocation of nerve tissue in WAD	To investigate responses to the brachial plexus provocation test (BPTT) in people with chronic WAD compared to controls	156 people with chronic WAD (>3mo) (81% female)	95 asymptomatic subjects (53% female)	Brachial plexus provocation test (BPPT)	WAD demonstrated that there was a significant difference between the pain reported (VAS) by the WAD group compared to the control group during BPPT	Generalised sensory hypersensitivity demonstrated in chronic WAD subjects	Significant
(Wallin & Raak, 2008) Quality of life in subgroups of individuals with whiplash-associated disorders	(1) to evaluate thermal pain thresholds and health related quality of life in people with WAD compared to healthy pain-free individuals, (2) to explore whether subgrouping of the people with WAD is possible according to thermal pain thresholds	26 participants with WAD (85 % female)	18 control subjects (95% female)	Quantitative Sensory Testing (thermal: cold, heat)	People with WAD are more sensitive to thermal (CPT and HTP) pain when compared with healthy pain-free individuals. Compared with healthy subjects, subgroup 1 (insensitive) shows significant difference concerning warm detection threshold WDT (p = 0.021) and a non-significant trend concerning cold detection threshold CDT (p =	Thermal pain hyperalgesia, especially for cold, seems to be a determinant for subgrouping people with WAD	Significant

	over trapezius, and if so (3) to explore differences between the subgroups				0.060) over the thenar eminence, whereas subgroup 2 (sensitive) differs significantly concerning CPT over the thenar eminence and all threshold measurements over the trapezius muscle		
(Wallin et al., 2012) Thermal detection and pain thresholds but not pressure pain thresholds are correlated with psychological factors in women with chronic whiplash-associated pain	To explorative study of chronic WAD and healthy pain-free controls (CON) (2) Detection and pain thresholds of thermal stimuli and Pressure within, near, and remote to the primary pain area (neck and shoulders),	28 people with chronic WAD (100% female)	29 healthy controls (100% female)	Pressure pain threshold (PPT) Thermal (cold and hot)	WAD showed generalized decreased PPT and CPT, altered HPT and cold detection thresholds in the upper part of the body than control	Indicate the need to consider that a blend of factors influences the pain thresholds in chronic WAD.	Significant
(Watson & Drummond, 2016) The Role of the Trigemino	To investigate signs of central sensitization in a cohort of people with chronic	22 people with chronic whiplash associated headache (91% female)	25 participants that were either headache-free or experienced mild non-	Photophobia Sensory Hyperalgesia Trigeminal Nociception	People in the whiplash group reported significantly greater light-induced pain than controls. The people with CWAH	Suggest mechanical hypersensitivity and photophobia in people with CWAH.	Significant

Cervical Complex in Chronic Whiplash Associated Headache: A Cross Sectional Study	whiplash associated headache (CWAH)		migrainous headache		reported significantly lower PPT at all sites.		
(Sterling, Jull, Vicenzino, & Kenardy, 2003) Sensory hypersensitivity occurs soon after whiplash injury and is associated with poor recovery	To determine if sensory hypersensitivity differed between people with acute WAD and asymptomatic controls	76 people with at 6 months whiplash (70% female)	20 asymptomatic volunteers (60% female)	Pressure pain thresholds (PPTs) Thermal (cold and heat) pain thresholds Brachial plexus provocation test (BPPT)	People with WAD with persistent moderate or severe symptoms demonstrated hypersensitivity to sensory tests (pressure and thermal pain thresholds and brachial plexus provocation test) compared to asymptomatic controls (all $p<0.01$).	Suggestive of centralised pain control mechanism for those with persistent moderate and severe symptoms.	Significant

(Lenoir et al., 2022) Are Reports of Pain, Disability, Quality of Life, Psychological Factors, and Central Sensitization Related to Outcomes of Quantitative Sensory Testing in Patients Suffering from Chronic Whiplash Associated Disorders?	To investigate the differences in QST between people with CWAD and pain-free controls	72 with chronic acute WAD (70.8% female)	55 pain-free controls (75.9% female)	Quantitative Sensory Testing (QST) with Electrical Detection Thresholds (EDT) and Electrical Pain Thresholds (EPT) Temporal Summation (TS) Paradigm Conditioned Pain Modulation (CPM)	EPTs left (P=0.011) and right wrist (P= 0.023) were lower in the CWAD group, but conditioned pain modulation and TS did not differ between groups.	QST outcomes between individuals with CWAD and PFCs, differences between both groups could be identified in the pain thresholds measured at the left and right wrist, which were characterised by lower pain thresholds in the CWAD group.	Significant

(Borsbo et al., 2012)– Subgroups based on thermal and pressure pain thresholds in women with chronic whiplash display differences in clinical presentation - an explorative study excluded – cluster analysis.

A.3.5. Chronic pain sensitivity evidence summary

Table 35: Summary of evidence for included studies in chronic pain sensitivity

Sub-category	Studies	Population	Assessment method	Conclusion	Evidence Summary
Pressure hyperalgesia Independent cohorts (n =11)	(Castaldo et al., 2019)	34 WAD 34 mechanical neck pain (MNP)	Pressure pain threshold (PPT)	There is no difference in PPT for all muscles between WAD and MNP groups.	10 - Sig 1 - NS

	(Chien et al., 2008b)* (Chien et al., 2009)*	50 WAD 38 with radiculopathy; 31 controls 31 WAD 31 controls	PPT	WAD and cervical radiculopathy groups demonstrated lower pain thresholds to pressure than the controls.	
	(Chien & Sterling, 2010)	50 WAD 28 with idiopathic neck pain (INP) 31 controls	PPT	WAD demonstrated lowered pressure pain thresholds (PPTs) at all sites compared to the controls, but there was no difference between the two neck pain groups.	
	(Coppieters et al., 2016)	32 WAD 35 with idiopathic neck pain (INP) 28 controls	PPT	Decreased PPTs in WAD than controls.	
	(Lemming et al., 2012)	25 WAD 10 controls	Cuff pressure pain threshold	Cuff pressure pain thresholds were lower in subjects with WAD than controls.	
	(Scott et al., 2005)	29 WAD 20 INP 20 controls	PPT	Pressure pain thresholds were decreased in both subject groups when compared to controls.	
	(Sterling et al., 2008)	30 WAD 30 controls	PPT	Whiplash injured participants demonstrated lowered pain thresholds for pressure.	
	(Michele et al., 2002)	115 WAD 95 controls	PPT	People with chronic WAD had significantly lower PPTs than controls in both local and remote sites.	
	(Wallin et al., 2012)	28WAD 29 controls	PPT	WAD showed generalized decreased PPT in the upper part of the body than the control	
	(Sterling, Jull, Vicenzino, & Kenardy, 2003)	76 WAD 20 controls	PPT	People with WAD with persistent moderate or severe symptoms demonstrated hypersensitivity to sensory tests (pain pressure) than control	

	(Sterling, 2010)	62 acute WAD 22 controls	Nociceptive flexion reflex (NFR)	The WAD groups showed significantly lower NFR thresholds compared with controls.	
Thermal hyperalgesia (Independent cohorts n =10)	(Sterling & Pedler, 2009)	85 acute WAD (29 with neuropathic pain, 56 without defined by S-LANSS)	Brachial Plexus Provocation Test	Significant difference in BPPT test in people with acute WAD and neuropathic pain versus people with acute WAD and no neuropathic pain.	
	(Chien & Sterling, 2010)	50 WAD 28 with idiopathic neck pain (INP) 31 controls	Cold pain thresholds (CPT) and Heat pain thresholds (HPT)	The whiplash group demonstrated lowered cold pain thresholds compared to the idiopathic and control groups. For detection thresholds, the whiplash group showed elevated heat threshold compared to the idiopathic neck pain group and the controls	
	(Haggman-Henrikson et al., 2013)	10 WAD 10 controls	CPT and HPT	In WAD QST systematically showed significantly higher detection thresholds (i.e., decreased sensitivity) for both cold and warm stimuli than the healthy group.	
	(Ng et al., 2014)	30 WAD 30 controls	CPT	Col pain thresholds cold were significantly lower in participants with WAD.	
	(Scott et al., 2005)	29 WAD 20 INP 20 controls	CPT	Thermal thresholds (hot and cold) were altered in the WAD group than INP and control.	
	(Sterling et al., 2008)	30 WAD 30 controls	CPT	Whiplash injured participants demonstrated lowered pain thresholds for cold.	
	(Wallin & Raak, 2008)	26 WAD: 18 controls	CPT and HPT	People with WAD are more sensitive to thermal (CPT and HTP) pain when compared with healthy, pain-free individuals.	
	(Wallin et al., 2012)	28WAD: 29 controls	CPT	WAD showed generalized decreased CPT, altered HPT and cold detection thresholds in the upper part of the body than the control group.	
	(Sterling, Jull, Vicenzino, &	76 WAD 20 controls	CPT	Cold pain thresholds were higher, and PPT were lower in people with moderate/severe symptoms compared to the control group.	

	Kenardy, 2003)				
	Sterling 2010	62 acute WAD 22 controls	CPT	Cold pain thresholds were higher in people with moderate/severe symptoms compared with lower risk groups in acute phase.	
Dynamic pain sensitivity testing (Independent cohorts n=4)	(Coppieters et al., 2015)	16 WAD; 21 fibromyalgia (FM) 22 controls	Conditioned Pain Modulation (CPM) test	No significant differences for the efficacy of endogenous pain inhibition (CPM) in all 3 groups	2 – NS 2 – Sig
	(Coppieters et al., 2016)	32 WAD 35 with idiopathic neck pain (INP) 28 controls	CPM	CPM values were Lower in participants with CWAD than in women who were healthy and participants with CINP	
	(Ng et al., 2014)	30 WAD 30 controls	Conditioned pain modulation (CPM)	CPM values were Lower in participants with WAD. A less efficacious CPM was also demonstrated in participants with WAD.	
	(Lenoir et al., 2022)	72 WAD 55 controls	Conditioned pain modulation (CPM)	Conditioned pain modulation did not differ between groups.	
Quantitative Sensory Testing (vibration) (Independent cohorts n =3)	(Chien et al., 2008b)* (Chien et al., 2009)*	50 WAD; 38 with radiculopathy; 31 controls 31 WAD; 31 controls	Quantitative Sensory Testing (vibration)	WAD group demonstrated elevated vibration compared to control	2 -Sig 1- NS
	(Chien & Sterling, 2010)	50 WAD; 28 with idiopathic neck pain (INP); 31 controls	Quantitative Sensory Testing (vibration)	WAD group demonstrated elevated vibration compared to control	

	(Moog M, 2002)	43 WAD; 43 controls	Quantitative Sensory Testing (vibration)	No differences in vibration perception threshold between WAD and control	
Brachial Plexus Provocation Test (BPPT) (Independent cohorts n =3)	(Ng et al., 2014)	30 WAD; 30 controls	Brachial Plexus Provocation Test (BPPT)	Higher pain in WAD group compared to the control group during BPPT	3 – Sig
	(Sterling et al., 2002)	156 WAD; 95 controls	Brachial plexus provocation test (BPPT)	Higher pain in WAD group compared to the control group during BPPT	
	(Sterling, Jull, Vicenzino, & Kenardy, 2003)	76 WAD 20 controls	Brachial plexus provocation test (BPPT)	Group with mild symptoms improved over time and showed no difference from control by 2 months. Group with moderate/severe symptoms showed no change over time and continued to demonstrate less elbow extension and higher Vas scores than controls at 6 months post-injury.	
Nociceptive Flexion Reflex (NFR) (Independent cohorts n =2)	(Sterling et al., 2008)	30 WAD; 30 controls	Nociceptive flexion reflex (NFR)	There were no group differences at NFR threshold	1 – Sig 1 – NS
	(Sterling, 2010)	62 acute WAD;22 controls	Nociceptive flexion reflex (NFR)	The WAD groups showed significantly lower NFR thresholds compared with controls.	
Others (Independent cohorts n =4)	(Banic et al., 2004)	27WAD; 22 fibromyalgia (FM); 29 controls	Spinal reflex Transcutaneous electrical stimulation of the sural nerve	Reflex thresholds were significantly lower in the whiplash compared with the control group	4 - Sig

	(Lemming et al., 2012)	25 WAD; 10 controls	Hypertonic saline was infused in the tibialis anterior muscle	Tonic pressure stimulation evoked higher maximal VAS and larger areas under the VAS curve in subjects WAD compared with controls	
	(Watson & Drummond, 2016)	22 WAD with headache; 26 controls headache free	Photophobia	People in the whiplash group reported significantly greater light-induced pain than controls.	
	(Lenoir et al., 2022)	72 WAD; 55 controls	Electrical Detection Thresholds (EDT) and Electrical Pain Thresholds (EPT)	EPTs left (P=0.011) and right wrist (P= 0.023) were lower in the CWAD	

*Same cohort in the sub-category

Table 36: Evidence to decision framework (pain sensitivity in acute WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○ Trivial ○ Small ● Moderate ○ Large ○ Varies ○ Don't know	Thermal hyperalgesia (cold, heat), pressure hyperalgesia, Conditioned Pain Modulation, and other pain sensitivity assessments (BPPT, vibration hyperalgesia, NFR) were significantly different between WAD and controls, and/or between moderate-to-severe subgroups of people with WAD compared with lower risk WAD subgroups. These findings were consistent across all studies. • Pressure hyperalgesia: 4/4 independent studies showed lower pressure pain threshold in people with acute WAD. • Thermal hyperalgesia: 3/3 independent studies showed alteration in thermal hyperalgesia in people with acute WAD. • Dynamic pain sensitivity testing: 2/2 independent studies reduced conditioned pain modulation (CPM) tolerance in people acute WAD.	Findings for cold hyperalgesia were consistent with the prognosis section of these guidelines, where assessment of cold hyperalgesia was also recommended to assess for determining those at risk of poor prognosis. Findings across the acute WAD studies are consistent with systematic reviews and suggest the presence of altered pain sensitivity in medium-high risk subgroups of people with acute WAD.

	• Other pain sensitivity test: 2/2 independent studies showing positive sign on brachial plexus provocation test, 1/1 study found lower vibration threshold and 1/1 study lower nociceptive flexion reflex (NFR) in people with acute WAD.	
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported.	Pain sensitivity testing can temporarily cause or increase acute pain, it is important for healthcare professionals to inform the person this may occur.
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ● Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Consistent findings were found across the included studies that suggest the presence of altered pain sensitivity in moderate-severe risk subgroups of people with acute WAD. Adverse effects are likely trivial in magnitude.	If HCPs know that a person is pain sensitive from these clinical tests, the findings can guide treatment direction (see recommendations for moderate-severe risk subgroups). The assessment should only be performed if it can be reasonably completed in the clinical setting and the persons clinical presentation indicates the need for assessment.
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ○Moderate costs ○ Negligible costs and savings	Not reported.	Some tests require specialised equipment and are associated with higher costs. However, there are valid alternatives to assessing pain sensitivity that do not require specialised equipment and are relatively lower in cost. For

○ Moderate savings ○ Large savings ● Varies ○ Don't know		example, descriptions on how to clinically assess cold hyperalgesia using ice is freely available on Whiplash Navigator https://mywhiplash.com.au/ PPT can be assessed using a pressure algometer. Conditioned pain modulation (CPM) testing in the included studies utilises laboratory equipment (e.g., circulating ice bath). However, CPM testing be performed using a clinical alternative with a pressure cuff. NFR test is considered to be moderate in cost as it requires a High Voltage Constant Current Stimulator and EMG. Assessment of vibration hyperalgesia is considered to be moderate in cost as it requires a specialised vibrometer device.
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know		Primary HCPs can easily administer clinical versions of pain sensitivity assessments as part of routine consultation and with no additional costs. However, HCP training may be required to carry out the tests effectively.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ● Probably yes ○ Yes ○ Varies ○ Don't know	Not reported.	Some people may have a temporary increase in pain as a result of the assessment. However, healthcare professionals could use the assessments as education to explain how the test informs understanding of pain and in turn appropriate treatment. This is understood to improve acceptance by the person. *Consumers on the guideline panel find the recommended assessment acceptable.*
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations

○ No ○ Probably no ○ Probably yes ○ Yes ● Varies ○ Don't know	Not reported.	There are clinical alternatives to assessing pain sensitivity that do not require specialised equipment. E.g., descriptions and videos on how to perform a clinical version of cold hyperalgesia using ice is freely available from Whiplash Navigator https://mywhiplash.com.au/ HCP training may be required to carry out the tests effectively. At present, the CPM clinical test is not outlined on Whiplash Navigator but is available via a handout presented on http://www.specialistphysioeducation.net.au (Rebbeck et al. "How to assess for pain sensitisation in the clinic: neck and arm pain focus"). There may be scope to include guidelines for performing CPM assessment on Whiplash Navigator. NFR test may not be as feasible in clinical settings as it requires a High Voltage Constant Current Stimulator and EMG. Assessment of vibration hyperalgesia may not be feasible in clinical settings as it requires a specialised vibrometer device.

A.3.6. Conclusions (pain sensitivity in acute WAD)

VOTE 1: Assessment thermal hyperalgesia, pressure hyperalgesia, dynamic pain sensitivity, brachial plexus provocation test in people with acute WAD

Are you for or against healthcare professionals assessing the following: pain sensitivity tests in people with acute whiplash: thermal hyperalgesia, pressure hyperalgesia, dynamic pain sensitivity, brachial plexus provocation test?

Type of recommendation (thermal hyperalgesia, pressure hyperalgesia, dynamic pain sensitivity, brachial plexus provocation test in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	●	○

Recommendations

There was guideline panel consensus to suggest that Healthcare professionals assess the following test(s): thermal hyperalgesia (CPT, heat), pressure hyperalgesia (PPT), dynamic pain sensitivity testing (CPM), and Brachial Plexus Provocation Test (BPPT).

(Panel vote summary: 11/12 (92%), conditional for 1/12 (8%) neutral)

Justification

- Consistent findings were found across the included studies that suggest the presence of altered pain sensitivity in moderate-severe risk subgroups of people with acute WAD.
- Adverse effects for assessing pain sensitivity using these methods are likely trivial in magnitude.
- Findings for cold hyperalgesia were consistent with the prognosis section of these guidelines, where assessment of cold hyperalgesia was recommended for determining those at risk of poor prognosis (see prognosis section for pain sensitivity).
- Primary HCP's can administer clinical versions of pain sensitivity tests and conduct them as part of a routine consultation. These clinical tests are relatively low cost to administer.

Subgroups considerations

- Pain sensitivity assessments should be performed only for people at medium-to-high risk of poor recovery.

Implementation considerations

Indications:

- For people stratified as med/ high risk of poor outcome and / or when clinically indicated (e.g., widespread pain, reports of pain with non-noxious stimuli).

How to assess:

- Cold hyperalgesia[1]: Ice Pain Test (Rebbeck et al., 2015). Perform with ice and ask a NRS rating for pain. NRS>5/10 for pain considered cold hyperalgesia (Maxwell & Sterling, 2013).
- Pressure hyperalgesia[1]: Best performed using a pressure algometer.

- Brachial Plexus Provocation Test (BPPT)[1] is a clinical test to assess neural tissue sensitivity. The test can be modified to not go to end of range (i.e., avoid excessive overpressure).
- Conditioned Pain Modulation (CPM): refer to the description of the test in the handout (Rebbeck et al. "How to assess for pain sensitisation in the clinic: neck and arm pain focus") presented on the following website http://www.specialistphysioeducation.net.au.

Considerations:

- Healthcare professionals should be cautious about carrying out a provocative pain sensitivity testing in people who present with widespread pain as some people may have a temporary increase in pain as a result of the assessment.

Contraindications:

- Cervical radiculopathy contraindicates provocative tests (upper limb neural tension test – brachial plexus).

What to do if test positive:

- Educate person on the purpose of the assessment and if positive on the assessment, take the opportunity to educate the person about pain hypersensitivity.
- Use results to guide treatment – for example if positive some treatments may be contra-indicated (e.g., manual therapy), whilst others may be required (e.g., medication review / stronger medications - refer to pharmacological recommendations).
- Referral to whiplash specialist for management.
- Consider psychologically informed exercise interventions (see treatment recommendation).
- Online resources[1] are available for healthcare professionals to become familiar with how to do this, however some may require training to effectively implement and interpret the findings from these tests.

[1] More details on how to perform these tests are on MyWhiplashNavigator .

https://www.mywhiplash.com.au/content/higher-risk-assessments#pain-sensitivity

VOTE 2: Assessment vibration hyperalgesia, nociceptive flexion reflex in people with acute WAD

Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with acute whiplash: vibration hyperalgesia, nociceptive flexion reflex?

Type of recommendation (vibration hyperalgesia, nociceptive flexion reflex in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	●	○	○	○

Recommendation
There was guideline panel consensus to suggest that healthcare professionals do not assess the following test(s): vibration hyperalgesia (vibrometer), Nociceptive Flexion Reflex (NFR) in people with acute WAD. *(Panel vote summary: 9/12 (75%) conditionals against; 1/12(5%) strong against; 1/12 neutral (5%); 1/12 (5%) conditional for)* **Justification** • Vibration and NFR thresholds were shown to be lower in WAD groups compared with controls, however, these findings were from single studies. • NFR test is not feasible in clinical settings as it requires a High Voltage Constant Current Stimulator and EMG, and specialised training to administer. • Assessment of vibration hyperalgesia may not be feasible in clinical settings as it requires a specialised vibrometer device. **Subgroups considerations** n/a **Implementation considerations** n/a

Table 37: Evidence to decision framework (pain sensitivity chronic WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○ Trivial ○ Small ○ Moderate ○ Large ● Varies ○ Don't know	Strong evidence for pressure and thermal hyperalgesia, where people with WAD were significantly different from control group: • Pressure hyperalgesia: 10/11 independent studies showed lower pressure pain threshold in people with acute WAD. • Thermal hyperalgesia: 11/11 independent studies showed thermal hyperalgesia in people with chronic WAD. Moderate evidence for differences between groups for BPPT • Brachial plexus provocation test: 3/3 studies positive for Brachial Plexus Provocation Test in people with WAD. Dynamic pain sensitivity testing: 2/4 independent studies reduced conditioned pain modulation (CPM) tolerance in people acute WAD. Vibration: 2/3 studies demonstrated elevated vibration compared to control group.	Findings across the chronic WAD studies were consistent with systematic reviews and suggest the presence of altered pain sensitivity in people with chronic WAD compared with controls or other pain groups. These findings are greater in people with moderate-severe disability.
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported.	Pain sensitivity testing can temporarily cause or increase chronic pain, it is important for healthcare professionals to inform the person this may occur.
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations

○ Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ● Varies ○ Don't know	Probably favours assessing thermal hyperalgesia (CPT, heat), pressure hyperalgesia (PPT), and Brachial Plexus Provocation Test (BPPT). Does not favour either assessing or not assessing Dynamic pain sensitivity pain Probably favours not assessing vibration hyperalgesia and Nociceptive Flexion Reflex (NFR) (vibrometer) Consistent findings were found across the included studies that suggest the presence of altered pain sensitivity in people with moderate-severe disability Adverse effects are likely trivial in magnitude.	If HCPs know that a person is pain sensitive from these clinical tests, the findings can guide treatment direction (see recommendations for moderate-severe risk subgroups). The assessment should only be performed if it can be reasonably completed in the clinical setting and the person's clinical presentation indicates the need for assessment.
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ○Moderate costs ○ Negligible costs and savings ○ Moderate savings ○ Large savings ● Varies ○ Don't know	Not reported.	Some tests require specialised equipment and are associated with higher costs. However, there are valid alternatives to assessing pain sensitivity that do not require specialised equipment and are relatively lower in cost. For example, descriptions on how to clinically assess cold hyperalgesia using ice is freely available on Whiplash Navigator https://mywhiplash.com.au/ PPT can be assessed using a pressure algometer. CPM testing in the included studies utilises laboratory equipment (e.g., circulating ice bath). However, CPM testing be performed using a clinical alternative with a pressure cuff. NFR test is considered to be moderate in cost as it requires a High Voltage Constant Current Stimulator and EMG. Assessment of vibration hyperalgesia is considered to be moderate in cost as it requires a specialised vibrometer device.
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations

○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know		Primary HCP's can easily administer these the clinical versions of the pain sensitivity assessments as part of routine consultation and with no additional costs. However, HCP training may be required to carry out the tests effectively.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ● Probably yes ○ Yes ○ Varies ○ Don't know	Not reported.	Some people may have a temporary increase in pain as a result of the assessment. However, healthcare professionals could use the assessments as education to explain how the test informs understanding of pain and in turn appropriate treatment. This is understood to improve acceptance by the person.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ○ Yes ● Varies ○ Don't know	Not reported.	There are clinical alternatives to assessing pain sensitivity that do not require specialised equipment. E.g., descriptions and videos on how to perform a clinical version of cold hyperalgesia using ice is freely available from Whiplash Navigator https://mywhiplash.com.au/ HCP training may be required to carry out the tests effectively. At present, the CPM clinical test is not outlined on Whiplash Navigator but is available via a handout presented on http://www.specialistphysioeducation.net.au (Rebbeck et al. "How to assess for pain sensitisation in the clinic: neck and arm pain focus"). There may be scope to include guidelines for performing CPM assessment on Whiplash Navigator.

		NFR test may not be as feasible in clinical settings as it requires a High Voltage Constant Current Stimulator and EMG. Assessment of vibration hyperalgesia may not be feasible in clinical settings as it requires a specialised vibrometer device.

A.3.7. Conclusions (pain sensitivity in chronic WAD)

VOTE 1: Assessment thermal hyperalgesia, pressure hyperalgesia, brachial plexus provocation test in people with chronic WAD

Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with chronic whiplash: thermal hyperalgesia, pressure hyperalgesia, brachial plexus provocation test?

Type of recommendation (hyperalgesia, pressure hyperalgesia, brachial plexus provocation test in people chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	●	○

Recommendations
There was guideline panel consensus to suggest that Healthcare professionals assess the following test(s): thermal hyperalgesia (CPT, heat), pressure hyperalgesia (PPT), and Brachial Plexus Provocation Test (BPPT) in people with chronic WAD. *(Panel vote summary: 12/12 (100%) conditional for)* **Justification** • Consistent findings were found across the included studies that suggest the presence of altered pain sensitivity in people with chronic WAD. • Adverse effects for assessing pain sensitivity using these methods are likely trivial in magnitude. • These clinical tests are relatively low cost to administer.

Subgroups considerations

- More severe or likely in those with moderate-severe disability.

Implementation considerations

Indications:

- Pain sensitivity assessment should be performed if clinically indicated (e.g., widespread pain, reports of pain with non-noxious stimuli).

How to assess:

- Cold hyperalgesia[1]: Ice Pain Test (Rebbeck et al., 2015). Perform with ice and ask a NRS rating for pain. NRS>5/10 for pain considered cold hyperalgesia (Maxwell & Sterling, 2013).
- Pressure hyperalgesia[1]: Best performed using a pressure algometer.
- Brachial Plexus Provocation Test (BPPT)[1] is a clinical test to assess neural tissue sensitivity. The test can be modified to not go to end of range (i.e., avoid excessive overpressure).

Considerations:

- Healthcare professionals should be cautious about carrying out a provocative pain sensitivity testing in people who present with widespread pain as some people may have a temporary increase in pain as a result of the assessment.

Contraindications:

- Cervical radiculopathy contraindicates provocative tests (upper limb neural tension test – brachial plexus).

What to do if test positive:

- Educate person on the purpose of the assessment and if positive on the assessment, take the opportunity to educate the person about pain hypersensitivity.
- Use results to guide treatment – for example if positive some treatments may be contra-indicated (e.g., manual therapy), whilst others may be required (e.g. medication review / stronger medications).

- Online resources[1] are available for healthcare professionals to become familiar with how to do this, however some may require training to effectively implement and interpret the findings from these tests.

[1] More details on how to perform these tests are on MyWhiplashNavigator

https://www.mywhiplash.com.au/content/higher-risk-assessments#pain-sensitivity

VOTE2: Assessment dynamic pain sensitivity testing (CPM) in people with chronic WAD

Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with chronic whiplash: dynamic pain sensitivity test?

Type of recommendation (dynamic pain sensitivity testing in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong recommendation consensus for measuring the factor(s)
○	○	●	○	○

Recommendations

The guideline panel cannot reach consensus for or against assessing the *following test(s): dynamic pain sensitivity testing (CPM) in people with chronic WAD.*

(Panel vote summary: 11/12 (92%) neutral, 1 conditional (8%) for)

Justification

- Inconsistent evidence, however, consistent findings were found across the included studies that suggest the presence of altered pain sensitivity in Chronic WAD.
- Adverse effects for assessing pain sensitivity using these methods are likely trivial in magnitude.

Subgroup considerations

- More severe or likely in those with moderate to severe disability.

Implementation considerations

Indications:

- People with widespread pain, especially nociplastic pain type.

How to assess

- Conditioned Pain Modulation (CPM): refer to the description of the test in the handout (Rebbeck et al. "How to assess for pain sensitisation in the clinic: neck and arm pain focus") presented on the following website http://www.specialistphysioeducation.net.au.

Considerations

- Healthcare professionals should be cautious about carrying out a provocative pain sensitivity testing in people who present with widespread pain as some people may have a temporary increase in pain as a result of the assessment.

What to do if test positive:

- Educate person on the purpose of the assessment and if positive on the assessment, take the opportunity to educate the person about pain hypersensitivity.
- Use results to guide treatment – for example if positive some treatments may be contra-indicated (e.g., manual therapy), whilst others may be required (e.g., medication review / stronger medications. Treatments recommended for medium/high risk group should be considered (see treatment section).

Online resources[1] are available for primary HCPs to become familiar with how to do this, however some may require training to effectively implement and interpret the findings from these tests.

[1] More details on how to perform these tests are on MyWhiplashNavigator (www.mywhiplash.com.au)

VOTE 3: Assessment vibration hyperalgesia, nociceptive flexion reflex in people with chronic WAD

Are you for or against healthcare professionals assessing the following pain sensitivity tests in people with chronic whiplash: Nociceptive Flexion Reflex (NFR) and vibration hyperalgesia?

Type of recommendation (vibration hyperalgesia, nociceptive flexion reflex in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor(s)	Conditional consensus recommendation for either measuring the factor(s) or not	Conditional consensus recommendation for measuring the factor(s)	Strong consensus recommendation for measuring the factor(s)
○	●	○	○	○

Recommendation
There was guideline panel consensus to suggest that healthcare professionals do not assess the following test(s): Nociceptive Flexion Reflex (NFR) and vibration hyperalgesia in people with chronic WAD. *(Panel vote summary: 11/11 conditional against (100%)* **Justification** • Vibration and NFR thresholds were shown to be inconsistent in WAD groups compared with controls, however, these findings were from few studies. • NFR test is not feasible in clinical settings as it requires a High Voltage Constant Current Stimulator and EMG, and specialised training to administer. • Assessment of vibration hyperalgesia may not be feasible in clinical settings as it requires a specialised vibrometer device.

A.4. Additional psychological factors

What psychological clinical assessments assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.4.1. Executive summary

What Psychological Factors should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: 2 studies evaluated psychological in people with whiplash compared with controls or other pain conditions. There is 1 inception cohort study evaluated psychological factors in sub-groups of people with WAD. Summary of findings here:

- Fear avoidance: 1/1 study showed that the moderate/severe subgroup presents higher fear avoidance.
- Self-efficacy: 1/1 study showed decreased self-efficacy in people with acute WAD.

Chronic whiplash: 2 studies evaluated psychological in people with whiplash compared with controls or other pain conditions. One inception cohort study evaluated psychological factors in sub-groups of people with WAD. Summary of findings here:

- Mental Disorders: 1/1 study showed people with whiplash had a more significant number of diagnoses of mental disorders and the most common is depression.
- Positive Symptoms Distress: 1/1 study showed whiplash symptoms are similar to other types of trauma.
- Perceived cognitive deficits: 2/2 studies showed people with whiplash report cognitive deficits.

A.4.2. Acute additional psychological factors

Additional psychological factors

Category: additional psychological factors

Sub-category: Psychological factors (fear avoidance and self-efficacy) – Acute WAD studies (n=2)

Table 38: Summary of included studies (acute additional psychological factors)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Pedler & Sterling, 2011)	To examine the development of fear	Inception cohort study 98 people with acute WAD		Fear-avoidance	On both measures, the moderate/ severe group scored	People with moderate/severe symptoms showed	Significant

Assessing fear-avoidance beliefs in patients with whiplash-associated disorders: A comparison of 2 measures	avoidance behaviours after a whiplash injury	from mixed sources. People grouped on NDI		Tampa Scale of Kinesio-phobia (TSK-17) and the Pictoril Fear of Activity Scale (PFActS-C)	significantly higher than the mild and recovered groups. TSK-17 scores, age and initial pain intensity at baseline significantly predicted NDI scores at 6 months (P=0.002).	higher fear avoidance than those with lesser symptoms.	Moderate/ severe> lower symptoms
(Bunketorp-Kall et al., 2007) The impact of subacute whiplash-associated disorders on functional self-efficacy: a cohort study	To analyse whether subacute WAD has an impact on self-efficacy beliefs	47 people with subacute WAD (<6 weeks or >3 months (64% female)	212 age and sex-matched control group	Self-Efficacy Scale (SES)	Both the mean (P<0.001) and median (P<0.001) total scores of the SES were significantly higher in the control group than the WAD group.	People with subacute WAD exhibit a reduction in self-efficacy beliefs compared with control	Significant Decline Self-efficacy WAD> C

A.4.3. Acute additional psychological factors evidence summary

Table 39: Summary of evidence for included studies in acute additional psychological factors

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Fear-avoidance (Independent cohort n=1)	(Pedler & Sterling, 2011)	98 people with acute WAD and people grouped on NDI	Fear-avoidance Kinesiophobia	People with moderate/severe symptoms showed higher fear avoidance than those with lesser symptoms.	1- Sig

Self-efficacy (Independent cohort n=1)	(Bunketorp-Kall et al., 2007)	47 sub-acute WAD 212 controls	Self-Efficacy Self-Efficacy Scale (SES)	People with subacute WAD exhibit lower self-efficacy beliefs than the general population.	1- Sig

A.4.4. Chronic additional psychological factors

Additional psychological factors

Category: additional psychological factors

Sub-category: Psychological factors (mental disorders, psychological distress and cognitive deficits)– chronic and mixed WAD studies (>3mon) (n=4)

Table 40: Summary of included studies (chronic additional psychological factors)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Kivioja et al., 2004) Psychiatric morbidity in patients with chronic whiplash associated disorder.	Prospective cohort study to compare psychiatric morbidity in people with chronic WAD versus recovered controls	38 people with acute WAD (within 1wk) (47% female)	38 asymptomatic controls (47% female)	Mental Disorders Structured clinical interview for diagnostic and Statistical Manual of Mental Disorders (DSM-IV)	The chronic WAD group had a significantly greater no. of diagnoses on DSM IV Axis 1 compared to controls (22 vs 11, $p<0.05$). Also, chronic WAD group had greater Axis 1 diagnoses before the accident (13 vs 3, $p<0.01$). Most common diagnosis was depression.	Psychiatric symptoms pre- and post-injury may be a diagnostic factor for chronic WAD.	Significant Depression WAD> C
(Radanov et al., 2011)	Compared Symptom Checklist 90-Revised (SCL-	156 participants with WAD (82% female)	54 with pain due to other types of traumas (body	Positive Symptom Distress (PSD)	The WP and non-WP groups showed mean T scores in the	WAD symptoms seem to be similar to group with other types of trauma; the only	NS

Are symptoms of late whiplash specific? A comparison of SCL-90-R symptom profiles of patients with late whiplash and patients with chronic pain due to other types of trauma	90-R) symptom profiles of people with late whiplash and people with chronic pain due to other types of traumas		trauma such as a back or head concussion, lower limb fracture) (67% female)	SCL-90-R	pathological range for the dimensions "Somatization," "Obsessive-Compulsive," and PSD. Multivariable revealed headache (OR 1.54; 95% CI 1.16, 2.03; p = 0.003) and lower emotional lability (OR 0.96; 95% CI 0.93, 0.98; p =0.003) were the only significant variables.	difference is a headache.	
(Sullivan et al., 2002) Perceived cognitive deficits, emotional distress and disability following whiplash injury	To describe the pattern of perceived cognitive deficits in people with whiplash injury	29 people with chronic WAD Grade I or II (55% female)	24 work-injured people with soft tissue injuries. (55% women) 28 non-injured controls (55% female)	Perceived cognitive deficit. Perceived Deficits Questionnaire (PDQ)	Both patient groups scored significantly higher than the nonpatient control group on perceived cognitive deficits but did not differ significantly from each other. Anxiety and depression contributed significant unique variance to the prediction of perceived cognitive deficits.	People with WAD report significant cognitive difficulties	Significant Cognitive Deficits WAD >C
(Beeckmans et al., 2017) Persistent cognitive deficits after	To evaluate persistent cognitive deficits in people with whiplash injury	61 people with whiplash injury (64% females)	30 healthy controls (63% females) 57 people	Perceived cognitive deficits. Neuropsychological tests	In both patient groups, participants showed persistent cognitive symptoms. The WI group, as compared to the HC	People with whiplash injury might present with persistent cognitive deficits compared to healthy control.	Significant Cognitive Deficits WAD >C

whiplash injury: a comparative study with mild traumatic brain injury patients and healthy volunteers	(WI) and compare these to cognitive functioning in people with mild traumatic brain injury (MTBI) and healthy controls (HC).		(51% females) with MTBI	assessing cognitive domains (attention, memory, visuospatial functions and executive functions).	group, was found to be significantly more deficient in speed of performance during sustained and divided attention, focused attention, alternating attention, the storage of new auditory verbal unrelated information into memory, the long-term delayed recall of stored auditory-verbal related information from memory, abstract reasoning and accuracy of performance during planning and problem-solving.		

Footnote: (Pedler & Sterling, 2013)- People with chronic whiplash can be sub-grouped on the basis of symptoms of sensory hypersensitivity and posttraumatic stress excluded because investigate cluster groups

A.4.5. Chronic additional psychological factors evidence summary

Table 41: Summary of evidence for included studies in chronic additional psychological factors

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Mental disorder (depression) (Independent	(Kivioja et al., 2004)	38 acute WAD; 38 controls	Statistical Manual of Mental Disorders (DSM-IV)	The chronic WAD group had a significantly greater no. of diagnoses. Most common diagnosis was depression.	1 - Sig

cohort n=1)					
Psychological distress (Independent cohort n=1)	(Radanov et al., 2011)	156 WAD 54 other traumas	Positive Symptom Distress (PSD) SCL-90-R	WAD symptoms seem to be like another type of trauma; the only difference is a headache.	1 - NS
Cognitive deficits (Independent cohorts n=2)	(Sullivan et al., 2002)	29 WAD 24 soft tissue injury 28 controls	Cognitive deficits	Significant perceived cognitive difficulties demonstrated in people with WAD	2 - Sig
	(Beeckmans et al., 2017)	61 WAD 30 MTBI 30 controls	Cognitive deficits	People with whiplash injury might have more persistent cognitive deficits than healthy control.	

Table 42: Evidence to decision framework (additional psychological factors in acute WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
●Trivial ○Small ○ Moderate ○ Large ○ Varies ○ Don't know	The strength of association for psychological factors is overall inconclusive due to the low number of studies. Both studies were significant when comparing people with WAD to control groups, however, assessed different constructs (fear avoidance and self-efficacy).	Psychological factors are evaluated more consistently in prognostic cohort studies and intervention trials compared with cross-sectional designs, and psychological functioning is a critical outcome for these guidelines. Inconclusive findings were shown for fear avoidance and self-efficacy for determining those at risk of poor prognosis (see prognosis section evidence for further details).
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations

○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported	When assessing psychological factors, timing of screening those factors is important; screening too early (<1-month) might negatively influence the person's health outcome.
Balance of effects **Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?**		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ● Varies ○ Don't know	Does not favour either assessing or not assessing fear avoidance and self-efficacy in people with acute WAD.	Fear avoidance and self-efficacy had inconclusive evidence for determining those at risk of poor prognosis (see prognosis section evidence for further details).
Resources required **How large are the resource requirements (costs)?**		
Judgement	Research evidence	Additional considerations
○ Large costs ○ Moderate costs ● Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	In the research studies, the psychological factors were assessed using validated questionnaires. Fear avoidance: TSK-17 and the PFActS-C scale Self-efficacy: Self-Efficacy Scale (SES)	These questionnaires (fear avoidance and self-efficacy) are freely available online.
Equity **What would be the Impact on health equity?**		
Judgement	Research evidence	Additional considerations

○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	No evidence	Primary HCP'S can easily administer these questionnaires, however, not all are translated to all languages.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Most "assessment" studies do not report adverse events.	Some people might find it stressful to complete these questionnaires.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	No evidence.	It is feasible because the factors are assessed by questionnaire. However, it should not be assessed in all groups; more likely to be assessed in those who are medium-high risk of poor prognosis. General Practitioners may lack time to administer and interpret these questionnaires.

A.4.6. Conclusions (additional psychological factors in acute WAD)

VOTE1: Assessment of fear avoidance and self-efficacy in people with acute WAD

Are you for or against healthcare professionals assessing the following additional psychological factors in people with acute WAD: fear avoidance and self-efficacy?

Type of recommendation (fear avoidance and self-efficacy in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	●	○	○

Recommendations
The guideline panel cannot reach consensus for or against assessing the following additional psychological factors: fear avoidance and self-efficacy in people with acute WAD. *(Panel vote summary: 12/12 (100%) neutral)* **Justification** • Psychological factors are generally evaluated in a prognostic context and used to determine the probability of poor recovery, rather than to determine the differences between people with WAD and other groups (refer to prognostic section in the guidelines). There is therefore limited evidence in the assessment component of the guideline. • The two studies were significant, however, there is only one study for each construct and the findings are therefore inconclusive. • Inconclusive findings were shown for fear avoidance and self-efficacy for determining those at risk of poor prognosis (refer to prognostic section in the guidelines). **Subgroup considerations** • People who are stratified as “low risk” of poor recovery are unlikely to present with psychological distress. These people are unlikely to require assessment of these factors. • However, people with acute WAD who are stratified a “medium/high risk” of poor recovery might present the need for assessing psychological factors, depending on a person’s clinical presentation (refer to prognostic section recommendations). **Implementation considerations** *Indications*:

For people who are stratified as medium-high risk of poor prognosis. Consider if relevant to clinical presentation.

How to assess:

- Fear avoidance, using the TSK-17 and PFActS-C scale
- Pain Self Efficacy, using the Pain Self Efficacy Questionnaire (PSEQ).

What to do:

- PSEQ scores 30-40 (amber) – consider specific concerns and obstacles that the person might have (Prof. Michael Nicholas, University of Sydney, author communication).
- Manage the beliefs (fear avoidance and self-efficacy within management strategies).
- Consider psychologically informed exercise (see treatment recommendations).
- PSEQ scores of <30 indicates low confidence in the person's ability to resume functional activities while in pain. Consider multidisciplinary care (see treatment recommendations) to address obstacles. For context, mean PSEQ scores of people attending multidisciplinary pain clinics is ~21 (Prof Michael Nicholas, University of Sydney, author communication).
- Pain self-efficacy can be used to measure outcome in chronic phase.

https://www.mywhiplash.com.au/content/higher-risk-assessments#psychological-distress

Table 43: Evidence to decision framework (additional psychological factors in chronic WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
●Trivial ○Small ○ Moderate ○ Large ○ Varies	The strength of association for psychological factors is overall trivial due to limited evidence. There were significant differences in depression and cognitive deficits when comparing WAD to control groups. There was no significant difference in psychological distress	Psychological functioning is evaluated more consistently in prognostic cohort studies and intervention trials and is a critical outcome for these guidelines.

○ Don't know	(Positive Symptom Distress) when comparing WAD and control groups.	Screening for a probable major depressive disorder in people with acute WAD was recommended in the prognosis section of these guidelines.
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported	
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ● Varies ○ Don't know	Probably favours assessing for depression when considered in conjunction with evidence from prognostic cohort studies and the recommendation presented in these guidelines. Does not favour either assessing or not assessing for psychological distress symptoms and perceived cognitive deficits as the evidence was inconclusive.	Screening for a possible major depressive disorder was recommended to determine those at risk of poor prognosis.
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ○ Moderate costs ● Negligible costs and savings ○ Moderate savings	In the research studies, the factors were assessed using scales including: Cognitive deficits: Perceived Deficits Questionnaire (PDQ) Depression: DSM-IV	Those questionnaires are easy to interpret. PDQ consists of 20 items that generates a total score and 4 subscale scores (attention/concentration, retrospective memory, prospective memory, and planning/organization).

○ Large savings ○ Varies ○ Don't know		Each item is rated on a 5-point scale ranging from 0 (never) to 5 (almost always). Depressive symptoms can be evaluated using the DASS-21.
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	No evidence.	HCP's can easily administer these questionnaires, however, not all are translated to all languages.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Most "assessment" studies do not report adverse events.	Some people might find it stressful to complete these questionnaires
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations

○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	No evidence.	It is feasible because the factors are assessed by questionnaire. However, it should not be assessed in all groups; more likely to be assessed in those who are medium-high risk of poor prognosis. General Practitioners (GP) may lack time to administer and interpret these questionnaires.

A.4.7. Conclusions (additional psychological factors in chronic WAD)

VOTE 1: Assessment of depression in people with chronic WAD

Are you for or against healthcare professionals assessing the following psychological factors in people with chronic WAD: depression?

Type of recommendation (depression in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	●	○

Recommendations
There was guideline panel consensus to suggest that healthcare professionals assess the following depressive symptoms in people with chronic WAD. *(Panel vote summary: 11/12 (92%) conditional for, 1/12 (8%) neutral)* **Justification** • There were significant differences in diagnosis of depression in chronic WAD compared with a control group in a single study. • Screening for a probable major depressive disorder in people with acute WAD was recommended in the prognosis section of these guidelines. **Subgroups considerations** n/a

Implementation considerations
• Please refer to the prognosis section for psychological factors.

VOTE 2: Assessment of psychological distress symptoms and perceived cognitive deficits in people with chronic WAD.

Are you for or against healthcare professionals assessing the following psychological factors in people with chronic WAD: psychological distress symptoms and perceived cognitive deficits?

Type of recommendation (psychological distress symptoms and perceived cognitive deficits in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong recommendation consensus for measuring the factor(s)
○	○	●	○	○

Recommendations
The guideline panel cannot reach consensus for or against assessing the following: psychological distress symptoms and perceived cognitive deficits in people with chronic WAD. *(Panel vote summary: 12/12 (100% neutral)* **Justification** • There were 2/3 studies significant. However, there were only few studies per construct. • Psychological factors are usually used in term of prognostic context and to assist healthcare professionals to determine the probably of poor recovery rather than to determine differences between groups (refer to prognostic section in the guideline). **Subgroup considerations** n/a **Implementation considerations** *Indications:*

- Healthcare professionals might consider to additionally assess perceived cognitive deficit associated with depression if clinically indicated (e.g., if the person reports cognitive deficits). In these instances, recommendations are to use the – the Perceived Deficits Questionnaire Depression (PDQ-D) or 5-item version PDQ-D-5.

https://workingwithdepression.psychiatry.ubc.ca/leaps/perceived-deficits-questionnaire-pdq/

A.5. Additional Symptoms

What clinical assessments of additional symptoms assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.5.1. Executive summary

What Additional Symptoms should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: Two cross-sectional studies evaluated symptoms in people with whiplash compared with controls or other pain conditions. Summary of findings here:

- Additional symptoms: 1/1 study showed patients present a higher prevalence of symptoms in people with WAD.
- Sleep quality: 1/1 study suggestive sleep disturbance in people with acute WAD.

Chronic whiplash: 4 cross-sectional studies evaluated symptoms in people with whiplash compared with controls or other pain conditions. Summary of findings here:

- Additional symptoms: 1/1 study indicates a higher prevalence of additional symptoms in people with WAD (e.g., dizziness).
- Jaw symptoms: 1/1 independent cohort showed patients present a higher frequency of jaw symptoms in people with WAD.
- Disabilities: 1/1 study indicates a higher prevalence of upper limb symptoms in people with WAD.

A.5.2. Acute additional symptoms

Additional symptoms

Category: Additional symptoms

Subcategories: Additional ssymptoms - Acute and Subacute WAD studies (n=2)

Table 44: Summary of included studies (acute additional symptoms)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Pajediene et al., 2015)	To investigate acute WAD in the Lithuanian population	71 people with acute WAD (<14d) (62% female)	53 controls with no history of car accidents	Additional Symptoms	93% of patients developed acute symptoms.	Road traffic accidents induce whiplash-associated disorder in people who seek help	Significant Symptoms

Patterns of acute whiplash-associated disorder in the Lithuanian population after road traffic accidents	unaware of the phenomenon.		(62% female)		The most frequent symptoms were neck or shoulder pain; reduced or painful neck movements, including decreased range of motion; multiple subjective symptoms according to QTFQ and significantly reduced pain threshold.	but who are unaware of the condition WAD.	WAD> C
(Valenza et al., 2012) Alteration in Sleep Quality in Patients with Mechanical Insidious Neck Pain and Whiplash-Associated Neck Pain	This study aimed to determine differences in sleep quality between people with mechanical neck pain, people with WAD, and healthy controls	22 people with acute (mean 22 days duration – paper table 1 WAD) (82% female)	18 healthy controls (78% female) 19 people with mechanical neck pain (79% female)	Sleep quality Pittsburgh Sleep Quality Index	People with WAD and mechanical neck pain group exhibited higher score in sleep quality (P < 0.001), sleep latency (P = 0.005), sleep efficiency (P = 0.002), sleep disturbances (P < 0.001), use of sleeping medication (P < 0.001), daytime dysfunction (P <0.001), and total Pittsburgh Sleep Quality Index score (P < 0.001) compared to healthy control	Sleep disturbances are a common finding in individuals with neck pain	Significant Sleep disturbance WAD>C

Excluded: Tannoury 2001 - Comparison acute WAD, illustrative finite element analyses of the neuraxis under conditions of deformative stress are presented in the two comparison groups of WAD

A.5.3. Acute additional symptoms evidence summary

Table 45: Summary of evidence for included studies in acute additional symptoms

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Additional Symptoms (Independent cohort n=1)	(Pajediene et al., 2015)	71 people with acute WAD 53 controls	Number of symptoms	93% of patients developed acute symptoms (Multiple symptoms)	1 – Sig
Sleep disturbance (Independent cohort n=1)	(Valenza et al., 2012)	22 WAD 19 mechanical neck pain 10 healthy controls	Pittsburgh Sleep Quality Index	Sleep disturbances are a common finding in individuals with neck pain	1 – Sig

A.5.4. Chronic additional symptoms

Additional symptoms

Category: Additional symptoms

Subcategories: Additional Symptoms - Chronic and mixed WAD studies (>3mon) (n=4)

Table 46: Summary of included studies (chronic additional symptoms)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Anstey et al., 2016) Are people with whiplash-associated neck pain different from people with nonspecific neck pain?	To compare people with WAD to people with nonspecific neck pain, in terms of their baseline characteristics	488 people with WAD (68% female)	2090 people with non-specific neck pain (NSNP) (59% female)	Additional Symptoms Activity limitation Dizziness Morning stiffness	People with WAD were statistically different from people with NSNP for all characteristics investigated (P<.006), except for	Individuals presenting to secondary care with persistent WAD experience greater symptom severity and poorer long-	Significant

	and pain and disability outcomes over 1 year				frequency of neck pain (P = .094). Most substantial differences between groups were the presence of dizziness and memory difficulties	term outcomes than those with NSNP	
(Haggman-Henrikson et al., 2011)* Frequent jaw-face pain in chronic Whiplash-Associated Disorders	To investigate the frequency of jaw-face pain and general symptoms	50 subjects with WAD (78% female)	50 control subjects	Jaw symptoms The jaw-face-head region and frequency of general symptoms. Multiple symptoms	88% of people with WAD reported frequent pain in the jaw-face, frequent pain in the neck (100%), shoulders (94%), head (90%) and back (27%). The people with WAD also reported stiffness and numbness in the jaw-face region and frequent general symptoms such as balance problems, stress, and sleep disturbances.	Frequent pain in the jaw and face can be part of the spectrum of symptoms in chronic WAD.	Significant Jaw and face symptoms WAD>C

(Gronqvist et al., 2008)* Impaired jaw function and eating difficulties in whiplash-associated disorders	To test the hypothesis of an association between neck injury and impaired eating behaviour	50 subjects with WAD (78% female)	50 control subjects	Eating dysfunction	People with WAD after the accident, reported pain and dysfunction during mouth symptoms, biting chewing, swallowing and yawning and felt fatigue, stiffness and numbness in the jaw-face region.	Suggest an association between neck injury and disturbed jaw function.	
(See & Treleaven, 2015) Identifying upper limb disability in patients with persistent whiplash	To identify symptoms and the degree and nature of UL functional difficulties.	24 people with chronic WAD (>3mo) (87.5% female)	24 asymptomatic controls (75% female)	Disabilities Disabilities of the Arm, Shoulder and Hand (DASH)	The results suggest that upper limb (UL) symptoms and functional deficits are prevalent in persistent WAD. All individual item scores on the DASH, except one, were significantly higher in the WAD group and the control group	Indicate the presence of upper limb symptoms in persistent WAD as well as limb functional difficulties.	Significant UL WAD>C

*2 papers reported on the same cohort - Haggman-Henrikson 2011 and Gronqvist 2008

A.5.5. Chronic additional symptoms evidence summary

Table 47: Summary of evidence for included studies in chronic additional symptoms

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Additional Symptoms (Independent cohort n=1)	(Anstey et al., 2016)	488 WAD 2090 people with non-specific neck pain (NSNP)	Activity limitation Dizziness Morning stiffness	Persistent WAD experience greater symptom severity and poorer long-term outcomes than those with NSNP	1 – Sig
Jaw symptoms (Independent cohort n=1)	(Haggman-Henrikson et al., 2011) (Gronqvist et al., 2008)	50 WAD 50 controls	Reported frequent of jaw and face symptoms	Frequent pain in the jaw and face can be part of the spectrum of symptoms in chronic WAD.	1 – Sig
Disability (Independent cohort n=1)	(See & Treleaven, 2015)	24 WAD 24 controls	Upper limb disabilities (DASH)	Indicate the presence of upper limb symptoms in persistent WAD as well as limb functional difficulties.	1 – Sig

Table 48: Evidence to decision framework (additional symptoms in acute and chronic WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○Trivial ●Small ○ Moderate ○ Large ○ Varies ○ Don't know	Consistent findings across the included studies showing increased jaw symptoms, upper limb disability, and sleep disturbance in WAD. Although all acute and chronic studies showed significance when comparing WAD to control groups, what they assessed varied across all studies.	
Undesirable Effects **How substantial are the undesirable anticipated effects associated with the assessment method?**		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported	Requires only questionnaire and/or self-report symptoms (e.g. DASH, Pittsburgh Sleep Quality Index).

Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
○ Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ● Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Probably favour assessing. Although what they assessed varied across all studies, healthcare professionals might assess symptoms depending on the person's individual presentation.	
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ○ Moderate costs ● Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	The research studies assessed disability due to upper limb pain and sleep quality using validated questionnaires: Disabilities of the Arm, Shoulder and Hand (DASH) Pittsburgh Sleep Quality Index (PSQI	These questionnaires (DASH AND PSQI) are freely available online.
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations

○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	No evidence.	Primary HCP'S can easily administer these questionnaires, however, not all are translated to all languages.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Most "assessment" studies do not report adverse events.	Some people might find it stressful to complete these questionnaires.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know	Most studies do not report adverse events.	It is feasible because a questionnaire assesses the factors. However, it should be assessed depending on the persons presentation.

A.5.6. Conclusion (additional symptoms in acute and chronic WAD)

VOTE1: Assessment of other symptoms (jaw, upper limb sleep quality) in people with acute and chronic WAD

Are you for or against healthcare professionals assessing the following additional symptoms in people with acute and chronic WAD: jaw symptoms, upper limb disabilities, sleep quality??

Type of recommendation (other symptoms in people with acute and chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendations for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
○	○	○	●	○

Recommendations
There was guideline panel consensus to suggest that healthcare professionals assess the following additional symptoms in people with acute and chronic WAD. *(Panel vote summary: 10/12 (83%) condition for, 2/12 (17%) neutral)*

Justification

- Studies were significant. However, there is only one study for each construct, and the findings are small.
- Assessing additional symptoms is usual practice for healthcare professionals to ask people about.
- Those symptoms are frequently reported in other musculoskeletal conditions, e.g., sleep disturbance.

Subgroups considerations

n/a

Implementation considerations

- Assessing symptoms is part of routine history. HCPs are already recommended to assess pain intensity, neck disability, pain sites, number of symptoms and specific symptoms such as headache and dizziness.
- HCPs should be aware that other areas that may be symptomatic are the aw and upper limb. Sleep quality/ disturbance is also recommended to be assessed.

How to assess:

- Sleep Quality: Pittsburgh Sleep Quality Index (PSQI)
- Disability of the Arm Shoulder and Hand (DASH) to assess person's ability to perform upper limb activities.

What to do:

- If sleep quality is impaired: It's important to help people understand that sleep issues are common and manageable and that negative thoughts about sleep can worsen symptoms. Encourage small steps towards better sleep routines and check how sleep issues are affecting physical therapy. If sleep deprivation is severe, check their safety for certain activities (e.g., driving). Suggest they speak to their GP about sleep issues and consider seeing a psychologist for targeted support. Self-guided sleep resources can also be helpful as a starting point or while waiting for professional help.

A.6. Advanced medical testing

What advanced medical testing methods assist in: a) classifying the grade of whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.6.1. Executive summary

What Advanced medical testing should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: Two prospective studies evaluated advanced medical testing in people with whiplash compared with controls or other pain conditions. Those two studies evaluated WAD subgroups. Summary of findings here:

- Stress hormone: 1/1 study found cortisol concentration in people with WAD score II–III was lower than in people with WAD score I.
- Inflammatory biomarkers: 1/1 study found the recovered/mild disability WAD group had higher levels of tumour necrosis factor alpha (TNF-α) at both time points than the moderate/severe WAD group and healthy controls, and 2/2 studies found a higher percentage of the inflammatory biomarker in people with acute WAD than controls.

Chronic whiplash: 5 cross-sectional studies advanced medical testing in people with whiplash compared with controls or other pain conditions. There is 1 study that evaluated advanced medical testing in sub-groups of people with WAD. Summary of findings here:

- Stress hormone: 1/1 study found dysregulation of hypothalamus pituitary adrenal (HPA) in people with WAD.
- Inflammatory biomarkers: 1/1 study found higher C11 (S-(+)-(d)-D-deprenyl (DDE) retention in people with whiplash in tissue regions adjacent to the spinous process and vertebra.
- Cerebral flow: 1/2 studies found lowered temporo-occipital blood flow in people with acute WAD than controls.
- Others: 1/1 study (Nerve fibre density) suggests small fibre structural and functional deficits in chronic and 1/1 study - Genetic marker- Individuals with a COMT pain vulnerable genotype were more likely to report moderate- to-severe musculoskeletal neck, headache and dizziness

A.6.2. Acute advanced medical testing

Stress hormone

Category: Advanced medical testing

Sub-category: Stress hormone – Acute and Subacute WAD studies (n=1)

Table 49: Summary of included studies (acute stress hormone)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Shaked et al., 2020) Can cortisol levels predict the severity of acute whiplash-associated disorders?	This prospective observational study was to investigate the relationship between acute serum cortisol concentrations and the severity of whiplash-associated disorders.	55 people) with acute WAD (<6h from injury) (45.5% female 36 WAD I 17 WAD II 12 WAD III		Stress hormone Serum cortisol concentration Blood sampling	The mean cortisol concentration of the people with WAD score 2–3 was significantly lower compared to the WAD 1, 9.5±6.9 vs. 13.22±8.3 µg% (p=0.02). The mean cortisol concentrations increased significantly from mild through moderate to serious grade of severity of accident as perceived by the person, 9.64±4.82, 11.59±6.85, 17.39±12.1 µg% (p=0.02).	The mean cortisol concentration of the people with WAD score 2–3 was significantly lower compared to the people with whiplash-associated disorder score 1. Low or relatively low cortisol concentrations might be associated with more severe forms of the disorder	WAD I ≠ WAD II-III*

Inflammatory biomarkers

Category: Advanced medical testing

Sub-category: Inflammatory biomarkers– Acute and Subacute WAD studies (n=2)

Table 50 Summary of included studies (acute inflammatory biomarkers).

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant

(Sterling et al., 2013) The Course of Serum Inflammatory Biomarkers Following Whiplash Injury and Their Relationship to Sensory and Muscle Measures: A Longitudinal Cohort Study	This study aimed to prospectively investigate changes in serum inflammatory biomarker levels from the acute (3 months) stages of whiplash injury	44 people with acute WAD (<3mo) (75% female)	18 asymptomatic controls (78% female)	Inflammatory Biomarkers Venous blood sampling	The recovered/mild disability WAD group had higher levels of TNF-α at both time points than both the moderate/severe WAD group and healthy controls. There were no differences found in serum IL-1β. Moderate relationships were found between hyperalgesia and CRP at both time points and between hyperalgesia and IL-1β 3 months post-injury.	Inflammatory biomarkers may play a role in outcomes following whiplash injury and WAD associated with hyperalgesia and fatty muscle infiltration in the cervical extensors.	Significant
(Kivioja, Rinaldi, et al., 2001) Chemokines and their receptors in whiplash injury: Elevated RANTES and CCR-5	To investigate involvement of the immune system in WAD	29 people with acute WAD (<4d) (34% female)	14 healthy controls (50% female)	Inflammatory Biomarkers Flow cytometry	Higher percentages of blood mononuclear cells (MNC) and T cells observed in people with WAD at 3 days post-injury compared with healthy controls ($p<0.05$). No differences between groups at 14 days.	Compared to healthy controls, acute WAD is associated with systemic but transient dysregulation in MNC and T cells.	Significant

(Kivioja, Ozenci, et al., 2001) Systemic immune response in whiplash injury and ankle sprain: elevated IL-6 and IL-10	To investigate involvement of the immune system in WAD, ankle sprain, MS and healthy subjects	27 people with acute WAD (33% female)	14 people with acute ankle sprain (35% female) 27 people with multiple sclerosis (66% female) 23 healthy controls (69% female)	Inflammatory Biomarkers Blood Cytokine-secreting cells.	Higher percentages of blood mononuclear (MNC) cells observed in people with WAD at 3 days post-injury compared with healthy controls ($p<0.01$). Similar results obtained for people with ankle sprain ($p<0.01$) versus healthy controls. Changes in MNC dissipate at 14 days.	Acute WAD is associated with systemic but transient dysregulation in MNC. Similar responses are found in people with acute ankle sprain.	Significant

A.6.3. Acute advanced medical testing evidence summary

Table 51: Summary of evidence for included studies in acute medical testing

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Stress hormone (Independent cohorts n=1)	(Shaked et al., 2020)	36 WAD I; 17 WAD II; 12 WAD III	Cortisol levels	Low or relatively low cortisol concentrations in WAD 2-3 compared to WAD 1.	WAD I ≠ WAD II-III*
Inflammatory biomarkers (Independent cohorts n=3)	(Sterling et al., 2013)	44 acute WAD; 18 controls	Inflammatory Biomarkers Venous blood sampling	Inflammatory biomarkers may play a role in outcomes following whiplash injury and WAD associated with hyperalgesia and fatty muscle infiltration in the cervical extensors.	3 – Sig
	(Kivioja, Rinaldi, et al., 2001)	29 acute WAD; 14 controls	Inflammatory Biomarkers Flow cytometry	Acute WAD is associated with systemic but transient dysregulation in MNC, and T cells compared to healthy controls.	

	(Kivioja, Ozenci, et al., 2001)	27 acute WAD; 14 acute ankle sprains 27 multiple scleroses 23 controls	Inflammatory Biomarkers Cytokine-secreting cells.	Acute WAD is associated with systemic but transient dysregulation in MNC. Similar responses are found in people with acute ankle sprain.	

A.6.4. Chronic advanced medical testing

Stress hormone

Category: Advanced medical testing

Sub-category: Stress hormone – Chronic and mixed WAD studies (n=1)

Table 52: Summary of included studies (chronic stress hormone)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Gaab et al., 2005) Reduced reactivity and enhanced negative feedback sensitivity of the hypothalamus pituitary adrenal (HPA) axis in chronic WAD	To investigate endocrine abnormalities in chronic WAD versus healthy controls	20 people) with chronic WAD (>6mo) (50% female)	20 healthy controls (50% female)	Stress hormone Serum cortisol concen-tration saliva sampling	People with chronic WAD demonstrated dysregulation of the HPA axis (through attenuated cortisol responses on awakening and suppression of cortisone after administration of dexamethasone) when compared to healthy controls.	People with chronic WAD demonstrated dysregulation of the HPA axis (through attenuated cortisol responses on awakening and suppression of cortisone after administration of dexamethasone) when compared to healthy controls.	Significant

Inflammatory biomarkers

Category: Advanced medical testing

Sub-category: Inflammatory biomarkers – Chronic and mixed WAD studies (n=1)

Table 53: Summary of included studies (chronic inflammatory biomarkers)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Linnman et al., 2011) Elevated [11C]-D-deprenyl uptake in chronic Whiplash Associated Disorder suggests persistent musculoskeletal inflammation	Explores if C11 (S-(+)-(d)-D-deprenyl (DDE) retention is elevated in the neck region in people with chronic WAD as compared to pain-free controls.	22 participants with WAD II (>6 months) (75% female)	14 healthy controls (75% female) 6 people with acute musculoskeletal pain (sprained ankle) (50% female)	Biomarkers 3D dynamical PET-CT (Carbon-11 marked DDE)	People with WAD had significantly higher DDE retention than controls in tissue regions adjacent to spinous process of the second vertebra (right C2 ROI p= 0.008, left C2 ROI p= 0.015), in the normal muscle tissue (p = 0.027) and in the peak soft tissue ROI (p = 0.035), but similar levels in the in the spongeus bone of the cervical vertebra (p = 0.48)	WAD has signs of local persistent peripheral tissue inflammation, which may serve as a diagnostic biomarker.	Significant

Cerebral blood flow

Category: Advanced medical testing

Sub-category: Cerebral blood flow Chronic and mixed WAD studies (n= 2 studies)

Table 54: Summary of included studies (chronic cerebral blood flow)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Linnman et al., 2009)	To compare resting state regional cerebral blood	21 participants with WAD II (>6 months) (80% female)	18 healthy controls (50% female)	Cerebral blood flow	Patients had heightened resting rCBF bilaterally in the posterior	Suggest an involvement of the posterior cingulate, parahippocampal and	Significant WAD <C

Chronic whiplash symptoms are related to altered regional cerebral blood flow (rCBF) in the resting state	flow (rCBF) by means of positron emission tomography with 15O labelled water in people with WAD with controls.			Positron emission tomography (PET)	parahippocampal and the posterior cingulate gyri, in the right thalamus and the right medial prefrontal gyrus as well as compared with healthy controls. The altered rCBF in the patient group was correlated to neck disability ratings	medial prefrontal gyri in WAD and speculate that alterations in the resting state are linked to an increased self-relevant evaluation of pain and stress.	
(Sundstrom et al., 2006) Altered cerebral blood flow in chronic neck patients but not in whiplash patients: a 99mTc-HMPAO rCBF study	To compare cerebral blood flow in people with chronic WAD, people with chronic neck pain (without trauma) and healthy controls	27 people with chronic WAD (67% women)	18 people with chronic neck pain (72% women) 15 healthy controls (47% women)	Cerebral blood flow Single photon emission computed tomography (SPECT) using technetium99m hexamethylpropylene amine oxime (HMPAO)	Significant regional blood flow changes in chronic neck pain group, no change in WAD or healthy controls ($p<0.05$).	Differences in blood flow suggest different pain mechanisms for chronic neck pain and WAD groups.	NS

Chronic - Others

Category: Advanced medical testing

Sub-category: Others – Chronic and mixed WAD studies (n= 2 studies)

Table 55: Summary of included studies (chronic others)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(F Scott et al., 2020) Small fibre pathology in chronic whiplash-associated disorder: A cross-sectional study	Small fibre pathology in chronic whiplash-associated disorder: A cross-sectional study	24 people with chronic (>3mo) WAD (67% female)	24 pain-free controls (67% female)	Skin biopsy Nerve fibre density	The WAD group exhibited lower IENFD at the finger (WAD: median [IQR] 4.5 [4.9] fibres/mm; control 7.3 [3.9]; p = .010), but not the ankle (WAD: mean [SD] 7.3 [3.7] fibres/mm; control 9.3 [3.8]; p = .09). Dermal innervation was lower in the WAD group at the finger (WAD: median [IQR] 3.7 [2.8] nerve bundles/mm2 ; controls: 4.9 [2.1]; p = .017) but not the ankle (WAD: median [IQR] 2.1 [1.9] nerve bundles/mm2 ; controls: 1.8 [1.8]; p = .70). In the WAD group, hand thermal and light touch detection were impaired, and heat pain thresholds were lowered (p ≤ .037).	Findings suggest small fibre structural and functional deficits in chronic WAD, implicating potential involvement of small fibre pathology	Significant
(McLean et al., 2011) COMT haplotype	COMT haplotype predicts immediate musculoskelet	89 people with acute WAD (54% females)	People sub-grouped on COMT genotype.	Blood test Genetic marker (COMT)	Individuals with a COMT pain vulnerable genotype were more likely to report moderate- to-	The identification of genes associated with post-MVC symptoms may also provide	Significant

predicts immediate musculoskeletal neck pain and psychological symptoms after MVC	al neck pain and psychological symptoms after MVC				severe musculoskeletal neck pain (76 versus 41%, RR = 2.11 (1.33 - 3.37)), moderate or severe headache (61 versus 33%, RR = 3.15 (1.05 - 9.42)), and moderate or severe dizziness (26 versus 12%, RR = 1.97 (1.19 - 3.21)). Individuals with a pain vulnerable genotype also experienced more dissociative symptoms in the ED, and estimated a longer time to physical recovery (median 14 versus 7 days, p = .002) and emotional recovery (median 8.5 versus 7 days, p = .038)	new insights into pathophysiology.	

A.6.5. Chronic advanced medical testing evidence summary

Table 56: Summary of evidence for included studies in chronic advanced medical testing

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Stress hormone (Independent cohort n=1)	(Gaab et al., 2005)	20 patients 20 Control	Cortisol levels	Chronic WAD patients demonstrated dysregulation of the HPA axis through attenuated cortisol.	1 – Sig

Inflammatory biomarkers (Independent cohort n=1)	(Linnman et al., 2011)	22 acute WAD; 6 sprained ankles 14 controls	Inflammatory biomarker	WAD have signs of local persistent peripheral tissue inflammation	1 – Sig
Cerebral blood flow (Independent cohorts n=2)	(Linnman et al., 2009)	21 WAD II 18 controls	Positron emission tomography (PET)	Altered regional cerebral blood flow in resting state in WAD	1 – Sig 1 – NS
	(Sundstrom et al., 2006)	27 WAD 18 chronic neck pain 15 controls	Single photon emission computed tomography (SPECT)	No alteration to regional cerebral blood flow detected in chronic WAD subjects	
Others (Independent cohorts n=2)	(F Scott et al., 2020)	24 WAD 24 Control	Skin biopsy Nerve fibre density	Suggest small fibre structural and functional deficits in chronic WAD, implicating potential involvement of small fibre pathology.	2 – Sig
	(McLean et al., 2011)	89 WAD People sub-grouped on COMT genotype	Genetic marker (COMT)	Individuals with a COMT pain vulnerable genotype were more likely to report moderate- to-severe musculoskeletal neck, headache and dizziness	

Table 57: Evidence to decision framework (advanced medical testing in acute WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○Trivial ●Small ○ Moderate ○ Large ○ Varies ○ Don't know	Stress hormone: people with WAD score 2–3 was significantly lower compared to the WAD I Inflammatory biomarkers: Significant differences in inflammatory biomarker levels in people with WAD compared with controls (3/3 studies).	These studies are more exploratory studies that investigate the mechanism instead of being a validated accuracy diagnostic study. Acute inflammatory responses are expected post-injury.
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations

○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Saliva and blood tests are required to evaluate stress hormone and inflammatory biomarkers. Undesirable effects not reported in studies but are likely to be trivial.	
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
● Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Differences in stress hormone and inflammatory biomarkers were found, however, the studies are more explanatory and not diagnostic accuracy studies.	
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ○ Moderate costs ● Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	Not reported.	Saliva and blood tests are relatively low cost
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations

○ Reduced ○ Probably reduced ● Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	No evidence.	Saliva and blood tests are generally available.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know		Saliva and blood tests are in routine use in clinical settings.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ● Yes ○ Varies ○ Don't know		Saliva and blood tests are in routine use in clinical settings.

A.6.6. Conclusion (advanced medical testing in acute WAD)

VOTE1: Assessment of stress hormone and inflammatory biomarkers in people with acute WAD

Are you for or against healthcare professionals assessing the following advanced medical testing in people with acute WAD: stress hormone and inflammatory biomarkers?

Type of recommendation (stress hormone and inflammatory biomarkers in people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
●	○	○	○	○

Recommendations
There was strong guideline panel consensus that primary healthcare professionals do not assess the following in people with acute WAD. *(Panel vote summary: 11/12 92% strong against; 1/112 8% conditional against)* **Justification** • These studies are more explanatory studies and not diagnostic studies. Therefore, it would not help diagnose WAD conditions or the treatment direction. • Only a few studies and weak evidence.

Table 58: Evidence to decision framework advanced medical testing in chronic WAD

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○Trivial ●Small ○ Moderate ○ Large ○ Varies ○ Don't know	Although most chronic studies showed significance when comparing WAD to control groups, what they assessed, and the technique used varies across all studies. Stress hormone (cortisol): only one study comparing chronic WAD to control. Inflammatory biomarkers: Only one study showed higher DDE retention than controls in the spinous process of the second vertebra and muscle tissue. Cerebral blood flow: Inconclusive evidence, with 1/2 studies showing cerebral blood flow than the control group.	These studies are more exploratory studies investigating the mechanism instead of being a validated accuracy diagnostic study.

	Skin biopsy (nerve fibre density) – only one study showing small fibre structural and functional deficits in WAD. Genetic marker - Individuals with a COMT pain vulnerable genotype were more likely to report moderate- to-severe musculoskeletal neck pain, headache and dizziness	
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Saliva and blood tests are required to evaluate stress hormones and inflammatory biomarkers. Undesirable effects not reported in studies but are likely to be trivial for all assessment types	
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
● Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Differences in the stress hormone, inflammatory biomarkers, genetic marker, and nerve fibre density were found in people with WAD versus controls. Inconclusive evidence for cerebral blood flow. However, the studies are more explanatory and not diagnostic accuracy studies.	
Resources required How large are the resource requirements (costs)?		
Judgement	Research evidence	Additional considerations
○ Large costs ○ Moderate costs ○ Negligible costs and	Not reported.	Saliva and blood tests are relatively low cost. PET, SPECT, genetic assessment, and skin biopsy are associated with moderate costs.

savings ○ Moderate savings ○ Large savings ● Varies ○ Don't know		
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
○ Reduced ○ Probably reduced ○ Probably no impact ○ Probably increased ○ Increased ● Varies ○ Don't know	No evidence.	Saliva and blood tests are generally available. PET, SPECT, genetic assessment, and skin biopsy are less accessible and costlier, and require specialised equipment and training.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
○ No ○ Probably no ○ Probably yes ○ Yes ● Varies ○ Don't know	No included evidence.	Saliva and blood tests are in routine use in clinical settings. PET and SPECT are in routine use and are likely acceptable. Skin biopsy may not be acceptable for routine assessment.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations

○ No ○ Probably no ○ Probably yes ○ Yes ● Varies ○ Don't know	No included evidence.	Saliva and blood tests are in routine use in clinical settings. PET, SPECT, genetic assessment, and skin biopsy are less accessible and costlier and require specialised equipment and training.

A.6.7. Conclusion (advanced medical testing in chronic WAD)

VOTE1: Assessment of stress hormone, inflammatory biomarkers, blood flow, skin biopsy and genetic markers in people with chronic WAD

Are you for or against healthcare professionals assessing the following advanced medical testing in people with chronic WAD: stress hormone and inflammatory biomarkers, blood flow, skin biopsy and genetic markers?

Type of recommendation (stress hormone, inflammatory biomarkers, blood flow, skin biopsy and genetic markers in people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
●	○	○	○	○

Recommendations
The panel recommends not assessing any stress hormone, inflammatory biomarkers, blood flow, skin biopsy, or genetic markers. *(Panel vote summary: 11/12 92% strong against; 1/12 8% conditional against)*

Justification

- Although most chronic studies showed significance when comparing WAD to control groups, what they assessed, and the technique used varies across all studies.
- Only a few studies assess people with WAD compared to the control group.

- Saliva and blood tests are generally available. However, PET, SPECT, genetic assessment, and skin biopsy are less accessible and costlier and require specialised equipment and training.

A.7. Imaging

What imaging methods assist in: a) classifying the grade of acute whiplash associated disorders; b) determining dysfunction in people with acute or chronic whiplash associated disorders compared with other populations (e.g., healthy, idiopathic neck pain); c) determining the direction of treatment(s); and/or d) evaluating the effectiveness of treatment intervention(s).

A.7.1. Executive summary

What specialised Imaging should healthcare professionals assess in people with acute and chronic whiplash?

Acute whiplash: 6 studies evaluated imaging in people with whiplash compared with controls or other pain conditions. There is 1 study that evaluated symptoms/disability sub-groups. Summary of findings here:

- Morphology - Structure changes: 2/3 independent cohorts showed structured changes (e.g., alar and transverse ligament) in people with WAD.
- Morphology - Muscle Fat Infiltration (MFI): 1/1 study showed at 3 months higher MFI in cervical neck extensor muscle in people with WAD in the sub-group of moderate/severe disability.
- Morphology - Muscle size: 1/1 study showed no difference in the cross-sectional area of neck muscle in people with acute WAD.
- Muscle stiffness: 1/1 study showed increased muscle stiffness in the trapezius in people with acute WAD.

Chronic whiplash: 38 cross-sectional studies evaluated imaging in people with whiplash compared with controls or other pain conditions. Summary of findings here:

- Morphology - Structure changes: 2/5 independent cohorts showed structured changes (e.g., alar and transverse ligament) in people with WAD.
- Morphology - Structure changes (others): 2/3 independent cohorts of structure changes (e.g., cervical spine meniscoid, jaw injury bone) in people with WAD
- Morphology - Muscle Fat Infiltration (MFI): 6/6 independent cohorts showed higher MFI in cervical extensor muscle in people with WAD.
- Morphology - Muscle size: 2/5 independent studies showed neck muscle cross-sectional area differs in people with WAD.
- Muscle morphology (Ultrasound): 2/2 independent cohorts of higher neck muscle deformation in people with WAD.
- Metabolites measured by Magnetic resonance spectroscopy (MRS): 1/2 studies showed metabolic changes in the spinal cord in people with WAD.
- Brain structure: 2/3 independent cohorts showed changes in brain structure or connectivity in people with WAD.

- Nerve mobility: 1/2 study showed reduced median nerve sliding in people with WAD.
- Others: 1/1 study reported rotatory CT has a low diagnostic value for chronic WAD.

A.7.2. Acute imaging

Morphology structures changes

Category: Imaging

Sub-category: Morphology structure changes – acute/subacute WAD studies (n= 4 studies)

Table 59: Summary of included studies (acute morphology structure changes)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Erika Jasmin et al., 2011) Alterations of the Transverse Ligament: An MRI Study Comparing Patients With Acute Whiplash and Matched Control Subjects	To evaluate whether there is an injury to the transverse ligament of the atlas in people with acute whiplash	90 people with acute WAD (50% female)	90 healthy controls	Morphology Cervical structures Transverse ligament MRI	WAD had a minimally thicker transverse ligament than control subjects (only in men was a significant p = 0.03). WAD, signal alteration of the transverse ligament (p = 0.03) was seen on STIR (post-traumatic oedema) and native VIBE sequences. The contrast between the transverse ligament and the CSF on VIBE images was significantly (p = 0.005) lower in WAD than in control subjects. With the application of a	Possible involvement of the transverse ligament in acute WAD	Significant Morphology alterations WAD>C

					contrast agent, the contrast difference between the transverse ligament and CSF WAD and control subjects were less pronounced (p = 0.038).		
(Vetti, Krakenes, Damsgaard, et al., 2011)* Magnetic resonance imaging of the alar and transverse ligaments in acute whiplash-associated disorders 1 and 2: a cross-sectional controlled study	To describe alar- and transverse-ligament magnetic resonance imaging (MRI) high-signal changes in WAD grades 1 and 2 in relation to the severity and mechanics of trauma and to compare them with controls	114 consecutive people with WAD grades I-II (57% female)	157 controls (48% female)	Morphology Cervical structures Alar ligament Transverse ligament MRI	MRI showed grades 2 to 3 alar ligament changes in 40 (35.1%) and grades 2 to 3 transverse ligament changes in 27 (23.7%) WADS. Such changes were related to contemporary head injury (p = 0.041 alar), neck pain (p = 0.042 transverse), and sex (p= 0.033 transverse) but did not differ between WAD and controls (p = 0.433 alar; and 0.254 transverse)	No difference between WAD and controls, indicating that whiplash trauma does not induce high signal changes	NS
(Vetti, Krakenes, Ask, et al., 2011)* Follow-Up MR Imaging of the Alar and Transverse	To explore changes in the signal intensity of the alar and transverse ligaments during the first year after a whiplash injury	91 participants with WAD II-III (58% female)	52 participants with neck pain (>3 months)	Morphology Cervical structures Alar ligament Transverse ligament	Alar and transverse ligament grading were unchanged from the initial to the follow-up. images. The prevalence of grades 2–3 high signal intensity in WAD was thus	Dedicated upper neck MR imaging cannot be recommended as a routine examination in these people.	

Ligaments after Whiplash Injury: A Prospective Controlled Study				MRI	identical in the acute phase and after 12 months. It did not differ from the prevalence in no injured neck pain controls (alar ligaments P= .151; transverse ligament P=- 1.000).		
(Anderson et al., 2012) Are there cervical spine findings at MR imaging that are specific to acute symptomatic whiplash injury? A prospective controlled study with four experienced blinded readers	To compare the magnetic resonance (MR) imaging findings in people with acute whiplash injury with those in matched control subjects.	100 people with acute (<48h) WAD (53% female)	100 healthy controls (53% female)	Morphology Cervical structures Vertebral body, muscle strain or tear, perimuscular fluid MRI	MR imaging findings significantly associated with whiplash injuries were occult fracture (P < .01), bone marrow contusion of the vertebral body (P = .01), muscle strain (P <.01) or tear (P < .01), and the presence of perimuscular fluid (P <.01). While 10 findings thought to be specific for whiplash trauma were significantly (P <.01) more frequent in patients (507 observations), they were also regularly found in healthy control subjects (237 observations).	MR imaging at 1.5 T reveals only limited evidence of specific changes to the cervical spine and the surrounding tissues in people with acute symptomatic whiplash injury compared with healthy control subjects.	Significant WAD>control structural observations

**2 papers reported the same cohort – Vetti, Krakenes, Damsgaard, et al., 2011, Vetti, Krakenes, Ask, et al., 2011

Morphology muscle fat infiltration

Category: Imaging

Sub-category: Morphology Muscle Fat Infiltration (MFI) - acute/subacute WAD studies (n= 1 study)

Table 60: Summary of included studies (acute morphology muscle fat infiltration)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Elliott et al., 2011) The Temporal Development of Fatty Infiltrates in the Neck Muscles Following Whiplash Injury: An Association with Pain and Posttraumatic Stress	To 1) investigate the temporal development of MFI following whiplash injury 2) investigate differences in MFI between those who recover and those who report persistent symptoms at six months post injury	44 people with acute WAD classified on NDI (74% female) NDI scores at 6-months post-injury as either recovered (NDI,10%), mild (NDI 10–28%) or moderate/severe (NDI ≥30%).		Muscle Fat Infiltration Cervical extensor muscles MRI	There was no difference in muscle fat between the groups at 4 weeks post-injury. By 3 months, those with moderate/severe symptoms had higher levels of muscle fat ($p<0.01$) Muscle fat may develop between 4 and 12 weeks in those with moderate-severe pain and disability	MFI in the cervical extensors occur soon following whiplash injury and suggests the possibility for the occurrence of a more severe injury with subsequent PTSD in people with persistent symptoms.	Significant Differences in subgroup

Morphology muscle size

Category: Imaging

Sub-category: Morphology Muscle Size - acute WAD studies (n= 1 study)

Table 61: Summary of included studies (acute morphology muscle size)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant

(Ulbrich et al., 2011) Cervical muscle area measurements in acute whiplash patients and controls	To quantitatively compare the muscle cross-sectional areas (CSAs) of the cervical muscles in people with symptomatic acute whiplash versus healthy controls	38 consecutive people with acute WAD (50% female)	38 controls (50% female)	Muscle recruitment Cervical muscle area Cross-sectional areas (CSA) MRI	There were no significant differences between people with acute WAD and controls for all CSAs	There was no difference in the cross-sectional area of neck muscles	NS

Muscle stiffness

Category: Imaging

Sub-category: Muscle Stiffness - acute/subacute WAD studies (n= 1 study)

Table 62: Summary of included studies (acute muscle stiffness)

Author Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Aljinovic et al., 2020) Can measuring passive neck muscle stiffness in whiplash injury patients help detect false whiplash claims?	To investigate the difference in neck muscle stiffness using shear wave ultrasound elastography between subjects who suffered an uncomplicated whiplash injury and a control group	75 people with acute (<3mo) WAD (57% female)	75 healthy controls (55% female)	Muscle stiffness Shear wave elastography (SWE) Ultrasound (US)	Increased muscle stiffness in trapezius muscle bilaterally in the whiplash group when compared to the control group (p< 0.001). People with less than 76 kPa of muscle stiffness in trapezius muscle are unlikely to belong to WAD group (sensitivity 90% for right and 97% for	People measuring below 76 kPa of muscle stiffness in the trapezius muscle might have no whiplash injury.	Significant Stiffness WAD>C

					left trapezius muscle, specificity 72% and 73%, respectively).		

A.7.3. Acute imaging evidence summary

Table 63: Summary of evidence for included studies in acute imaging

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Morphology Structure changes (Independent cohorts n=3)	(Erika Jasmin et al., 2011)	90 acute WAD 90 controls	Cervical structures transverse ligament - MRI	Possible involvement of the transverse ligament in acute WAD.	2- Sig 1 - NS
	(Vetti, Krakenes, Damsgaard, et al., 2011)*	114 WAD grades I-II 157 controls	Cervical structures Alar and transverse ligament - MRI	No difference between WAD and controls, indicating that whiplash trauma does not induce high signal changes	
	(Vetti, Krakenes, Ask, et al., 2011)*	91 WAD grades I-II 52 neck pain	Cervical structures Alar and transverse ligament - MRI	The prevalence of high signal WAD 2-3 similar in acute and at 12 months and did not differ from the prevalence of noninjury neck pain controls	
	(Anderson et al., 2012)	100 WAD 100 controls	Cervical structures Bone and muscle - MRI	Limited evidence of specific changes to the cervical spine and the surrounding tissues in people with acute compared to control.	
Morphology Muscle Fat Infiltration (Independent cohort n=1)	(Elliott et al., 2011)**	44 people with acute WAD were subclassified as recovered, mild and moderate/ severe based on NDI.	Cervical extensor muscles - MRI	People with WAD in the moderate/severe disability group at 3 months showed an increased in MFI in cervical extensor muscles	1 - Sig
Morphology Muscle size	(Ulbrich et al., 2011)	38 WAD 38 controls	Cervical muscle area	There was no difference in the cross-sectional area of neck muscles	1 - NS

(Independent cohort n=1)			Cross-sectional area -MRI		
Muscle stiffness (Independent cohorts n=1)	(Aljinovic et al., 2020)		Trapezius muscle Shear wave elastography- US	People with less than 76 kPa of muscle stiffness in trapezius muscle are unlikely to belong in the WAD group	1 - Sig

*2 papers reported same cohort – Vetti, Krakenes, Damsgaard, et al., 2011, and Vetti, Krakenes, Ask, et al., 2011; ** Subgroups

A.7.4. Chronic imaging

Morphology structure changes

Category: Imaging

Sub-category: Morphology Structure changes - Chronic and mixed WAD studies (>3mon) (n=8 studies)

Table 64: Summary of included studies (chronic morphology structure changes)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Main Outcome	Comments	Significant
(Dullerud et al., 2010) Magnetic resonance imaging of ligaments and membranes in the craniocervical junction in whiplash-associated injury and in healthy control subjects	Assess MRI signal alterations of the ligaments and loss of integrity of the membranes in the craniocervical junction in people with WAD and compare them with uninjured control subjects.	28 participants with WAD (60% female)	27 uninjured controls subjects (59% female)	Morphology Cervical structures Alar ligament Transverse ligament Craniocervical membranes MRI	No statistically significant difference between control subjects and people with WAD was revealed for any of the structures assessed (p <0.10).	Lack of significant differences between groups. It is not recommended that MRI with the current technique and classification system be used in the routine workup of people with WAD.	NS

(Kaale et al., 2005a)* Head position and impact direction in whiplash injuries: associations with MRI verified lesions of ligaments and membranes in the upper cervical spine	To compare MRI abnormalities with accident-related factors	92 people with chronic WAD (64% female)	30 healthy controls (63% female)	Morphology Cervical structures Alar ligament Transverse ligament Craniocervical membranes MRI	People with WAD had more high-grade lesions than controls ($p<0.05$).	People with WAD had more high-grade lesions than controls	Significant Damage WAD>C
(Kaale et al., 2005b)* Whiplash Associated Disorders impairment rating: neck disability index score according to the severity of MRI findings of ligaments and membranes in the upper cervical spine	To relate MRI findings with pain and disability ratings from the NDI	92 people with chronic WAD (64% female)	30 healthy controls (63% female)	Morphology Cervical structures Alar ligament Transverse ligament Craniocervical membranes MRI	The NDI score significantly increased with signs on MRI ($p=0.002$). An increase in NDI score with increasing number of structures (ligaments, membranes) with high-grade MRI changes was significant ($p=0.003$).	High-resolution MRI can show structural damage correlated to NDI score.	
(Krakenes et al., 2003)*	To analyse and classify structural	92 people with chronic WAD (64% female)	30 healthy controls (63% female)	Morphology	22 out of 32 ligaments in control group (73%) were	A higher proportion of transverse ligament	

MR analyses of the transverse ligament in the late stage of whiplash injury	changes in transverse ligaments in chronic WAD using high-resolution MRI			Cervical structures Alar ligament Transverse ligament MRI	classified as normal, compared with 32 of 9the 2 in WAD group (36%).	damage in WAD group.	
(Knackstedt et al., 2012) Magnetic resonance imaging of craniovertebral structures: clinical significance in cervicogenic headaches	To investigate the relevance of morphological changes in the main stabilising structures of the craniocervical junction in persons with cervicogenic headache (CEH)	22 people with chronic WAD (59% female)	46 people with chronic cervicogenic headache (CEH) (78% female) 19 people with chronic migraine (89% female)	Morphology Cervical structures Alar ligament Transverse ligament MRI	MRI of the craniovertebral and the cervical junctions, the alar and transverse ligaments disclosed no significant differences between those with CEH, WLaH and or migraine.	Morphological MRI changes in craniovertebral ligaments showed similar frequency in people with CEH compared. to those with WLaH and/or migraine	NS
(Lindgren et al., 2009) Dynamic kine magnetic resonance imaging in whiplash patients and in age- and sex-matched controls	To compare the findings and motion patterns in the upper cervical spine, 25 people with whiplash trauma with longstanding pain, limb symptoms and loss of balance, indicating a problem at the	25 participants with WAD (75% female)	25 control participants (75% female)	Morphology Cervical structures Alar ligament Transverse ligament MRI	The signal from the alar ligaments was abnormal in 92% of the people with WAD and in 24% of the control subjects (P<0.0001). Abnormal movements at the level of C1-C2 were more common in people with WAD than in controls (56% versus 20%, P=0.028).	People with WAD with longstanding symptoms had both more abnormal signals from the alar ligaments and more abnormal movements in the dMRI at the C0-C2 level than control	Significant Damage WAD>C

	level of C0-C2, as well as matched healthy controls						
(Myran et al., 2008)** Magnetic resonance imaging assessment of the alar ligaments in whiplash injuries: a case-control study	Assessing signal intensity areas in the alar ligaments.	59 participants with WAD I-II (>6 months). (59% female)	57 with chronic nontraumatic neck pain (>6 months) (66% female) 57symptomatic subjects (49% female)	Morphology Cervical structures Alar ligament MRI	Alar ligament changes Grades 0 to 3 were seen in all 3 diagnostic groups. Areas of high signal intensity (Grade 2–3) were found in at least one alar ligament in 49% of the people with WAD Grade I–II, in 33% of the chronic neck pain group and in 40% of the control group (X^2, P = 0.22).	No significant difference in alar ligament signal intensity changes on MRI between WAD, people with chronic neck pain and subjects without neck pain or previous neck trauma	NS
(Myran et al., 2011) ** Clinical Characteristics, Pain, and Disability in Relation to Alar Ligament MRI Findings	To evaluate the association between degree of signal changes in the alar ligaments on MRI with respect to pain and disability.	59 participants with WAD I-II (>6 months) (59% female)	57 with chronic nontraumatic neck pain (>6 months) (66% female) 57asymptomatic subjects (49% female)	Morphology Cervical structures Alar ligament MRI	No significant correlation between the alar ligament changes and measures for pain and disability	The diagnostic value and the clinical relevance of MR-detectable areas of high intensity in the alar ligaments remain questionable.	

*3 papers reported same cohort Kaale 2005a, Kaale 2005b, Krakenes 2003; **2 papers reported the same cohort Myran 2008, Myran 2011

Morphology structure changes - others

Category: Imaging

Sub-category: Morphology Structure changes – Others -Chronic and mixed WAD studies (>3mon) (n=3 studies)

Table 65: Summary of included studies (chronic morphology structure changes - others)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Farrell et al., 2016) Morphology of cervical spine meniscoid in individuals with chronic whiplash-associated disorder: A case-control study	To investigate cervical spine meniscoid morphology in individuals with chronic WAD.	20 people with chronic (>3mo) WAD (50% female)	20 healthy controls (50% female)	Morphology Cervical Meniscoid morphology MRI	Lateral atlantoaxial joints, median meniscoid length was greater in the control group (ventral, 6.07 mm; dorsal, 7.24 mm) than the WAD group (ventral, 5.01 mm; P = .06; and dorsal, 6.48 mm; P<.01). At the dorsal aspect of zygapophyseal joints, meniscoid were more frequently fibrous in the chronic WAD group.	Cervical spine meniscoid display morphological differences in a chronic WAD compared to age- and sex-matched controls.	Significant Damage WAD>C
(Grushka et al., 2007) Radiographic and clinical features of temporomandibular dysfunction in patients following indirect trauma: A retrospective study	To determine clinical and radiographic differences between post-MVA and people with nontraumatic temporomandibular dysfunction (TMD)	54 subjects with WAD (80% female)	82 non-trauma TMD (84% female)	Morphology TMD disc changes MRI	The MRI and bone scan data demonstrated significant differences between the 2 groups in a number of features. Most notably, MRI findings demonstrated a significantly higher incidence of disk changes in the control group	Post-MVA patients demonstrate no evidence of jaw injury by bone scan and MRI study.	Significant (against) Disk changes WAD <C

					compared with the post-MVA group.		
(Lee et al., 2018) Magnetic resonance imaging-based prediction of the relationship between whiplash injury and temporomandibular disorders	Evaluate whether the initial clinical findings in people with temporomandibular disorders (TMD) with whiplash injury are correlated with their magnetic resonance imaging (MRI) characteristics.	76 people with WAD and TMD (wTMD) (71% female)	58 people with post-traumatic TMD (43% female) 85 people with idiopathic TMD (67 % female)	Morphology TMD disc changes MRI	The lateral pterygoid muscle (LPM) atrophy was most seen in the wTMD group, as was disk deformity.	WAD may lead to TMD via different mechanisms from other macrotraumas.	Significant Disk changes WAD >C

Morphology muscle fat infiltration

Category: Imaging

Sub-category: Morphology Muscle Fat Infiltration - Chronic and mixed WAD studies (>3mon) (n=8 studies)

Table 66: Summary of included studies (chronic morphology muscle fat infiltration)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Abbott et al., 2015) The geography of fatty infiltrates within the cervical multifidus and semispinalis	To quantify the magnitude and distribution of muscle fat infiltration (MFI) within the cervical multifidus and semispinalis cervicis muscles in participants	5 people with chronic (60% female)	5 people who have recovered from WAD) (60% female) 5 healthy controls (60% female)	Muscle Fat Infiltration Neck muscles MRI	Muscle fat infiltration is more concentrated in all participants' medial portion of the muscles. However, the magnitude of MFI in the medial quartiles (1 and 2) is greatest in the chronic WAD group,	Preliminary evidence of unique patterns of MFI distribution within the deep extensor muscles of individuals with chronic WAD, individuals who have recovered from a whiplash injury, and healthy controls	Significant MFI WAD> C

cervicis in individuals with chronic whiplash-associated disorders	with chronic WAD compared to those who have fully recovered from a whiplash injury and healthy controls.						
(Abbott et al., 2018) The qualitative grading of muscle fat infiltration in whiplash using fat and water magnetic resonance imaging	To establish a qualitative MRI measure for MFI and evaluate its ability to differentiate between individuals with severe whiplash-associated disorder (WAD), mild or moderate WAD, and healthy controls	31 people with chronic (>6mo) WAD (55% female)	31 healthy controls (55% female)	Muscle Fat Infiltration Neck muscles MRI	Significant differences ($p<0.05$) in regional MFI were particularly notable between the severe WAD group and healthy controls.	Increased MFI within the cervical multifidus muscles of individuals with persistent WAD compared to those with milder symptoms and healthy controls.	Significant MFI WAD> C
(Elliott et al., 2006)* Fatty infiltration in the cervical extensor muscles in persistent whiplash	To quantitatively compare the presence of fatty infiltrate in the cervical extensor muscles in people with chronic WAD II	79 people with chronic WAD (>3mo) (100% female)	34 healthy controls (100% female)	Muscle Fat Infiltration Neck muscles MRI	WAD subjects had significantly larger amounts of fatty infiltrate for all cervical extensor muscles compared with controls (all $p<0.0001$).	Greater fatty deposits in cervical extensor muscles of people with chronic WAD.	Significant MFI WAD> C

associated disorders	and healthy controls						
(Elliott et al., 2010)* Magnetic Resonance Imaging Findings of Fatty Infiltrate in the Cervical Flexors in Chronic Whiplash	To quantify physical structure changes MFI and CSA of the anterior cervical muscles (longus colli, longus capitis, and sternocleidomastoid [SCM] muscles) in people with chronic WAD compared to healthy controls	78 people with chronic WAD (>3mo) (100% female)	31 healthy controls (100% female)	Muscle Fat Infiltration Neck muscles MRI	The WAD subjects had significantly larger MFI and CSA for the anterior muscles than healthy control subjects (all P < 0.0001). In addition, the amount of MFI varied by both cervical level and muscle, with the longus capitis/colli having the largest amount of fatty infiltrates at the C2–C3 level (P = 0.0001).	Greater MFI and CSA in the anterior neck muscles, especially in the deeper longus capitis/colli muscles, in subjects with chronic WAD when compared to healthy controls	
(Elliott, Sterling, et al., 2008) Fatty infiltrate in the cervical extensor muscles is not a feature	To Investigate the presence of fatty infiltrate in the cervical extensor musculature in people with insidious onset neck pain to	79 WAD subjects (100% female)	23 insidious-onset neck pain (<3 months) (100% female)	Muscle Fat Infiltration Cervical extensor Decision tree to distinguish groups	Differences in the fat indices of all muscles in WAD participants demonstrated significantly higher amounts of total fatty infiltration when compared with the insidious-onset	Fatty infiltrates in the cervical extensor musculature, and widespread hyperalgesia have been identified in people with chronic WAD. Classification tree	Significant MFI WAD>C

of chronic, insidious-onset neck pain	better understand the possible pathophysiology underlying such changes in chronic WAD				neck pain participants ($p < 0.001$). The analysis revealed that the strongest features distinguishing the two groups were (1) the fat index scores and (2) CPT	determined that the insidious-neck pain group could be clearly distinguished from the WAD group based on average muscular fat and cold pain thresholds.	
(Karlsson et al., 2016)** An Investigation of Fat Infiltration of the Multifidus Muscle in Patients With Severe Neck Symptoms Associated With Chronic Whiplash-Associated Disorder	To develop a method using water/fat MRI to investigate fat infiltration and cross-sectional area of multifidus muscle in individuals with WAD compared to healthy controls	31 people with chronic WAD (>6mo)	31 healthy controls	Muscle Fat Infiltration Multifidus Muscle MRI	WAD with severe disability had 38% greater muscular fat infiltration compared to healthy controls (P = .03) and 45% greater fat infiltration compared to those with mild to moderate disability related to WAD (P=0.02). There were no significant differences between those with mild to moderate disability and healthy controls. No significant differences between groups were found for multifidus cross-sectional area.	Participants with severe disability after a whiplash injury had higher fat infiltration in the multifidus compared to controls and to those with mild/moderate disability secondary to WAD.	Significant MFI WAD severe disability> C
(Karlsson et al., 2019)** The relation between	To investigate the relationship between fat infiltration in	31 people with chronic WAD (>6mo) (55% female)	31 healthy controls (55% female)	Muscle Fat Infiltration Cervical multifidi and	No significant differences ($p = 0.11$) in the lower extremities MFI	WAD has a local effect on muscle fat infiltration rather than a generalized one.	

local and distal muscle fat infiltration in chronic whiplash using magnetic resonance imaging	the cervical multifidi and fat infiltration measured in the lower extremities to move further into understanding the complex signs and symptoms arising from a whiplash trauma			lower extremities MRI	between the groups were found.		
(Valera-Calero et al., 2021) Echo-intensity, fatty infiltration, and morphology ultrasound imaging assessment in healthy and whiplash associated disorders populations: an observational study	Echo-intensity, fatty infiltration, and morphology ultrasound imaging assessment in healthy and whiplash associated disorders populations: an observational study	41 people with chronic (>6mo) WAD (70.8% female)	39 healthy controls (44% female)	Muscle Fat Infiltration Cervical multifidus and short rotators Ultrasound (US) imaging	Between-groups differences in both cervical multifidus (CM) and short rotators (SR), were observed for fatty infiltration percentage (mean: 4.9%; P<0.001; mean: 3.5%; P<0.05, respectively) and mean EI (mean: 4.1; P<0.001; mean: 3.2; P<0.05, respectively): people with WAD exhibited higher fatty infiltration than controls.	US assessment of deep cervical extensors revealed greater fatty infiltration, but no differences in muscle morphology, between people with WAD and pain-free controls.	Significant MFI WAD>C

*2 studies Elliott 2006 and Elliott 2010 same cohort
** 2 studies Karlsson 2016 and Karlsson 2019 same cohort

Morphology muscle size

Category: Imaging

Sub-category: Morphology Muscle Size - Chronic and mixed WAD studies (>3mon) (n=6 studies)

Table 67: Summary of included studies (chronic morphology muscle size)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Cagnie et al., 2010) Use of muscle functional magnetic resonance imaging to compare cervical flexor activity between patients with whiplash-associated disorders and people who are healthy	Compare the recruitment pattern of deep and superficial neck flexors between p with WAD and the control group using muscle functional magnetic resonance imaging (mfMRI)	16 people with WAD with ≥6 months (69% female)	19 healthy controls (48% female)	Muscle recruitment Cervical flexor mfMRI	When comparing the WAD and control groups, the results lacked significance, although the people with WAD demonstrated a trend for lower T2 shifts in both the longus colli (Lco), longus capitis (Lca), (p<.060)	Failed to demonstrate a changed activity pattern in the WAD group compared with the control group	NS
(Elliott, Jull, et al., 2008)* MRI study of the cross-sectional area for the cervical	To measure the cross-sectional area (CSA) of cervical extensor muscles, (2) determine	79 subjects with WAD (100% female)	34 healthy controls (100% female)	Muscle recruitment Cervical extensor Cross sectional area (CSA)	The cervical multifidus muscle in the WAD group had a significantly larger rCSA at all spinal levels and in contrast, there were variable differences	WAD group show quantifiable alterations in rCSA of the cervical paraspinal musculature that differ significantly from subjects with no history of neck pain.	Significant rCSA WAD>C

extensor musculature in patients with persistent whiplash associated disorders	whether there was a difference in CSA between WAD and healthy control			MRI	in rCSA measures across levels in the intermediate and superficial extensor muscles when compared to the healthy controls (Po<0.0001).		
(Elliott et al., 2014)* Differential changes in muscle composition exist in traumatic and nontraumatic neck pain	To clarify relative constituents of viable muscle in 2-dimensional cross-sectional area (CSA) measures of ventral and dorsal cervical muscles in people with chronic WAD idiopathic neck pain, and healthy controls.	79 people with chronic WAD (>3mo) (100% female)	23 people with chronic idiopathic neck pain (>3mo) (100% female) 34 healthy controls (100% female)	Muscle recruitment Neck muscle -CSA MRI	Without fat removed, relative CSA of 7 of 14 muscle regions in the participants with chronic WAD was larger, 3 of 14 smaller and 4 of 14 similar to healthy individuals. When T1-weighted signal representing the lipid content of these muscles was removed, 8 of 14 relative muscle CSA in people with whiplash were similar, 5 of 14 were smaller and only 1 of 14 was larger than those observed in healthy controls. Removal of fat from the relative CSA measurement did not alter findings between participants with idiopathic neck pain and healthy controls.	Generalized cervical muscle hypertrophy in people with chronic WAD is likely due to heightened levels of fatty infiltrate within the muscles.	

(Matsumoto et al., 2010)** Prospective ten-year follow-up study comparing patients with whiplash-associated disorders and asymptomatic subjects using magnetic resonance imaging	To clarify long-term impact of whiplash injury on a person's symptoms and on magnetic resonance imaging (MRI) findings of the cervical spine	133 people with WAD (53% female)	223 control subjects (45% female)	Muscle recruitment Cervical Spine-CSA MRI	There was no difference in the change in CSA over time between the symptomatic and asymptomatic people.	Although some people with WAD are more likely to suffer from long-lasting neck pain, MRI findings cannot explain the symptoms	NS
(Matsumoto et al., 2012)** Cross-sectional area of the posterior extensor muscles of the cervical spine in whiplash injury patients versus healthy volunteers--10-year follow-up MR study	To elucidate the changes in the posterior extensor muscles 10 years after whiplash injury.	23 people with WAD (43% female)	60 control subjects (40% female)	Muscle recruitment Posterior extensor muscles - CSA MRI	The mean change in CSA over time was 361.8 ± 804.9 mm2 in the people with whiplash and 218.1 ± 520.7 mm2 in the controls (p = 0.34). There was no the difference in the change in CSA over time between the symptomatic and asymptomatic people.	There was no significant difference in the change in CSA between people with whiplash and healthy volunteers after a 10-year follow-up period.	

(Van Looveren et al., 2021) Changes in Muscle Morphology in Female Chronic Neck Pain Patients Using Magnetic Resonance Imaging	Understanding changes in muscle morphology in people with chronic idiopathic neck pain (CINP) and chronic WAD (CWAD)	37 people with chronic WAD (100% female)	45 people with chronic (>3mo) idiopathic neck pain 35 healthy controls (HC)	Muscle recruitment Neck muscle (CSA) MRI	A significantly larger cross-sectional area was found in some extensor (levator scapulae, semispinalis capitis, trapezius) and flexor (longus colli, longus capitis, sternocleidomastoid) muscles in the HC group compared to the CINP and/or CWAD group.	Suggest changes in muscle morphology in both neck pain cohorts.	Significant rCSA WAD<C

*2 studies Elliott 2008 and Elliott 2013 same cohort.

** 2 studies Matsumoto 2010 and Matsumoto 2012 same cohort

Muscle morphology ultrasound

Category: Imaging

Sub-category: Muscle morphology (Ultrasound) - Chronic and mixed WAD studies (>3mon) (n=3 studies)

Table 68: Summary of included studies (chronic muscle morphology ultrasound)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Peterson et al., 2016) Changes in Dorsal Neck Muscle Function in Individuals	To compare mechanical neck muscle function, deformation and deformation rate in five	40 people with chronic WAD (>6mo) (70% female)	40 healthy controls (70% female)	Muscle Morphology Neck muscle Ultrasound (US)	The WAD group had higher deformation rates in the multifidus muscle during the first ($p < 0.04$) and 10th (only women, $p < 0.01$) arm elevations	We found that individuals with WAD have higher deformation rates in the multifidus muscle compared with healthy controls.	Significant Deformation WAD>C

with Chronic Whiplash-Associated Disorders: A Real-Time Ultrasound Case-Control Study	dorsal neck muscles in individuals with chronic WAD versus healthy controls during repetitive arm elevation				compared with the control group.		
(Peolsson et al., 2016) Multivariate analysis of ultrasound-recorded dorsal strain sequences: Investigation of dynamic neck extensions in women with chronic whiplash associated disorders	To compare the strain of dorsal multilayer neck muscles in individuals with chronic WAD and matched healthy controls, during a standardised dynamic resisted neck extension.	9 people with chronic WAD (100% female)	9 healthy controls (100% female)	Muscle Morphology Neck muscle US During neck extensions	The WAD group showed more shortening during the neck extension phase in the trapezius muscle and during both the neck extension and the return to neutral phase in the multifidus muscle < 0.01.	An altered mechanical strain of the trapezius and multifidus muscles in individuals with WAD, compared with healthy controls when performing a standardised low-loaded neck extension.	
(Rahnama et al., 2018) Alterations in the Mechanical Response of Deep Dorsal Neck Muscles in Individuals Experiencing	To investigate and compare the mechanical responses of dorsal neck muscles in individuals with WAD versus healthy individuals.	36 people with chronic WAD (72% female)	36 healthy controls (72% female)	Deformation Neck muscle US	WAD showed higher deformations of the semispinalis cervicis (P = 0.02) and multifidus (P = 0.002) muscles and higher deformation rates (P = 0.03 and 0.0001, respectively).	Mechanical responses of the deep dorsal neck muscles differ between individuals with WAD and healthy controls, possibly reflecting that these muscles use altered strategies while performing a neck extension task.	Significant Deformation WAD>C

Whiplash-Associated Disorders Compared to Healthy Controls: An Ultrasound Study							

Metabolites

Category: Imaging

Sub-category: Metabolites – measured by Magnetic Resonance Spectroscopy (MRS) Chronic and mixed WAD studies (>3mon) (n=3 studies)

Table 69: Summary of included studies (chronic metabolites)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Elliott et al., 2012) Spinal cord metabolism and muscle water diffusion in whiplash	To quantify spinal cord metabolites and neck muscle fast and slow water diffusion in a small sample of people with chronic whiplash and healthy controls	5 people with chronic (>6mo) whiplash;	7 controls	Metabolites N-cetylaspartate/creatine ratios Magnetic resonance spectroscopy (MRS)	Significant reductions in N-acetylaspartate/creatine ratios were found in subjects with chronic whiplash compared to healthy controls (P= 0.02). Significantly higher fast apparent diffusion coefficients (ADCs) were found in chronic whiplash when cocompared toy controls (P= 0.01). There was no difference in slow	Changes in cord biochemistry in tandem with altered water diffusion in the cervical multifidus in chronic whiplash.	Significant WAD>control spinal cord dysfunction

					ADCs between the two groups (P= 0.3).		
(Farrell et al., 2020)* Spinal cord injury is not a feature of chronic whiplash-associated disorder: a magnetic resonance spectroscopy study	Injury to the cervical spinal cord has been suggested as a mechanism that may underpin chronic whiplash-associated disorder (WAD). This study aimed to assess metabolite concentrations indicative of neuronal injury or pathology in the cervical cord in people with chronic WAD	41 people with chronic WAD (61% female)	14 healthy controls (64% female)	Metabolites N-acetylaspartate (NAA), creatine (Cr) and choline (Cho) MRS	There were no differences between the WAD and control groups for NAA/Cr, NAA/Cho, or Cr/Cho.	Major metabolic changes not being present in chronic WAD	NS
(Farrell et al., 2021)* Magnetic Resonance Spectroscopy Assessment of Brain Metabolite Concentrations in Individuals With Chronic	Investigated metabolite profiles of brain regions in people with chronic WAD compared with controls	38 people with chronic (>3mo) WAD (61% female)	16 healthy controls (69% female)	Metabolites Anterior cingulate cortex (ACC), primary motor cortex (1MC), and somatosensory cortex (SSC), ratios of metabolite concentrations	No group differences were observed for NAA:Cr, NAA: Cho, Cr:Cho, Glx:NAA, Glx:Cr, Glx:Cho, Ins:NAA, Ins:Cr, Ins: Cho or Ins:Glx for left or right ACC, 1MC, or SSC following correction for multiple comparisons.	Data do not reflect group differences in metabolite ratios at the ACC, 1MC, or SSC between people with chronic WAD compared with controls	

Whiplash-associated Disorder: A Cross-sectional Study				were calculated for N-acetylaspartate (NAA), creatine (Cr), choline(Cho), myo-inositol (Ins), and glutamate/glutamine (Glx). MRS			

*2 papers reported same cohort Farrell 2021 and Farrell 2020

Brain

Category: Imaging

Sub-category: Brain - Chronic and mixed WAD studies (>3mon) (n=4 studies)

Table 70: Summary of included studies (chronic brain)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Sturzenegger et al., 2008) MRI-based brain volumetry in chronic whiplash patients: no evidence for	To investigate whether traumatic brain injury can be identified using a magnetic resonance (MR)-based quantitative analysis of normalized deformation (VBR) in people with	21 participants with WAD I-II (71% female)	18 healthy controls (72% female)	Brain volumetry MRI	The values of normalized VBR did not differ in people with whiplash when compared with that in healthy controls (F = 0.216, P = 0.645).	Does not support the loss of brain tissue following whiplash injury as measured by VBR	NS

traumatic brain injury	chronic whiplash with subjective cognitive impairment that cannot be objectively confirmed by neuropsychological						
(Coppieters et al., 2021)* Enhanced amygdala-frontal operculum functional connectivity during rest in women with chronic neck pain: Associations with impaired conditioned pain modulation	To examine resting-state functional connectivity alterations and associations with pain outcomes, self-reported central sensitization-related symptoms, and quantitative sensory testing (QST) measures in people with chronic non-traumatic (idiopathic/CINP) neck pain and chronic traumatic (whiplash associated/CWAD) neck pain compared to pain-free controls	37 people with chronic WAD (100% female)	38 people with chronic idiopathic neck pain (100% female) 32 healthy controls (100% female)	Amygdala-frontal operculum functional connectivity MRI	Left amygdala functional coupling during rest with the left frontal operculum in women with CINP and CWAD compared to controls. This increased resting-state functional connectivity was associated with more self-reported symptoms related to central sensitization and decreased efficacy of conditioned pain modulation. Furthermore, enhanced connectivity between the left amygdala and left frontal orbital cortex, and between the left pallidum and the left frontal operculum was	CWAD showed the most pronounced alterations in resting-state functional connectivity, encompassing subcortical limbic (amygdala) and basal ganglia (pallidum), and ventral frontal regions (frontal operculum, orbitofrontal cortex) when compared to CINP and controls.	Significant WAD>control Brain alterations

					observed only in people with CWAD compared to healthy controls.		
(Coppieters et al., 2018)* Differences in white matter structure and cortical thickness between patients with traumatic and idiopathic chronic neck pain: Associations with cognition and pain modulation?	To examine alterations in cortical thickness and white matter (WM) structure, and the presence of brain microhemorrhages in a group encountering chronic neck pain of traumatic origin when compared with a group characterized by nontraumatic chronic neck pain and healthy controls.	37 people with chronic WAD (100% female)	37 people with chronic idiopathic neck pain (100% female) 31 healthy controls (100% female)	Cortical thickness and white matter MRI	Cortical thinning in the left precuneus was revealed in CWAD compared with people with CINP. Also, decreased fractional anisotropy and increased mean and radial diffusivity values could be observed in the left cingulum hippocampus and tapetum in CWAD compared with CINP and in the left tapetum in people with CWAD compared with controls.	Results emphasize the role of structural brain alterations in women with CWAD compared with CINP	
(Coppieters et al., 2017)* Decreased Regional Grey Matter Volume in Women with Chronic Whiplash-Associated Disorders: Relationships	To examine regional GMV alterations in people with CWAD compared to people with non-traumatic chronic idiopathic neck pain (CINP), who normally do not show CS at a group level, and healthy controls.	31 people with chronic WAD (100% female)	34 people with chronic idiopathic neck pain (100% female) 28 healthy controls (100% female)	Regional Grey Matter Volume MRI	Regional GMV of the right lateral orbitofrontal cortex, left supramarginal cortex, and left posterior cingulate cortex was decreased in people with CWAD compared to healthy controls (P =0.023; P = 0.012; P	Evidence for decreased GMV in cortical regions associated with pain and cognitive processing in women with CWAD compared to women with CINP and healthy women	

with Cognitive Deficits and Disturbed Pain Processing					= 0.047, respectively). Additionally, GMV of the right superior parietal cortex and left posterior cingulate cortex was decreased in people with CWAD compared to people with CINP (P = 0.008; P = 0.035, respectively).		

3 papers reported same cohort Coppieters 2021, Coppieters 2018, Coppieters 2017*

Nerve mobility

Category: Imaging

Sub-category:

Nerve Mobility - Chronic and mixed WAD studies (>3mon) (n=2 studies)

Table 71: Summary of included studies (chronic nerve mobility)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Farooq, 2012) Effects of whiplash injury on median nerve mobility: A	Compare median nerve movement in subjects who have previously had a whiplash associated	7 people with chronic WAD (29% female)	10 healthy controls (50% female)	Nerve mobility Longitudinal nerve Ultrasound	Longitudinal nerve movement was reduced by 24% in the WAD group compared with control group, where the mean movement was 1.31 (SD=0.49)	No differences in nerve sliding in WAD,	NS

comparative study	disorder (WAD) with a control group				mm and 1.73 (SD=0.92) mm respectively. Transverse movement was reduced by 66.7% in subject group compared with control group, where the mean movement was -0.06 (SD=0.51) mm and -0.18 (SD=0.54) mm respectively.		
(Greening et al., 2005) In vivo study of nerve movement and mechanosensitive of the median nerve in whiplash and non-specific arm pain patients	To examine median nerve sensitivity in people with WAD with chronic neck and arm pain	9 people with chronic WAD (56% female)	8 healthy controls (50% female)	Nerve mobility Longitudinal and transverse median nerve Ultrasound	Ultrasound used to measure longitudinal (forearm) and transverse (wrist) median nerve movement. Longitudinal movement reduced in WAD by 71% ($p<0.05$), mean 1.32mm (95%CI 0.91-1.73) compared to .38mm (95%CI 0.2-0.56).	Reduced median nerve sliding in people with chronic WAD may reflect underlying nerve pathology	Significant nerve sliding WAD<C

Others

Category: Imaging

Sub-category: Others - Chronic and mixed WAD studies (>3mon) (n=1 study)

Table 72: Summary of included studies (chronic - other)

Author, Year	Aim	WAD Population	Comparison Population	Main Outcome assessed	Results	Comments	Significant
(Patijn et al., 2001) CT study of craniovertebral rotation in whiplash injury	To examine the diagnostic value of rotatory CT in people with WAD and normal controls	47 people with chronic WAD (>6mo) (55% female)	26 healthy controls (62% female)	Computed tomography (CT)	The test correctly classified 80% of people with WAD 11% of normal subjects were classified as false positive.	The study concludes that rotatory CT has low diagnostic value for chronic WAD.	Inconclusive

A.7.5. Chronic imaging evidence summary

Table 73: Summary of evidence for included studies in chronic imaging

Sub-category	Studies	Population	Measurement	Conclusion	Evidence Summary
Morphology Structure changes Craniovertebral ligament (Independent cohorts n=5)	(Dullerud et al., 2010)	28 WAD 27 controls	Cervical structures Alar and transverse ligament - MRI	MRI is not recommended as a routine workup in WAD	2 – Sig 3 – NS
	(Kaale et al., 2005a, 2005b; Krakenes et al., 2003)	92 WAD 30 controls	Cervical structures Alar and transverse ligament - MRI	People with WAD had more high-grade lesions than controls. MRI can show structural damage correlated to NDI score.	
	(Knackstedt et al., 2012)	22 WAD 46 people with chronic cervicogenic headache 19 people with chronic migraine	Cervical structures Alar and transverse ligament - MRI	Similar frequency of changes in craniovertebral ligaments across the group.	

	(Lindgren et al., 2009)	25WAD 25 controls	Cervical structures Alar and transverse ligament - MRI	WAD had both more abnormal signals from the alar ligaments and more abnormal movements in the dMRI at the C0-C2 level than the control.	
	(Myran et al., 2008) (Myran et al., 2011)	28 WAD I-II 57 chronic nontraumatic neck pain 57 controls	Cervical structures Alar - MRI	No difference in alar ligament signal intensity changes across groups. The diagnostic value and the clinical relevance of MR-detectable areas of high intensity in the alar ligaments remain questionable.	
Morphology Structure changes Others (Independent cohorts n=3)	(Farrell et al., 2016)	20 WAD 20 controls	Cervical Meniscoid morphology	Morphological differences of cervical spine meniscoids between the WAD and control groups may form a component of the pathoanatomic of chronic WAD.	2 – Sig 1 – neg. Sig
	(Grushka et al., 2007)	54 WAD; 82 non-trauma temporomandibular dysfunctions (TMD)	TMD disc changes - MRI	Post-MVA people demonstrate no evidence of jaw injury by bone scan and MRI study.	
	(Lee et al., 2018)	76 people with WAD and TMD 58 people with post-traumatic TMD 85 people with idiopathic TMD	TMD disc changes MRI	A whiplash injury may lead to TMD via different mechanisms	
Morphology Muscle Fat Infiltration (Independent cohorts n=6)	(Abbott et al., 2015)	5 WAD 5 WAD recovered 5 controls	Cervical multifidus and semispinalis cervicis	The magnitude of MFI in the medial quartiles (1 and 2) is greatest in the chronic WAD group	6 – Sig
	(Abbott et al., 2018)	31 WAD 31 controls	Cervical multifidus - MRI	Increased MFI within the cervical multifidus muscles of individuals with persistent WAD	

	(Elliott et al., 2006) (Elliott et al., 2010)	79 WAD 34 controls 78 WAD 31 controls	Cervical multifidus – MRI Longus capitis/colli muscles - MRI	Greater fatty deposits in the cervical extensor, deeper longus capitis/colli muscles of people with chronic WAD.	
	(Elliott, Sterling, et al., 2008)	79 WAD 23 insidious-onset neck pain	Cervical extensor	Insidious-neck pain group could be distinguished from the WAD group using a decision tree based on average muscular fat and cold pain thresholds.	
	(Karlsson et al., 2016) (Karlsson et al., 2019)	31 WAD 31 controls	Multifidus - MRI	WAD with a severe disability had higher fat infiltration in the multifidus compared to controls and to those with mild/moderate disability.	
	(Valera-Calero et al., 2021)	41 WAD 39 controls	Cervical muscles - US	US assessment of deep cervical extensors revealed greater fatty infiltration.	
Morphology Muscle Size (Independent cohorts n=4)	(Cagnie et al., 2010)	16WAD 19 controls	Cervical flexor activity – Muscle functional- MRI	Failed to demonstrate a changed activity pattern in the WAD group compared with the control group	2 – Sig 2 – NS
	(Elliott, Jull, et al., 2008) (Elliott et al., 2014)	79 WAD 34 controls 79 WAD 23 chronic idiopathic neck pain 34 controls	Cervical extensor Cross-sectional area (rCSA) - MRI	WAD rCSA of the cervical paraspinal musculature differs from subjects with no history of neck pain.	
	(Matsumoto et al., 2010) (Matsumoto et al., 2012)	133 WAD 223 controls 23 WAD 60 controls	Cervical extensor rCSA-MRI	No difference in the change in CSA over time between the symptomatic and asymptomatic people in cross-sectional and after a 10-year follow-up period.	
	(Van Looveren et al., 2021)	37 WAD 45 idiopathic neck pain 35 controls	Cervical extensor rCSA-MRI	Suggest changes in muscle morphology in both neck pain cohorts.	

Muscle morphology (Ultrasound) (Independent cohorts n=2)	(Peolsson et al., 2016; Peterson et al., 2016)	40 WAD 40 controls 9 WAD 9controls	Multifidus muscle - US Neck muscle - US During neck extensions	WAD have higher deformation rates in the multifidus muscle compared to controls. An altered mechanical strain of the trapezius and multifidus muscles in individuals with WAD when performing a standardised low-loaded neck extension.	2 – Sig
	(Rahnama et al., 2018)	36 WAD 36 controls	semispinalis cervicis and multifidus - Ultrasound	Deep dorsal neck muscles differ between individuals with WAD and controls	
Metabolites measure by MRS (Independent cohorts n=2)	(Elliott et al., 2012)	5 WAD 7 controls	N-cetylaspartate/creatine ratios - Magnetic resonance spectroscopy (MRS)	Changes in cord biochemistry in tandem with altered water diffusion in the cervical multifidus in chronic whiplash.	1 – Sig 1 – NS
	(Farrell et al., 2020)&	41 WAD 14 controls	N-acetylaspartate (NAA), creatine (Cr) and choline (Cho) - MRS	Major metabolic changes do not present in chronic WAD	
	(Farrell et al., 2021)	38 WAD 16 controls	Acetylaspartate(NAA), creatine (Cr), choline(Cho), myo-inositol (Ins), and glutamate/glutamine (Glx) - MRS	No group differences in metabolite ratios at the ACC, 1MC, or SSC between people with chronic WAD compared with controls.	
Brain (Independent cohorts n=3)	(Sturzenegger et al., 2008)	21 WAD I-II 18 controls	Brain volumetry -MRI	It does not support the loss of brain tissue following whiplash injury as measured normalised deformation	2 – Sig 1 – NS

	(Coppieters et al., 2021)	37 CWAD 38 Idiopathic Neck pain (CNIP) 32 controls	Amygdala-frontal operculum functional connectivity	Group difference was enhanced amygdala functional coupling during rest with the frontal operculum in women with CINP and CWAD compared to healthy controls.	
	(Coppieters et al., 2018)	37 CWAD 374 CNIP 28 controls	Cortical thickness and white matter	CWAD showed the most pronounced alterations in resting-state functional connectivity.	
	(Coppieters et al., 2017)	31 CWAD 37 CNIP 31 controls	Regional Grey Matter Volume	Emphasise the role of structural brain alterations in women with CWAD compared with CINP.	
Nerve Mobility (Independent studies n=2)	(Farooq, 2012)	7 WAD 10 controls	Longitudinal nerve Ultrasound	No difference in never sliding in WAD than control.	1 –Sig 1– NS
	(Greening et al., 2005)	9 WAD 8 controls	Longitudinal and transverse median nerve-Ultrasound	Reduced median nerve sliding in people with chronic WAD may reflect underlying nerve pathology.	
Others (Independent cohort n=1)	(Patijn et al., 2001)	47 WAD 26 controls	Computed tomography (CT)	The study concludes that rotatory CT has a low diagnostic value for chronic WAD.	1-Inconclusive

***** Discrimination between groups

Table 74: Evidence to decision framework (imaging in acute WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○Trivial ○Small ○ Moderate ○ Large ● Varies ○ Don't know	There are only a few acute studies, and the evidence is varying from inconclusive to small. • Morphology - Structure changes - 2/3 independent studies showed structured changes (e.g., alar and transverse ligament) in people with WAD.	These studies are more exploratory studies investigate the mechanism instead of being a validated accuracy diagnostic study. Consistent with previous guidelines and literature

	• Morphology – Muscle Fat Infiltration (MFI): 1/1 study showed at 3 months higher MFI in cervical neck extensor muscle in people with WAD in the sub-group of moderate/severe disability. • Morphology - Muscle size: 1/1 study showed no difference in cross-sectional area of neck muscle in people with acute WAD. • Muscle stiffness: 1/1 study showed increased muscle stiffness in trapezius in people with acute WAD.	
Undesirable Effects How substantial are the undesirable anticipated effects associated with the assessment method?		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported.	Trivial adverse effects expected with MRI. Some the people can tolerate going to an MRI; however, for some people, it might be contraindicated due to claustrophobia.
Balance of effects Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?		
Judgement	Research evidence	Additional considerations
● Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Not reported	The studies are more explanatory and not diagnostic accuracy studies and won't assist in treatment direction.
Resources required How large are the resource requirements (costs)?		

Judgement	Research evidence	Additional considerations
○ Large costs ● Moderate costs ○ Negligible costs and savings ○ Moderate savings ○ Large savings ○ Varies ○ Don't know	Not reported.	Equipment is costly and requires an advanced understanding in how to analysis it. A standard radiologist is not educated on how to analyse fat infiltration.
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
● Reduced ○ Probably reduced ○ Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	Not reported.	Due to the cost of the advanced image, not everyone can afford doing an MRI
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
● No ○ Probably no ○ Probably yes ○ Yes ○ Varies ○ Don't know	Not reported	Performing an MRI to evaluate morphological changes in the neck is not a routine exam for WAD conditions
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations

● No ○ Probably no ○ Probably yes ○ Yes ○ Varies ○ Don't know	Not reported.	Not feasible for people with WAD to undergo MRI imaging to evaluate morphological changes in neck structures (e.g., musculature).

A.7.6. Conclusion (imaging in acute WAD)

VOTE1: Assessment of for structure changes, muscle fat infiltration and muscle size and muscle stiffness people with acute WAD

Are you for or against healthcare professionals assessing the following imaging technique in people with acute WAD: magnetic resonance imaging (MRI) and Ultrasound (US) to assess changes in Morphology – structure changes, muscle fat infiltration and muscle size- and muscle stiffness?

Type of recommendation (structure changes, muscle fat infiltration and muscle size and muscle stiffness people with acute WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
●	○	○	○	○

Recommendations
There was strong guideline panel consensus that primary healthcare professionals do not assess the following imaging techniques: Magnetic resonance imaging (MRI) and Ultrasound (US) to assess changes in morphology – structure changes, muscle fat infiltration and muscle size- and muscle stiffness in people with acute WAD. *(Panel vote summary: 10/12 strong against (83%), 1/12 conditional against, 1/12 conditional for)* **Justification** • Studies are largely inconclusive

- Studies are more exploratory studies and not diagnostic studies, therefore at present the imaging techniques do not assist in diagnosing WAD nor helping in treatment.
- The techniques and equipment are very costly (e.g., MRI).
- The analysis requires advanced neuroimaging expertise not readily available in the clinical setting.

Table 75: Evidence to decision framework (imaging in chronic WAD)

Strength of association How substantial are the assessed outcome differences between people with WAD and control populations?		
Judgement	Research evidence	Additional considerations
○Trivial ○Small ○ Moderate ○ Large ● Varies ○ Don't know	The evidence is largely inconclusive for morphology (structure changes, muscle size, muscle morphology with ultrasound), metabolites measured by MRS, Brain, and nerve mobility. The exception is for muscle fat infiltration (MFI), with 6/6 showing an increase of MFI in people with WAD compared to the control group. • Morphology - Structure changes: 2/5 independent studies showed structured changes (e.g., alar and transverse ligament) in people with WAD. • Morphology - Muscle Fat Infiltration (MFI): 6/6 independent studies showed higher MFI in cervical extensor muscle in people with WAD. • Morphology - Muscle size: 2/4 independent studies showed neck muscle cross-sectional area differ in people with WAD. • Muscle morphology (Ultrasound): 2/2 independent studies higher neck muscle deformation in people with WAD • Metabolites measure by Magnetic resonance spectroscopy (MRS): 1/2 studies showed metabolic changes in spinal cord in people with WAD.	These studies are more exploratory studies investigating the mechanism instead of being a validated accuracy diagnostic study. Consistent with previous guidelines and literature

	• Brain: 2/3 independent studies showed significant in people with WAD Nerve Mobility: 1/2 studies showed reduced median nerve sliding in people with WAD.	
Undesirable Effects **How substantial are the undesirable anticipated effects associated with the assessment method?**		
Judgement	Research evidence	Additional considerations
○ Large ○ Moderate ○ Small ● Trivial ○ Varies ○ Don't know	Not reported.	Trivial adverse effects expected with MRI. Some the people can tolerate going to an MRI; however, for some people, it might be contraindicated due to claustrophobia.
Balance of effects **Does the balance between desirable and undesirable effects favour assessing or not assessing these factors?**		
Judgement	Research evidence	Additional considerations
● Favours not assessing ○ Probably favours not assessing ○ Does not favour either assessing or not assessing ○ Probably favours assessing ○ Favours assessing ○ Varies ○ Don't know	Not reported	The studies are more explanatory and not diagnostic accuracy studies and won't assist in treatment direction.
Resources required **How large are the resource requirements (costs)?**		
Judgement	Research evidence	Additional considerations
○ Large costs ● Moderate costs ○ Negligible costs and savings	Not reported.	Equipment is costly and requires an advanced understanding in how to analysis it. A standard radiologist is not educated on how to analyse fat infiltration.

○ Moderate savings ○ Large savings ○ Varies ○ Don't know		
Equity What would be the Impact on health equity?		
Judgement	Research evidence	Additional considerations
● Reduced ○ Probably reduced ○ Probably no impact ○ Probably increased ○ Increased ○ Varies ○ Don't know	Not reported.	Due to the cost of the advanced imaging, not everyone can afford one.
Acceptability Is the assessment method acceptable to key stakeholders?		
Judgement	Research evidence	Additional considerations
● No ○ Probably no ○ Probably yes ○ Yes ○ Varies ○ Don't know	Not reported	Performing an MRI to evaluate morphological changes in the neck is not a routine exam for WAD conditions.
Feasibility Is the assessment method feasible to implement?		
Judgement	Research evidence	Additional considerations

● No ○ Probably no ○ Probably yes ○ Yes ○ Varies ○ Don't know	Not reported.	Not feasible for people with WAD to undergo MRI imaging to evaluate morphological changes in neck structures (e.g., musculature).

A.7.7. Conclusion (imaging in chronic WAD)

VOTE 1: Assessment of structure changes, muscle fat infiltration, muscle size, muscle morphology (ultrasound)- metabolites, brain, nerve mobility and CT (ROM) people with chronic WAD

Are you for or against healthcare professionals assessing the following imaging techniques in people with chronic WAD: magnetic resonance imaging (MRI) and Ultrasound (US) to assess changes in WAD morphology – structure changes, muscle fat infiltration, muscle size, muscle morphology, metabolites measured by MRS, Brain, and nerve mobility and others?

Type of recommendation (structure changes, muscle fat infiltration, muscle size, muscle morphology (ultrasound)- metabolites, brain, nerve mobility and CT (ROM) people with chronic WAD)

Strong consensus recommendation for not measuring the factor(s)	Conditional consensus recommendation to not measure the factor (s)	Conditional consensus recommendation for either measuring the factor (s) or not	Conditional consensus recommendation for measuring the factor (s)	Strong consensus recommendation for measuring the factor(s)
●	○	○	○	○

Recommendations
There was strong guideline panel consensus that primary healthcare professionals do not assess the following techniques Magnetic resonance imaging (MRI) and Ultrasound (US) to assess changes in WAD Morphology – structure changes, muscle fat infiltration, muscle size, muscle morphology, metabolites measured by MRS, Brain, and nerve mobility and others in people with chronic WAD. *(Panel vote summary: 10/10 (100%) strong against)*

Justification

- Studies are largely inconclusive with the exception of evidence for muscle fat infiltration.
- Studies are more exploratory studies and not diagnostic studies, therefore at present the imaging techniques do not assist in diagnosing WAD nor helping in treatment.
- The techniques and equipment are very costly (e.g., MRI).
- The analysis requires advanced neuroimaging expertise not readily available in the clinical setting.

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