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Ancillary Outcome Measures for Assessment of Individuals With Cervical Spondylotic Myelopathy

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Study Design. Narrative review.

Objective. To identify suitable outcome measures that can be used to quantify neurological and functional impairment in the management of cervical spondylotic myelopathy (CSM).

Summary of Background Data. CSM is the leading cause of acquired spinal cord disability, causing varying degrees of neurological impairment which impact on independence and quality of life. Because this impairment can have a heterogeneous presentation, a single outcome measure cannot define the broad range of deficits seen in this population. Therefore, it is necessary to define outcome measures that characterize the deficits with greater validity and sensitivity.

Methods. This review was conducted in 3 stages. *Stage I:* To evaluate the current use of outcome measures in CSM, PubMed was searched using the name of the outcome measure and the common abbreviation combined with "CSM" or "myelopathy." *Stage II:* Having identified a lack of appropriate outcome measures, we constructed criteria by which measures appropriate for assessing the various aspects of CSM could be identified. *Stage III:* A second literature search was then conducted looking at specified outcomes that met these criteria. All literature was reviewed to determine specificity and psychometric properties of outcomes for CSM.

Results. Nurick grade, modified Japanese Orthopaedic Association Scale, visual analogue scale (VAS) for pain, Short Form (36) Health Survey (SF-36), and Neck Disability Index were the most commonly cited measures. The Short-Form 36 Health Survey and Myelopathy Disability Index have been validated in the CSM population with multiple studies, whereas the modified Japanese Orthopaedic Association Scale score, Nurick grade, and European Myelopathy Scale each had only one study assessing psychometric characteristics. No validity, reliability, or responsiveness studies were found for the VAS or Neck Disability Index in the CSM population.

Conclusion. We recommend that the modified Japanese Orthopaedic Association Scale, Nurick grade, Myelopathy Disability Index, Neck Disability Index, and 30-Meter Walk Test are most appropriate for the assessment of CSM. However, 6 additional outcome measures (QuickDASH, Berg Balance Scale, Graded Redefined Assessment of Strength Sensibility and Prehension, Grip Dynamometer, and GAITRite Anlaysis) were identified, which provide complementary assessments for CSM.

Summary Statements. There does not exist a single or composite of outcome instruments that measures myelopathy impairment, function/disability, and participation that have also demonstrated reliability, validity, and responsiveness in a CSM population. More work in the development and psychometric evaluation of new or existing measures is necessary to identify the ideal composite of measures to be used in the clinical and research settings.

- The mJOA, Nurick grade, NDI, MDI, and 30MWT should be adopted in any clinical practice that treats CSM both for screening and clinical follow-up.
- We propose that clinicians and researchers consider using the ancillary measures identified, such as the QuickDASH, Berg Balance Scale, GRASSP version 1.0, Grip Strength, and GAITRite Analysis.
- It is highly recommended that baseline and follow-up measurements should be performed in patients with CSM.

Key words: impairment, tetraplegia, function, cervical spondylotic myelopathy.

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Cervical spondylotic myelopathy (CSM) results from the degenerative narrowing of the spinal canal, which causes spinal cord compression in a slow, progressive manner. This type of compression causes a delayed onset of adapted deficits in both the spinal cord and periphery. Although

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the result of this compression may be tetraparesis/tetraplegia, the impairments do not present as precisely as those that result from traumatic lesions. In fact, the severity of the compression and the deficits that result are variable across individuals. CSM is the leading cause of acquired spinal cord disability in the elderly.[1,2] The varying degree of impairment impacts independence and quality of life. Because CSM can have such a heterogeneous presentation, a single outcome measure cannot quantify the broad range of neurological deficits seen in this population. Therefore, in addition to a comprehensive clinical neurological examination and imaging, it is necessary to define outcome measures that characterize the deficits in this population with greater validity, reliability, and responsiveness.

The use of sensitive outcome measures is important to establish efficacy of interventions, assist in identifying the predictors of disease progression, and enable clinicians to offer treatment that is most effective and offered at the most appropriate time in the course of this disease. Understanding the deficits of this population will enable the field to establish a standard method to define a severity of disease index. Therefore, the objective of this review is to identify the most useful, quantitative, standardized outcome measures for the assessment of CSM that will establish a meaningful clinical dataset to enable clinicians to assess outcomes, monitor the natural history of CSM, and establish the prognostic value of clinical findings.

MATERIALS AND METHODS

The review process included 3 stages: (1) Initial search of PubMed to define existing measures in CSM; (2) Development of a disease framework to establish 4 criteria to select ancillary outcome measures; and (3) Second search of PubMed to determine the most useful outcome measures for assessment of CSM.

To establish the current state of outcome measurement in CSM, we evaluated the relative frequency of use of the most common outcome measures and their psychometric properties. PubMed was searched using the name of the outcome measure and the common abbreviation combined with the following terms: "CSM" or "myelopathy." The search results were limited to human studies published in the English language with no date restriction. The titles and abstracts of the studies identified were checked to verify that the outcome of interest was reported. We also sought to identify and summarize the studies evaluating the validity, reliability, and responsiveness of these outcome measures in the CSM population. Then, we provided a description and interpretation of each measure and an indication of whether the measure had been assessed for validity, reliability, or responsiveness in CSM.

The second stage consisted of defining a disease framework that would establish the selection criteria (Figure 1). Specific criteria were established to seek the most adequate and appropriate outcome measures that would characterize the CSM population optimally. Selection of outcome measures was based on the following criteria: (1) The measure/s are specific to the identified deficits and disabilities related to CSM and capture neurological impairment related to the upper and/lower limbs (Figure 3 defines the neurological and physical deficits that can be related to CSM). (2) The measure is rigorous and has sound psychometric development (reliability, validity, and responsiveness) in CSM or related populations with normative data available. (3) Feasible to administer in an outpatient care environment. (4) Falls into the Body and Structures and Ability categories of the International Classification of Functioning of the World Health Organization.[13]

The third stage consisted of a second literature search, which was conducted on specified outcomes that were known to address the specified criteria 1 and 4. The literature search was used to determine if criteria 2 and 3 were met for the outcome measures selected. Six measures were selected that are known to be useful in the measurement of upper limb function, disability, balance, and gait.

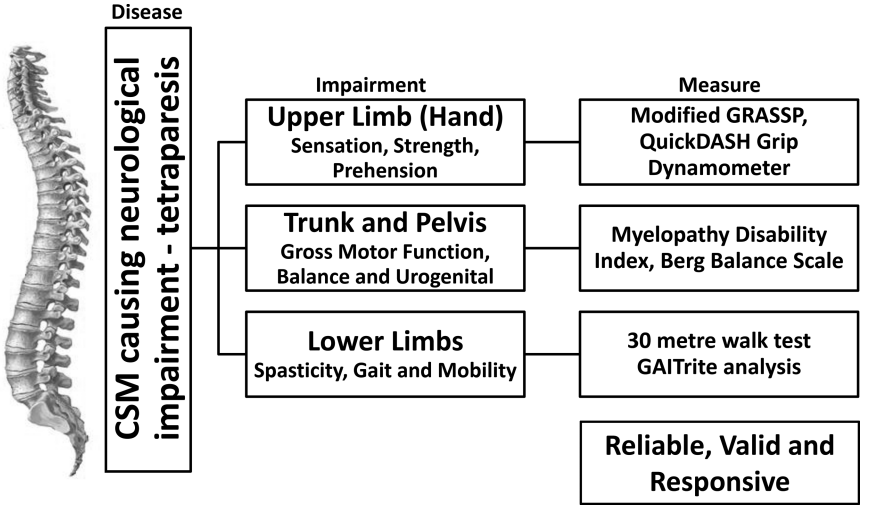

Figure 1. What should guide the selection of sensitive outcome measures for CSM? The figure defines the different constructs of impairment that can result from CSM and the general structure that drives the selection of outcome measures specific to the first criteria. CSM indicates cervical spondylotic myelopathy.

RESULTS

Stage 1—Defining the Measures Currently Used in the Field: What Is the Current Practice in CSM With Respect to Use of Outcomes Assessment?

The list of outcome measures and their frequency of use in the CSM population can be found in Figure 2. The most commonly cited measure is the Nurick grade (N = 62 studies), followed by modified Japanese Orthopaedic Association Scale (mJOA) (N = 57), visual analogue scale (VAS) for pain (N = 27), Short-Form 36 Health Survey (SF-36) (N = 18), and Neck Disability Index (NDI) (N = 10). The Myelopathy Disability Index (MDI) (N = 6) and European Myelopathy Scale (EMS) (N = 4) were cited in less than 10 studies (Table 1; Figure 2).

The list of validity, reliability, and responsiveness study frequency in a CSM population was also established. The SF-36 was evaluated the most (N = 5) followed by MDI (N = 2), whereas mJOA scale, Nurick grade, and EMS each had one study assessing psychometric characteristics in a CSM population. No validity, reliability, or responsiveness study was found for the pain VAS or NDI in the CSM population (Table 1; Figure 3).

Modified Japanese Orthopaedic Association Scale

The mJOA[3] is a modified version of the original JOA scale. It is scored on a 0 to 18 point scale with the lowest score, representing greater disability (Table 1). It is a clinician-based measure that covers items such as upper and lower extremity motor function, hand sensation, and micturition. Only one study[4] was identified that tested reliability of the mJOA. This study found the mJOA to have a high degree of interobserver reliability (Table 1). Thus, this tool can be reliably used among multiple examiners.

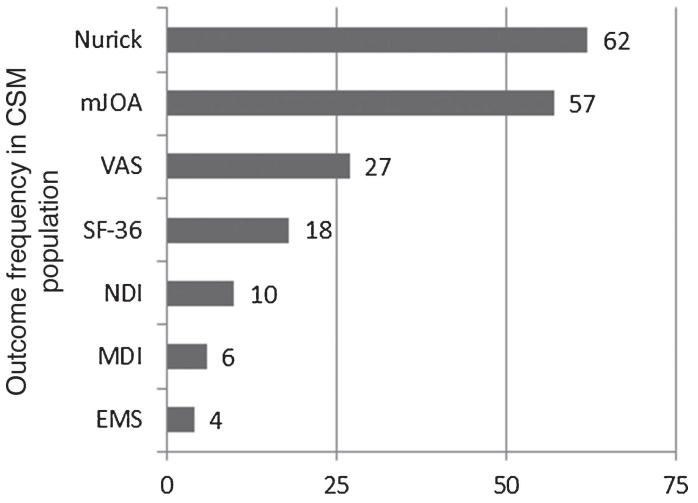

Figure 2. The frequency of use of CSM outcome measures in existing studies. The figure defines how often the outcome measures discussed in this study have been used in studies related to the CSM population. CSM indicates cervical spondylotic myelopathy; mJOA, Modified Japanese Orthopaedic Association; MDI, Myelopathy Disability Index; NDI, Neck Disability Index; EMS, European Myelopathy Scale; VAS, visual analogue scale; SF-36, Short-Form 36 Health Survey.

Nurick Scale

The Nurick Scale[4] was developed to assess gait impairment in patients with CSM. The Nurick Scale is a clinician-based measure containing six grades of CSM ranging from 0 to 5, with a focus on gait impairment (Table 1). As the grade increases the disability increases. One study[5] was identified that tested the validity, reliability, and responsiveness of the Nurick Scale. This study compared 7 different outcome measures in a CSM population. The Nurick Scale was validated against the postoperative MDI, EMS, and Ranawat Scale (Table 1).

Myelopathy Disability Index

The MDI[6] was developed to measure disability objectively in rheumatoid arthritis complicated by CSM. The MDI consists of 10 items ranging from 0 to 3 points (Table 1). It is a self-report measure that covers the items sit-to-stand, eating, walking, hygiene, and grip strength. These 10 items are summed and converted to percentage with a maximum score of 100 and minimum score of 0.[5,6] Disability increases as the score increases. Two studies were identified that tested its validity, reliability, and responsiveness. In one study the MDI was validated against the 20-item Health Activity Questionnaire, Ranawat class, and Steinbrocker grade (Table 1).[6] In another study, the MDI was validated against the EMS.[5] The MDI was found to be reliable and responsive in both studies (Table 1).[5,6] Despite the rigor of this measure's development, it is one of the least used outcomes.

Neck Disability Index

The NDI[7] is a modification of the Oswestry Disability Index and developed as a self-report measure of neck pain. The NDI consists of 10 items ranging from 0 to 5 points (Table 1). Some items that the NDI measures are lifting, pain, driving, sleeping, and work activities. These 10 items are summed and normalized to 100. Maximum score is 100 and minimum score is 0. An increasing score indicates increasing disability. The NDI has not had validity or reliability testing in a CSM population but has in patients who underwent neck surgery.

European Myelopathy Scale

The EMS[8] was developed to assess myelopathy. It consists of the following 5 items: gait, hand function, proprioception, bladder and bowel function, and parasthesias. Items are scored from 1 to a variable maximum of 3, 4, or 5. Items are summed with a maximum score of 18 and a minimum score of 5 points. An increasing score indicates an increase in severity of myelopathy. One study has addressed validity, reliability, and responsiveness. The EMS was validated against the MDI and, in the same study, was found to have poor sensitivity to change.[5]

Short-Form 36 Health Survey

The Short-Form 36 Health Survey[9] is a measure of patient health status. The SF-36 consists of 8 subscales: Vitality, Physical Functioning, Bodily Pain, General Health, Physical Role, Emotional Role, Social Role, and Mental Health. Items of

TABLE 1. Outcome Measures Currently Used to Assess the CSM Population

Instrument	Scale Description	Interpretation	Validity	Reliability	Responsiveness
mJOA[77]	Myelopathy assessed on the basis of the following functions: Upper extremity motor function (5 points) Lower extremity motor function (7 points) Hand sensation (3 points) Micturition (3 points) Each function scored on a scale with minimum score of 0 and a variable maximum score of 3, 5, or 7.	Total grade is the sum of the subscales. Maximum score: 18 points Minimum score: 0 points The lower the score, the greater the disability.	Not available	Yes[4] Intraobserver reliability Kappa 0.79 ± 0.05 ($P < 0.001$)[4] Validated Dutch translation from English	Not available
Nurick Scale[4]	Myelopathy assessed by the following ambulatory scale: Grade 0: Signs/symptoms of root involvement, but without evidence of spinal cord disease. Grade 1: Signs of spinal cord disease, but no problems with walking Grade 2: Slight difficulty in walking that does not prevent full-time employment. Grade 3: Difficulty walking, which prevents full-time employment or the ability to do housework, but not severe enough to require someone else's help to walk. Grade 4: Able to walk with someone else's help or with an assistive device. Grade 5: Chairbound or bedridden	Grade given on the basis of severity of symptoms. Maximum grade: 5 Minimum grade: 0 The higher the grade, the greater the disability.	Yes[5]	Yes[5]	Yes[5]
MDI[5]	Myelopathy assessed by 10 items relating to the following functions: Rising from chair and bed (6 points) Eating (6 points) Walking (6 points) Hygiene (6 points) Grip (6 points) Each item scored on a scale with a minimum score of 0 and a maximum score of 3.	All items summed and converted to a percentage. Maximum score: 100 points Minimum score: 0 points The higher the score, the greater the disability.	Yes[5,6]	Yes[5,6]	Yes[5,6]
NDI[12]	Neck disability assessed by 10 subscales (10 items): Recreation Pain Intensity Self-care Lifting Reading Headaches Concentration Work Driving Sleeping Each item scored on a 0–5-point scale.	Score is the sum of all items normalized to 100. Maximum score: 100 points Minimum score: 0 points The higher the score, the greater the disability.	Yes[7]	Yes[7]	Not available

(*Continued*)

TABLE 1. (*Continued*)

Instrument	Scale Description	Interpretation	Validity	Reliability	Responsiveness
EMS[8]	Myelopathy severity is assessed on the basis of the following functions (5 items): Gait Hand function Proprioception and coordination Bladder and bowel function Parasthesias and dysesthesia Each function scored on a scale with a minimum score of 1 and a variable score of 3, 4, or 5.	Score is the sum of all items. Maximum score: 18 points Minimum score: 5 points 18–17 = normal status 16–13 = mild impediment (EMS I) 12–9 = distinct disablement (EMS II) 8–5 = severe handicap (EMS III) The lower the score, the greater the myelopathy severity.	Yes[5]	Yes[5]	Yes[5]
SF-36[9]	General health disability assessed from 8 subscales (36 items): Physical Functioning Bodily Pain Physical Role Limitations General Health Vitality Social Functioning Emotional Role Limitations Mental Health	Items of each subscale are averaged to yield score of 0–100. Maximum score: 100 points Minimum score: 0 points The lower the score, the greater the disability.	Yes[10–13]	Yes[11]	Yes[10,12,13]
VAS for pain*	Assessment made by indicating a position along a continuous line between 2 endpoints (1 item): Pain	If the line is horizontal, the further the position to the right the greater the pain. If the line is vertical, the higher the position the greater pain.	Not available	Not available	Not available

**No original reference found.*

mJOA indicates Modified Japanese Orthopaedic Association; MDI, Myelopathy Disability Index; NDI, Neck Disability Index; EMS, European Myelopathy Scale; VAS, visual analogue scale; SF-36, Short Form (36) Health Survey.

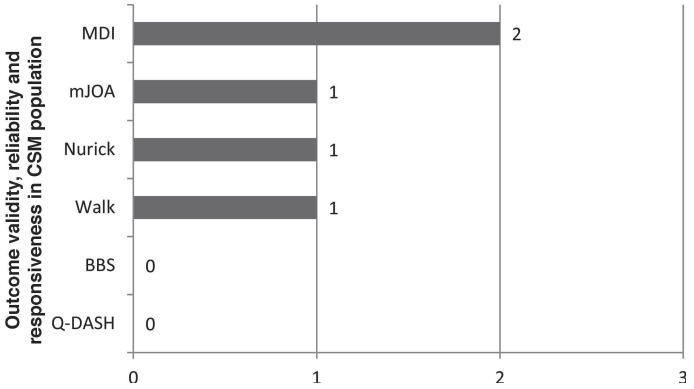

Figure 3. Frequency of validity, reliability, and responsiveness of common outcomes measures used in the CSM population. CSM indicates cervical spondylotic myelopathy.

each subscale are averaged to yield a score of 0 to 100. A score closer to zero represents greater disability. The SF-36 has been tested for validity, reliability, and responsiveness in the CSM population. Guilfoyle *et al* validated the SF-36 against the MDI and Roland-Morris scale.[9] King and Roberts validated the SF-36 against the Nurick Scale, Cooper Scale, and Harsh Scale[10]; Latimer *et al* compared the SF-36 with the NDI, MDI, and VAS for neck and arm pain.[11] King and Roberts[10] found the SF-36 to be reliable. The SF-36 was found to be responsive in 3 studies.[11–13]

Visual Analogue Scale (VAS) for Pain

The visual analogue scale (VAS) for pain is a single item asking respondents to rate their pain level on a continuous line between 2 end points. On a horizontal line, the further to the left the mark the greater the pain. On a vertical line, the higher the mark the greater the pain. No studies exist testing validity, reliability, or responsiveness of the VAS in the CSM population.

Stage 2—Defining a Framework and Setting Selection Criteria for the Second Search: What Are the Requirements of Outcome Measures Specific to CSM?

The Gap

The initial literature search does identify measures specific to CSM, which have some psychometric development. However, none of these measures objectively quantify physical findings of the individual. Despite frequency of use, there continues to be a gap due to the insensitivity of the available outcome measures. Therefore, it is necessary to identify ancillary measures that can be used to measure this population in detail a we continue to learn about this disease from the basic and clinical perspectives. Measurement in this field has lagged and will become a concept of significant interest as we learn more about the pathophysiology of this disease, and as new discoveries are translated to humans.[2] Selection criteria for outcome measures are defined in the Methods. The criteria were used to identify six outcome measures, QuickDASH, Berg Balance Scale, 30-Meter Walk Test (30MWT), a modified Graded Redefined Assessment of Strength Sensibility and Prehension (GRASSP), Grip strength (dynamometer), and GAITRite.

Stage 3—Targeted Literature Search on Specified Outcome Measures Selected on the Basis of Criteria in Stage 2: What Are the Most Reliable, Valid, Responsive, and Quantitative Outcome Measures That Can Be Used for CSM?

A number of measures do exist, which are appropriate to administer in the CSM population despite their development and use in different but similar patient groups. These ancillary measures can provide information that is more sensitive and developed in a more rigorous fashion than existing tools. These measures are described in Table 2, and how to consider their use is described in Table 3.

QuickDASH

The QuickDASH[14] was developed to measure physical function and symptoms related to upper limb musculoskeletal disorders by creating a shorter version of the Disabilities of the Arm Shoulder and Hand questionnaire (DASH; see Hudak *et al*[15]) (see erratum). The QuickDASH consists of 3 modules (2 modules are optional). The disability and symptom module consists of 11 items ranging from 1 to 5 points (Table 1). It is a self-report measure that covers activities of daily living, recreation activities, social activities, work activities, arm/hand sensation and pain, and sleeping. Items are summed and then normalized from 0 to 100. The higher the score, the greater the disability. For this metric, no validity, reliability, or responsiveness studies were identified in a CSM population. Other populations in which validity, reliability, or responsiveness have been tested include: upper extremity musculoskeletal disorders,[14,16–26] carpal tunnel syndrome,[27] neck pain,[18,19,28,29] upper limb burn,[30] and Duypuytren disease.[31]

Berg Balance Scale

The Berg Balance Scale[32] was developed to measure balance among elderly people with impairment. The Berg Balance Scale consists of 14 items scored from 0 to 4 points (Table 1). It is a performance measure that evaluates unsupported standing balance, unsupported sitting balance, and transfers. Maximum score is 56 and minimum score is 0. A lower score represents greater disability. No validity, reliability, or responsiveness studies were identified in a CSM population. Other populations in which validity, reliability, or responsiveness have been tested include: stroke,[33–42] balance disorder,[43,44] elderly,[45–49] multiple sclerosis,[41–53] and Parkinson disease,[54–56] Neurological disorders including spinal cord and brain injury,[57–59] cognitive disability,[60,61] and knee arthroplasty.[62]

Walk Test—30-Meter Walk Test

Several walking tests were identified, including the 30MWT, 10-Meter Walk Test (10MWT), and 6-Minute Walk Test (6MWT). The 30MWT[63] seems to be the most common and was developed to measure disability of patients with CSM. The 30MWT is a performance measure of time in seconds to walk 30 m (Table 1). The greater the time, the greater the disability.

TABLE 2. Outcome Measures That Can Be Used In Assessing Patients With CSM

Instrument	Scale Description	Interpretation	Validity	Reliability	Responsiveness
QuickDASH[14]	Three modules Disability/symptom score Work score (optional) Sports/performing arts score (optional) Disability/symptom score contains 11 items. ADLs (25 points) Recreational activities (5 points) Social activities (5 points) Work activities (5 points) Arm/hand pain and sensation (10 points) Sleeping (5 points) Each item scored on a scale with a minimum score of 1 and a maximum score of 5.	Optional sections are not required for CSM. Scores summed and normalized to 100. Maximum score: 100 points Minimum score: 0 points The higher the score, the greater the disability.	Yes[16,18,20–24,26]	Yes[20,22]	Yes[17,19,20,25,27]
BBS[32,33]	Balance assessed by 14 balance-related items. Standing unsupported (40 points) Sitting unsupported (4 points) Transfers (12 points) Each item scored on a scale with a minimum score of 0 and a maximum score of 4.	Items summed. Maximum score: 56 points Minimum score: 0 points The lower the score, the greater the disability.	Yes[38,40,42–44,46,47,49,52–54,56,57,59,62]	Yes[4,34,36–38,40,43,50,51,58–61]	Yes[37,39,42,43,48]
Walking tests, timed 30MWT[63]	Most common timed-walk tests Timed 30MWT,* measure of time in seconds and a count of cadence to walk 30 m. Timed 10MWT, measure of time in seconds to walk 10 m. Timed 6MWT, measure of distance to walk for a total duration of 6 min.	The greater the time and the cadence, the greater the disability.	Yes[63]	Yes[63,64]	Not available
GRASSP[65]	GRASSP The GRASSP[59] was developed as a clinical outcome measure specific to upper limb impairment in individuals with complete or incomplete tetraplegia.	5 subtests include: Dorsal sensation Palmar sensation Strength Prehension ability Prehension performance Five numerical scores provide a comprehensive profile of upper limb function for right and left sides separately.	Yes[65–67]	Yes[65–67]	Not available
Grip dynamometer[68]	Grip dynamometer Grip dynamometer is an instrument used for measuring the force of handgrip muscular contraction. It has been tested in healthy volunteer individuals.[62–64]	This measure gives a single continuous reading in lb/ft or kg/ft.	Yes[70]	Yes[67–70]	Not available

(*Continued*)

TABLE 2. (*Continued*)

Instrument	Scale Description	Interpretation	Validity	Reliability	Responsiveness
GAITRite Analysis[71]	GAITRite Analysis[71] is a computerized walkway system embedded with pressure sensors that detect a series of footfalls. The walkway is connected to a personal computer with application software.	GAITRite Analysis provides the temporal and spatial gait parameters.	Yes[72,73,76]	Yes[74,75,77]	Responsiveness[72]

30MWT indicates 30-Meter Walk Test; 10MWT, 10-Meter Walk Test; BBS, Berg Balance Scale; GRASSP, Graded Redefined Assessment of Strength Sensibility and Prehension; CSM, cervical spondylotic myelopathy; ADL, activities of daily living.

One study[63] was identified that tested its validity and reliability, and no studies were identified that tested responsiveness. The 30MWT was validated against the MDI and Nurick Scale and was highly reproducible. The 30MWT has also been tested in a chronic obstructive pulmonary disease population.[64]

Graded Redefined Assessment of Strength Sensibility and Prehension

The GRASSP[65] was developed as a clinical outcome measure specific to upper limb impairment in individuals with complete or incomplete traumatic tetraplegia. It comprises 5 subtests for each upper limb: dorsal sensation, palmar sensation, strength, and prehension. There are 5 numerical scores that provide a comprehensive profile of upper limb function. No validity, reliability, or responsiveness studies were found in a CSM population in the literature. However, the GRASSP has been validated in the chronic traumatic SCI population.[65–67]

Grip Dynamometer

Grip dynamometer is an instrument used for measuring the force of handgrip muscular contraction. Currently no validity, reliability, or responsiveness studies were found in a CSM population. It has been tested in healthy volunteer individuals.[69, 74–76]

GAITRite Analysis

GAITRite Analysis[71] is a computerized walkway system embedded with pressure sensors that detect a series of footfalls. The walkway is connected to a personal computer with application software that calculates temporal and spatial gait parameters. No studies were identified in a CSM population testing validity, reliability, or responsiveness. However, the GAITRite system has been tested in these populations: elderly,[71–74] children with motor disabilities,[73] knee replacement,[74] and patients with Parkinson disease.[77]

DISCUSSION

As the literature and practice regarding the management of CSM evolves, a remaining challenge is the lack of validation of the outcome measures that are being used to evaluate and define the population. The literature establishes that there is a paucity of measures available, particularly specific,

TABLE 3. Framework for Implementation of Measurement in the CSM Population

Construct	Screening	Clinical Longitudinal	Research Longitudinal
Upper limb	GRASSP partial Grip strength	GRASSP complete Grip strength QuickDASH	GRASSP complete Grip strength QuickDASH
Balance		BBS	BBS
Gait	30MWT	30MWT 10MWT 6MWT	30MWT 10MWT 6MWT GAITRite Analysis
Global	NDI mJOA MDI	NDI mJOA MDI	NDI mJOA MDI SF-36

The outcome measures specific to the construct as defined in Figure 2, and how they can be useful in clinical practice (screening, clinical research, research longitudinal) is shown in Table 3. This table is useful to define the selection of measures. Each construct should be considered carefully and how assessment will benefit clinical practice. Not all measures must be implemented, however, when considering a battery of tests multiple constructs, ICF classifications and clinical feasibility should be addressed. The bolded measures are the 2 outcomes recommended for use always with the CSM population.

mJOA indicates modified Japanese Orthopaedic Association Assessment; SF-36, Short-Form 36 Health Survey; NDI, Neck Disability Index; MDI, Myelopathy Disability Index; GRASSP, Graded Redefined Assessment of Strength Sensibility and Prehension; CSM, cervical spondylotic myelopathy; 30MWT indicates 30-Meter Walk Test; 10MWT, 10-Meter Walk Test; 6MWT, 6-Minute Walk Test; ICF, International Classification for Functioning.

quantitative, sensitive, and validated measures. There are 2 main factors that limit individuals with CSM, upper limb function, and gait impairment (which is closely related to balance). Urogenital dysfunction is also a consequence of cervical cord compression. Consideration of all aspects of impairment and their impact on function are very important. Furthermore, because the variability of impairment is so large, using more than one outcome assists in characterization of the individual, which will enlighten the clinician. Ultimately the selected outcomes will establish more detail at baseline, allow for outcome assessment and assist in decision making pretreatment to determine if there is progression of disease.

The 2 most commonly used measures to quantify CSM are the JOA scale[78] and the Nurick grade.[4] Both are measures of signs and symptoms, which evaluate gait, lower extremity function, hand function, and bladder control. Despite the widespread use of these outcome measures, they lack the sensitivity to assess the full range of CSM, especially patients with a mild presentation. However, the mJOA is the only measure that addresses the bladder dysfunction in this disease. Commonly used self-perceived measures of improvement in CSM are the NDI[79] and the general outcome, SF-36.[80] These measures have both been validated for use in patients with cervical spine disorders and provide adequate information regarding self-perceived function.[79,80] Neither the JOA nor Nurick assess in a quantitative manner gait, balance, or hand function as it may relate to one's ability to function on a daily basis. Thus, a method using ancillary measures to define severity is required to define clinical presentation in a standardized manner. Measures with greater responsiveness are necessary to define the milder subpopulation and define the predictors of progression, particularly for those individuals who are not offered surgery early in the course of CSM. Use of ancillary measures will also provide the pertinent information required to establish predictors of recovery and outcome after intervention.

To date, the most common methods for treating CSM are by conservative management or performing decompressive surgery. Surgery is more commonly offered to those with a moderate to severe presentation of CSM; however, there is an increase in the number of individuals with mild CSM having surgery. Surgical techniques and approaches have evolved during the past 2 decades, as a result, outcomes are much improved.[81,82] Despite the advances in surgical management, the void that remains in the clinical field is the lack of outcome measures which can characterize the population with greater precision. More sensitive outcomes will be useful in establishing efficacy of interventions; assist in identifying the predictors of disease progression and enable clinicians to offer treatment that is most effective and offered at the most appropriate time in the course of this disease. Essentially this will lead to the treatment of CSM before the irreversible sequelae are manifested. Understanding the deficits of this population will enable the establishment of a standard method to define a severity of disease index. Therefore, the objective of this review was to identify the most clinically relevant, quantitative, reliable, valid, and responsive outcome measures for the assessment of CSM that will establish a meaningful clinical dataset, which will allow clinicians to assess outcomes, monitor the natural history of CSM, and establish the predictive value of clinical findings.

Clinicians should consider use of the ancillary measures: QuickDASH, Berg Balance Scale, GRASSP Version 1.0, Grip Strength, GAITRite Analysis, and the 30MWT.

These measures should be implemented into clinical practice either for screening, longitudinal clinical assessment, or longitudinal research assessment. A clinician should consider the use of the outcome measure prior to selection and whether the role of the measure is for screening, longitudinal follow-up, or research follow-up. Use of measures will vary depending on the practice one conducts. However, the NDI and mJOA should always be administered when a patient presents with CSM. These should be standard measures used across centers (see Supplemental Digital Content Appendix 1, available at http://links.lww.com/BRS/A822).

CONCLUSION

The goal of this review was to identify the most reliable, valid, responsive, and quantitative, outcome measures for the assessment of CSM that will establish a meaningful clinical dataset to allow clinicians to assess outcomes, monitor the natural history of CSM, and establish the prognostic value of clinical findings. The CSM population is a heterogeneous population that cannot be defined thoroughly with a single score on a single outcome measure. Because the clinical presentation and manifestation of CSM is not unidimensional, it is not feasible to use a single unidimensional outcome without missing a large aspect of meaningful clinical information. On the basis of the measures that are available specifically for CSM and related populations, we have established a framework for the use of outcome measures. In summary, we recommend that the mJOA, Nurick grade, MDI, NDI, and 30MWT are most appropriate for the assessment of CSM. However, 6 additional outcome measures (QuickDASH, Berg Balance Scale, GRASSP, Grip Dynamometer, GAITRite Anlaysis) were identified, which provide complementary assessments for CSM.

Summary Statements. There does not exist a single or composite of outcomes instruments that measures myelopathy impairment, function/disability, and participation that has also demonstrated reliability, validity, and responsiveness in a CSM population. More work in the development and psychometric evaluation of new or existing measures is necessary to identify the ideal composite of measures to be used in the clinical and research settings.

- The mJOA, Nurick grade, NDI, MDI, and 30MWT should be adopted in any clinical practice that treats CSM both for screening and clinical follow-up.
- We propose that clinicians and researchers consider using the ancillary measures identified, such as the QuickDASH, Berg Balance Scale, GRASSP version 1.0, Grip Strength, and GAITRite Analysis.
- It is highly recommended that baseline and follow-up measurements should be performed in patients with CSM.

➢ Key Points

- ❑ Although a single outcome measure cannot define the broad range of deficits seen in the CSM population, we recommend the use of the mJOA, NDI, Nurick Scale, and the 30MWT.
- ❑ Use of reliable, valid, and responsive outcome measures in CSM is necessary to establish improved management of the population.
- ❑ Measures that specifically and sensitively quantify gait, balance, hand strength, hand function, and self-perceived function related to tetraparesis provide more refined information regarding this population.
- ❑ Use of such measures will improve clinical management, monitoring, and prognosis for patients with CSM.

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