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# Muscle Dysfunction in Cervical Spine Pain: Implications for Assessment and Management

**N**eck pain can be a disabling and recurrent disorder characterized by periods of remission and exacerbation.<sup>9</sup> It has been estimated that in any 6-month period 54% of adults will experience neck pain, with approximately 5% having substantial activity limitations due to their neck disorder.<sup>8</sup> Alarming, a cross-sectional study has suggested that only 6.3% of individuals who suffered from neck pain in the previous year were free of recurrence.<sup>60</sup>

This tendency for chronicity of some mechanical neck pain (MNP) disorders may at least in part be attributed to inadequate recovery of cervical muscle function postinjury, especially considering the

heavy dependency of the cervical vertebral column on its muscles for its physical support.<sup>58</sup> Similar to findings in low back pain, cervical muscle dysfunction does not appear to spontaneously recover follow-

ing the alleviation of symptoms.<sup>67</sup> There is an ever growing number of mechanistic studies identifying muscle dysfunction in individuals with MNP.<sup>10,21,32,56</sup> Pertinent to clinical practice, programs to retrain muscle function have shown favorable responses in terms of improvements in neck pain, disability, and function.<sup>37,79</sup> A recent systematic review suggests that the combination of exercise and manual therapy are the most efficacious of all conservative managements for subacute or chronic MNP.<sup>28</sup> While the evidence indicates the importance of assessing and training cervical muscle function in the management of MNP, the development of clinical guidelines for its optimal implementation in clinical practice requires additional efforts. The myriad of muscle impairments identified and heterogeneity of patients presenting with MNP continue to challenge the acumen of even the most astute clinician, with regard to assessment and clinical relevance of such deficits. In accordance, we have yet to reach consensus about the optimal method of measuring, classifying, and training cervical muscle function.<sup>39</sup>

The following clinical commentary is divided into 3 sections: the first provides an overview of the evidence concerning muscle dysfunction in MNP, and the sec-

• **SYNOPSIS:** There is irrefutable evidence of an association between mechanical neck pain (MNP) and dysfunction of the muscles of the cervical spine. A myriad of impairments have been demonstrated that include changes in the physical structure (cross-sectional area, fatty infiltration, fiber type), as well as changes in behavior (timing and activation level), of the cervical muscles. Such changes suggest an impaired capacity of the cervical muscles to generate, sustain, and maintain precision of the required levels of torque needed for optimal function. In the context of physical support, these changes potentially have deleterious consequences for the cervical region, which relies heavily on its muscles for mechanical stability. While interventions focused on the retraining of cervical muscle function have shown favorable responses in alleviating MNP, the development of best practice strategies for the

assessment and management of cervical muscle dysfunction is still a work in progress. One obstacle in researching the efficacy of cervical muscle training is that, as yet, we do not possess the capacity to optimally measure and classify those patients most likely to respond to different methods of training that would enrich clinical practice. While gains in this area are emerging, the ability of a clinician to best identify the need and implement the most appropriate method of training cervical muscle function is still largely dependent on a comprehensive examination of the patient that considers all aspects of the patient's disorder and functional requirements.

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ond and third sections consider the implications of the evidence for assessment and training of cervical muscle function in clinical practice. While evidence from mechanistic and interventional studies have justified the need to address cervical muscle dysfunction in MNP, research into cervical muscle dysfunction is in its infancy and has only just begun to inform the assessment and management of the complex cervical motor system for the varied MNP presentations managed in clinical practice. Clinicians working within an evidence-based practice framework are still dependent on integrating their individual clinical expertise with the available evidence<sup>62</sup> to comprehensively assess and train cervical muscles tailored to the individual patient's needs. It should be noted that it is beyond the scope of this commentary to comprehensively detail assessment and training procedures of the cervical motor system, and for this the reader is directed elsewhere.<sup>36</sup>

## MUSCLE DYSFUNCTION IN MECHANICAL NECK DISORDERS

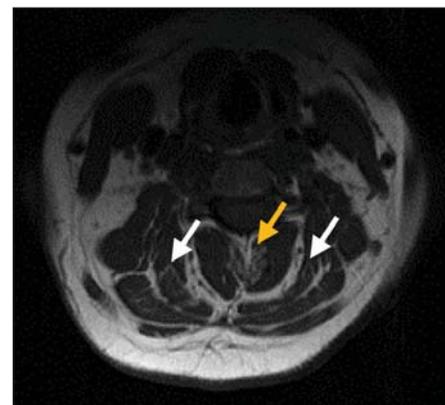
**T**HE CERVICAL SPINE IS A REGION OF sophisticated motor function. The cervical muscles serve the sensory systems and support and orientate the head in space relative to the thorax.<sup>36</sup> Further to this, the motor system of the cervical region complements other vital functions such as respiration, phonation, and swallowing.<sup>48</sup> The cervical vertebral column is highly dependent on the active support of muscles for physical support. Patients' complaints of a "heavy head" make sense when one considers that buckling of a cervical vertebral column that is devoid of muscles occurs with loads of less than 20% to 25% the weight of the head.<sup>58</sup> Biomechanical models suggest that control of buckling and unwanted rotary intersegmental motion, which can result from the contraction of large multisegmental muscles during daily tasks, is dependent on precise control of the deeper muscles.<sup>78</sup> A deep sleeve

of muscles envelope the cervical vertebral column, and it is these deep muscles that are best suited to provide precise control of segmental motion.<sup>7,46</sup> Certainly, the angle of the cervical column has been associated with the morphology and physical integrity of deep muscles such as longus colli<sup>46</sup> and semispinalis cervicis.<sup>63</sup> With such reliance on active support mechanisms, it is feasible that aberrant neuromuscular control of the cervical spine may irritate pain-sensitive cervical structures and contribute to, or perpetuate, MNP.<sup>36,57</sup> Recent studies support this notion by identifying specific changes in the physical structure, behavior, and function of the cervical muscles in patients with MNP.

### Changes in Physical Structure

Radiological imaging studies have shown alterations in the physical structure of cervical muscles in patients with chronic MNP. Changes include widespread atrophy, pseudo hypertrophy, and fatty replacement of the cervical extensor muscles.<sup>1,10,40</sup> These changes are most notable in the suboccipital and deep multifidus muscles, possibly due to their high density of type I fibers and muscle spindles,<sup>7</sup> but also occur in the more superficial layers such as the semispinalis capitis muscle.<sup>8,32</sup> Additionally, biopsy studies have shown fiber type changes in both the ventral and dorsal muscles of the cervical spine in individuals with longstanding neck pain that appear to be unique to type I slow-twitch fibers.<sup>73</sup> The mechanisms underlying these observed changes in muscle structure and their precise relationship to the functional and physical impairments known to characterize patients with traumatic neck disorders is not fully understood.<sup>10</sup> Nevertheless, there are some reasoned hypotheses.

It has been suggested that changes in cervical muscle structure in patients with MNP may be related to many different factors, including but not limited to (1) injury, (2) presence of pain, (3) general disuse, (4) nerve pathology, and (5)



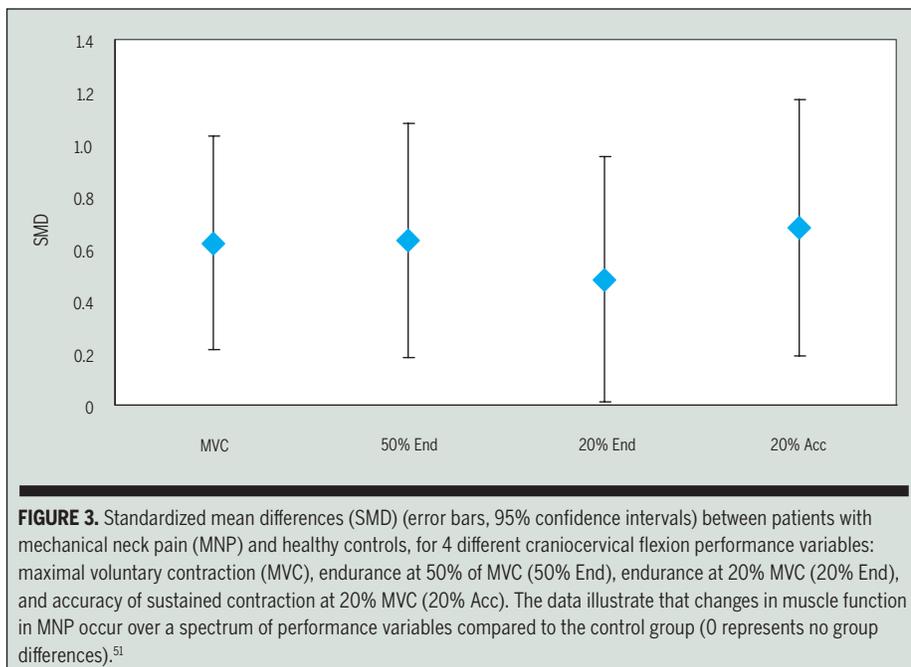
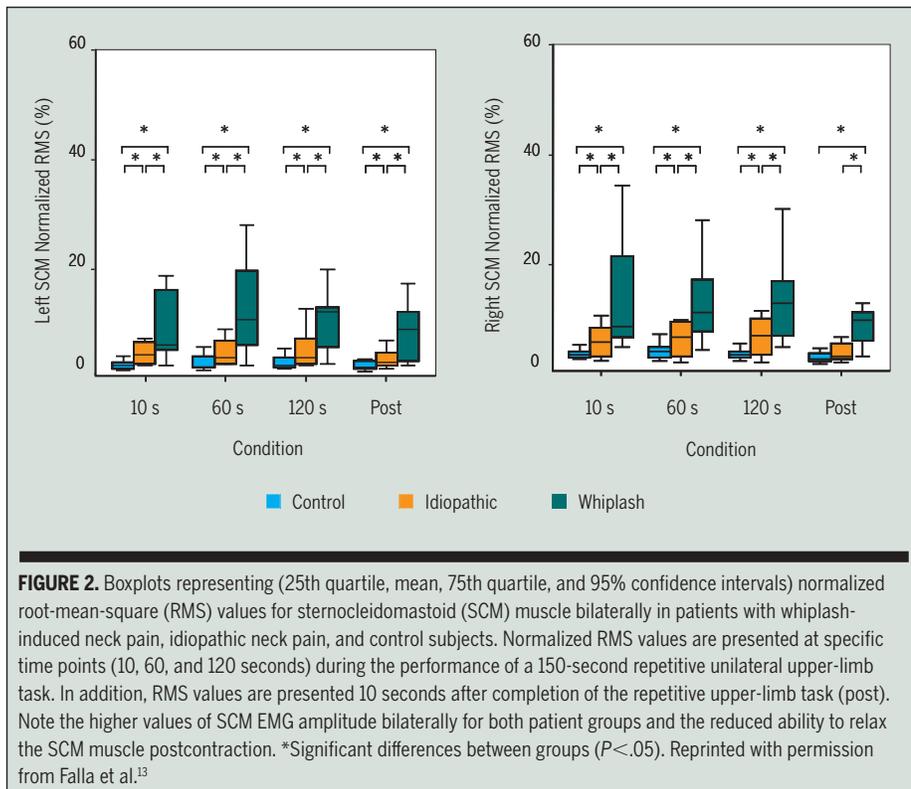
**FIGURE 1.** T1-weighted axial magnetic resonance imaging at the C5 segmental level in a patient with chronic whiplash, illustrating signal intensity change (bright) throughout the cervical extensor musculature, indicative of muscular degeneration (fatty replacement). As can be observed, there is signal change present in the deep multifidus, semispinalis cervicis (orange arrow), and semispinalis capitis bilaterally (white arrows).

inflammatory responses to injury, with subsequent demyelinated nerve tissue.<sup>10,12</sup> The mechanism of injury itself appears to play a role in the observed changes in some patients. For example, fatty replacement of the cervical extensor muscles was observed in patients with whiplash-associated disorders<sup>10</sup> (FIGURE 1) but was not found in patients with MNP of an insidious onset.<sup>12</sup> The reported group differences in fatty changes of the cervical extensors suggest that the findings are unique to traumatic whiplash. However, it is noteworthy that the subjects with whiplash in this study<sup>12</sup> had much higher levels of pain and disability when compared to subjects with persistent insidious onset neck pain, which may also explain the observed group differences.

### Changes in Muscle Behavior

Changes in the behavior of the cervical muscles, as measured using electromyography, are consistently observed in people with MNP. These changes indicate a reorganization of the motor strategy to perform specific tasks. In contrast to the consistent functional muscle synergies that are present in pain-free individuals to generate multidirectional patterns of force,<sup>6,74</sup> neck pain is associated with dis-

## [ CLINICAL COMMENTARY ]



turbed neural control of the cervical muscles. Changes in muscle behavior include heightened activity of the superficial muscles such as the sternocleidomastoid and anterior scalene muscles during craniocervical flexion<sup>21,32</sup> and upper-limb movements<sup>13</sup> (FIGURE 2), as well as heightened

coactivation of the superficial cervical flexor and extensor muscles during isometric contractions.<sup>23</sup> The superficial cervical flexor muscles also appear to be slower to relax following movement or muscle contraction,<sup>13</sup> as does the upper trapezius muscle in response to repetitive upper-

limb movements.<sup>13,24,51</sup> Thus, heightened activity of the superficial muscles appears to be independent of the task, suggesting that neck pain is associated with a loss of the well-defined preferred directions of muscle action that are observed in individuals free of neck pain.<sup>6,74</sup> Augmented activity of the superficial neck muscles may be compensatory for changed activation of the deep cervical muscles, which, on the contrary, show signs of inhibition in neck pain,<sup>21</sup> including a delay in the speed of their activation when challenged by postural perturbations.<sup>18</sup>

Experimental studies suggest that the reorganization of functional muscle synergies observed in patients with MNP reflects a change in the neural strategy to permit motor and force output to be maintained in the presence of pain, by redistributing loads between synergists and antagonist muscles specific to the task performed.<sup>15,25</sup> Although these adaptations may seem to be optimal responses to the painful condition for the motor output to be maintained, the substantial changes in activation of the cervical muscles may have long-term consequences. For instance, prolonged overactivity of the superficial cervical muscles may have deleterious effects on the properties of the muscle fiber membrane, resulting in greater muscle fatigability.<sup>14</sup>

There are numerous mechanisms that may underlie the described changes in muscle behavior. These include reflex-mediated adaptation of motor neuron discharges to pain,<sup>22,65</sup> alterations in cortical excitability and changes in the descending drive to muscles,<sup>44</sup> changes in muscle spindle sensitivity through sympathetic activation,<sup>59</sup> as well as other adverse effects of stress, fear, and anxiety.<sup>2,52</sup>

### Changes in Function

The changes in structure (cross-sectional area, fatty tissue, and fiber type) and behavior (timing and activation level) of the cervical muscles have implications for the muscles' capacity to generate and sustain torque to the cervical spine and head (FIGURE 3) with the necessary preci-

sion required for the intricate function of the region. For example, when compared to control populations, studies have shown that patients with MNP have deficiencies in maximal strength,<sup>31,56,76</sup> endurance,<sup>16,56,76</sup> precision during dynamic movement<sup>64</sup> and sustained isometric contractions,<sup>56</sup> efficiency of contraction,<sup>16</sup> and repositioning acuity.<sup>41,71</sup> Of particular note, changes in the endurance,<sup>16,56</sup> precision,<sup>56</sup> and efficiency<sup>16</sup> of cervical muscles to sustain torque have been found at moderate and low intensities of contraction (20%-50% maximal), which resemble the effort intensity commonly used in many activities of daily living. Additionally, it is speculated that changed afferent input from neck muscles due to pain or impaired neuromuscular control may influence gaze stability due to the reflex interactions between visual input and afferent input from cervical structures,<sup>4</sup> and may contribute to the disturbed oculomotor control observed in people with MNP.<sup>72,77</sup>

Functionally, these impairments could affect the patient's ability to optimally orientate the cervical column or to provide the support required of the motion segments during daily tasks involving movement of the head and neck or upper limbs. It should be noted, however, that potentially, individuals might remain symptom free in the presence of the impairments if their functional demands do not exceed the physiological capacity of their impaired cervical motor system. However, clinicians will be familiar with the patient's history suggestive of symptom-free function until the commencement of a new activity or increased intensity of a pre-existing activity. In such circumstances, it is likely that the demands required of the patient's cervical muscle system exceeded its physiological capacity.

### Key Points

Changes in physical structure and behavior of the cervical muscles are evident in MNP disorders and, in accordance, deficits in the capacity of the cervical muscles

to generate and sustain force have been shown to be a feature of these disorders.

Although research into cervical muscle dysfunction in MNP continues, sufficient evidence already exists to indicate that assessment of cervical muscle function should be routine in the clinical examination of patients with MNP.

## CLINICAL ASSESSMENT OF CERVICAL MUSCLE FUNCTION

**T**HE CHALLENGE FOR CLINICIANS assessing muscular deficits in the cervical region is the fact that mechanical neck disorders are not homogenous. MNP can manifest as motor impairments in 1 or more directions of motion, may involve the neighboring thorax and shoulder girdle, and may potentially have a multitude of biological and psychological contributions.<sup>36</sup> Additionally, the physical conditioning requirements of patients presenting with MNP are not homogenous. For example, the strength and endurance demands on cervical and axio-shoulder muscle function in a storeman lifting heavy boxes repetitively above chest height will be different to those required by a screen-based keyboard operator. A comprehensive initial patient interview is necessary to ascertain the individual's functional requirements and problematic activities to permit appropriate goal setting.

In the physical assessment, clinicians can utilize both quantitative and observational clinical tests to detect changes in cervical muscle function (eg, inability to generate and sustain force with accuracy), which have been informed by research.

### Quantitative Assessment

Conventional methods to quantify elements of cervical muscle dysfunction have focused on specific uniplanar cervical muscle groups and, in particular, the flexor and extensor muscle groups. Many of these research methods utilize sophisticated techniques, such as electromyography (muscle behavior)<sup>18,21,35</sup> and imaging (muscle physical structure),<sup>11,40</sup>

that are not available in most clinical settings. Some clinical settings may have access to dynamometry devices that can be utilized to detect changes in muscle maximal strength,<sup>31,56,76</sup> endurance,<sup>16,56,76</sup> and precision<sup>56</sup> of contraction that have been identified in both the cervical flexor and extensor muscle groups in patients with MNP. Other clinical tests not requiring dynamometry devices have been described to quantify aspects of performance<sup>27,36,45</sup> of these muscle groups; however, they do rely on the observational skill of the clinician to determine the point of test failure, perhaps lessening the objectivity of the measure. Within the cervical flexor and extensor muscle group, and based on the anatomical configuration of the deep cervical muscles, there is also justification to assess the muscles of the craniocervical region separately from the muscles of the typical cervical region. Dynamometry methods have been used in research settings to measure the performance of these craniocervical muscles<sup>56,76</sup>; however, the best validated quantifiable measure of their performance available for clinical use to date is the craniocervical flexion test, particularly in its capacity to assess deep cervical flexor muscle function.<sup>21,35</sup>

Caution should be taken in weighting too heavily quantitative measures of cervical muscle strength and endurance. They measure only one element of muscle performance, and there may be difficulty in establishing criteria as to normal versus impaired performance, particularly due to the varied methods and technologies used, the spectrum of age ranges of patients seen in clinical practice, and the varied functional requirements of patients with respect to strength and endurance requirements.

### Observational Assessment

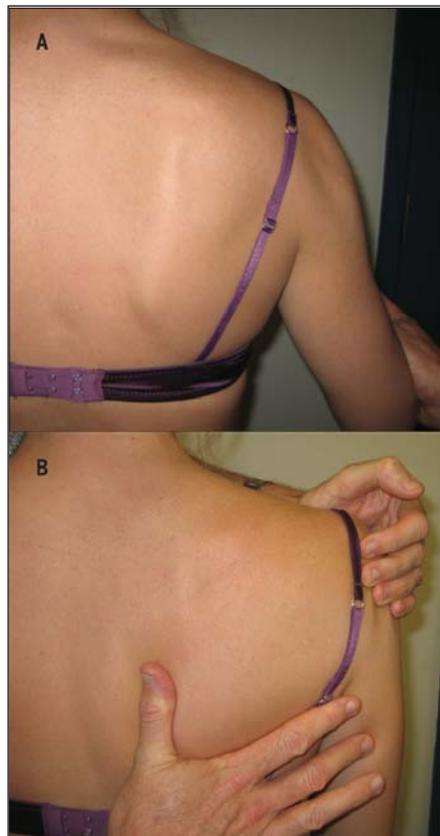
Cervical muscle performance in terms of its control in the orientation and motion of the head and cervical spine can be assessed during the observation of functional activities, particularly those reported by the patient to be problem-

## [ CLINICAL COMMENTARY ]

atic for, or aggravating of, their disorder. Commonly in patients with MNP, these activities may involve prolonged sitting postures, movements towards the extremes of range, such as cervical extension, or repetitive, prolonged, or strenuous upper-limb activities.

The observation of dynamic postural control (the patient's ability to actively control spinal posture) of the cervical spine, although not usually directly quantifiable, is cornerstone in the clinical assessment of cervical muscle function. Much work is being performed to better understand and identify the role of cervical muscle dysfunction in the control of spinal posture.<sup>19,69,70</sup> Posture orientation of the cervicothoracic spine will impact on the distribution of load between anterior and posterior cervical vertebral elements.<sup>42</sup> Studies investigating prolonged sitting postures in patients with neck pain have shown the angle of the cervical lordosis to change in response to an increasing thoracic kyphosis over time, changes that were not observed in those without neck pain.<sup>19,69</sup> Associated with these postural changes were altered activation of the cervical extensor and upper trapezius muscles.<sup>70</sup> Although it is convenient to infer cause and effect from these observations and MNP, scientific validation of a correlate between postural deviation and neck pain remains inconclusive, and the clinical assessment of posture remains challenging.<sup>26,76,80</sup> Nevertheless, patients who report specific postures as an aggravating factor, who demonstrate poor cervicothoracic postural habit when asked to mimic their aggravating activity, and in whom there is a lessening of symptoms with postural correction strategies, could be considered at least in part to have a postural component to their disorder that usually requires a re-training approach combining correction strategies at the cervical, thoracic, and lumbar regions.<sup>36</sup>

Shoulder girdle function and, in particular, scapular control during tasks of the upper limb are important considerations



**FIGURE 4.** Observation of scapula orientation relative to the thorax during upper-limb tasks, such as (A) isometric shoulder abduction (resisted by the therapist's hand), may be used to clinically assess the capacity of the axioscapular muscles to orientate the scapula under load. If the scapula appears poorly orientated, such as in A (eg, downwardly rotated, protracted, and winging of the medial border [internal rotation] and inferior angle [anterior tilt]), it can be repositioned with the assistance of the therapist (B), after which the patient's capacity to replicate the corrected position unassisted can be assessed.

in the assessment of neck disorders. Aberrant axioscapular muscle function is often observed in patients with MNP. Such findings include disturbed axioscapular muscle activity during repetitive upper-limb tasks<sup>13,51</sup> and morphological and histological changes in the upper trapezius muscle.<sup>38,43</sup> Due to their superior attachments, muscles such as levator scapulae and upper trapezius have the capacity to induce motion and abnormally load cervical motion segments in the presence of impaired axioscapular muscle function.<sup>3</sup> From a clinical perspective, some individuals with MNP presentations appear recalcitrant to improvement unless ax-

ioscapular function is addressed. Clinical observations where patients report that upper-limb activities aggravate their MNP are common. In addition, patients often demonstrate poor control of scapular orientation and motion (considered to be indicative of axioscapular muscle dysfunction) during weight-bearing and non-weight-bearing (FIGURE 4A) upper-limb tasks. Assisting the patient to correct scapular orientation (FIGURE 4B) and then observing the patient's capacity to replicate the corrected scapular position unassisted,<sup>49,50</sup> as well as maintain the corrected scapular position while the upper-limb tasks (FIGURE 4A) are repeated, are helpful clinical tests of axioscapular muscle function. As abnormal orientation of the scapula also appears to be present in some healthy individuals with no history of neck pain, the relevance of any observed altered scapular orientation to a patient's neck pain disorder needs to be established. Comparing the patient's painful neck symptoms, painful cervical movements, and palpable tenderness in axioscapular muscles, immediately before and after repositioning of the scapula, are helpful assessment strategies.<sup>36</sup> Repositioning of the scapula with the assistance of strapping tape may permit any changes in symptoms suggestive of axioscapular involvement to be evaluated over a longer period.

### Key Points

No single test is conclusive or all encompassing in the assessment of cervical muscle function. Clinicians rely on a battery of clinical tests, including both quantifiable and observational tests, to gain information concerning the patient's cervical muscle function.

The clinical assessment should determine if the patient's disorder fits a pattern consistent with cervical muscle dysfunction that may include aberrant performance during dynamic postural tasks, active movements of the cervical spine and shoulder girdle, and specific performance tests of select muscle groups.

## IMPLICATIONS FOR THE TRAINING OF CERVICAL MUSCLE FUNCTION

**T**RAINING AIMED AT IMPROVING THE performance of the cervical muscles is effective for the alleviation of pain and improvement of disability and function associated with mechanical neck disorders.<sup>28,39</sup> The challenge for clinicians is to optimize the training of muscles to best address the patient's key functional deficits. Appropriate progression of a patient's training program is dependent on diligent monitoring of the patient's response to exercise in terms of change in pain and disability, improvement in functional activities, and change in motor performance. The patient's response to tests of cervical muscle function will change as the stage and severity of the disorder improves. The following section will address key questions regarding clinical management of cervical muscle dysfunction, to highlight the clinical reasoning process required to manage the diverse presentations of muscle dysfunction commonly encountered in the clinical setting.

### What Should Guide Exercise Prescription for the Management of Neck Pain?

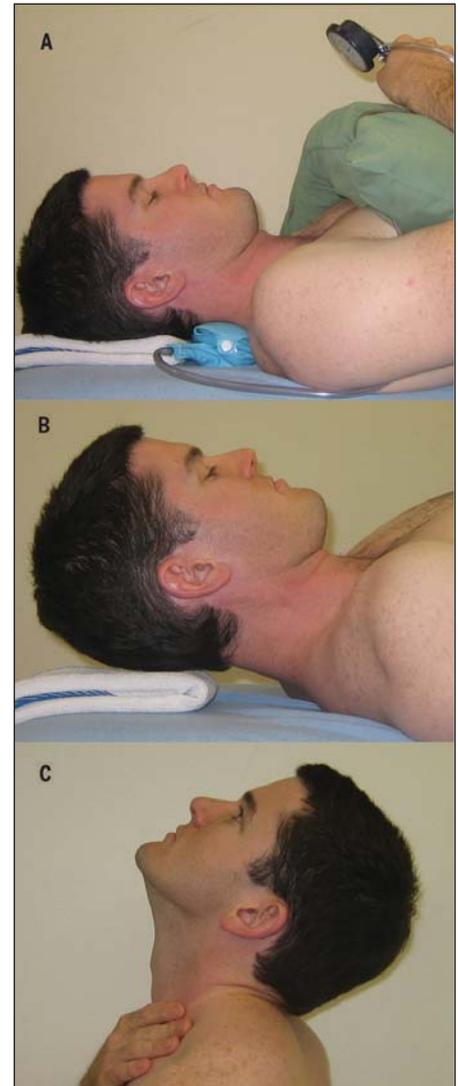
Exercise prescribed to train cervical muscle function is commonly directed towards individual muscle groups or towards the training of, or a component of, a problematic functional activity, or a combination of both. Regardless of the approach, the focus underlying all exercise strategies is towards the restoration of the patient's key functional deficits, and this should be reflected in all exercise prescription. This function-oriented approach is meaningful to the patient and encourages patient compliance. For example, in a patient with neck pain associated with prolonged sitting postures, incorporating practice of sitting posture correction skills (ie, correction strategies at the lumbar, thoracic, cervical, and shoulder girdle regions, as required) should be included immediately. We have previously shown that specific instruction



**FIGURE 5.** Training of the deep lower cervical extensor muscles. The exercise can be performed in the positions of prone on elbows (as in this figure), 4-point kneeling, or sitting. The patient is instructed to let the head and neck move into flexion, then to return to the starting position to train the eccentric/concentric function of the cervical extensors. During the exercise, the patient is encouraged to maintain a neutral craniocervical position, and, instead, the flexion/extension motion is encouraged at the lower cervical spine, facilitated in this figure by the therapist's fingers. Based on anatomical configurations of the extensor muscles, we propose that this maneuver encourages training of the deep lower cervical extensors while minimizing activity of the more superficial extensors such as the semispinalis capitis muscles that attach to the occiput.

from a physical therapist, when correcting an upright sitting posture, results in better activation of key cervical postural muscles, such as the deep cervical flexor muscles, as compared to a patient's attempt to sit in an upright posture with no prior instruction.<sup>20</sup> Patients are encouraged to incorporate their postural correction strategies into their daily sitting practices, making use of memory joggers or reminders to encourage regular practice and the acquisition of good postural habit. Postural training may be enhanced by the addition of specific exercises, as indicated by the physical examination, to enhance training of key postural muscles such as the deep lower cervical extensor muscles (**FIGURE 5**) and the deep craniocervical flexor muscles (**FIGURE 6A**), which are important postural synergists, especially in controlling forward head postures.

Specific training of more challenging functional activities, such as extension of the head and neck in an upright pos-



**FIGURE 6.** Progression of exercise to train cervical flexor muscle function. (A) Craniocervical flexion training with an emphasis on the coordinated action and low-load endurance of the deep and superficial cervical flexor muscles. Correct performance and progression of this exercise can be enhanced with the use of the Stabilizer pressure biofeedback device. (B) A progression of flexor muscle training. The head is gently lifted off, then lowered down to the supporting surface, while maintaining the craniocervical region in mild flexion to train the inner-range concentric and eccentric performance of all cervical flexor muscles. This exercise should be commenced carefully and within the capabilities of the patient, instructing them at first to only partially lift the weight of the head, progressing, as able, to lifting the full weight of the head off the supporting surface. (C) Training is progressed to an upright position so that the outer range eccentric and concentric performance of the flexors can be trained, progressively training further towards the extreme of range within the patient's capability.

ture, which requires an eccentric action of the cervical flexor muscles, is often too challenging in the early stages of rehabilitation and may provoke pain. Instead, specific training of the cervical flexor muscle group may need to be gradually progressed, at first incorporating coordination training of the deep and superficial cervical flexors and, subsequently, low-load endurance training of the deep cervical flexors (FIGURE 6A).<sup>33,55</sup> It may progress, as able, to incorporate concentric and eccentric contraction of the cervical flexors in their inner range, utilizing the weight of the head (FIGURE 6B), then, as able, progress to functional upright extension to train eccentric performance of the flexors in their outer range of motion (FIGURE 6C).

Training may also need to be directed towards axioscapular muscle function, particularly in patients who report activities of the upper limb to be problematic and have examination findings demonstrating signs of poor active control of the scapula. A priority is first given towards the patient attaining active control of scapular orientation, facilitated by the therapist (FIGURE 4B) and then practiced by the patient.<sup>49,50</sup> Once correct orientation of the scapula is acquired, training can then be progressed by challenging the maintenance of the new scapular position under load, using weight-bearing and non-weight-bearing tasks of the upper limb, consistent with the functional requirements of the patient. While additional exercise may also be directed towards training of specific axioscapular muscles,<sup>29</sup> we contend that maintaining the patient's underlying focus towards orientation of the scapula facilitates the coordinated action of all axioscapular muscles together, and this is needed to control the multidirectional rotations and translations capable by the mobile scapulae.<sup>47</sup> Although much is yet to be explored concerning axioscapular muscle function, initial studies have suggested that even a simple correction of scapular orientation requires the coordinated action of all 3 portions of the trapezius muscle.<sup>50</sup>

## What Intensity of Training Is Best to Improve the Performance of Cervical Muscles?

With respect to the intensity of training of individual muscle groups, more than 1 mode of exercise has shown positive benefits in the management of painful neck disorders.<sup>30,37,61,79</sup> Significant clinical benefits have been gained in studies utilizing either low-intensity training designed to train the coordinated function between deep and superficial muscles,<sup>37</sup> as well as exercise performed at higher loads designed to improve muscle strength and endurance.<sup>79</sup> The fact that enough patients experienced improvement with these different programs to gain an overall group benefit in controlled trials suggests that both protocols are appropriate for the management of MNP. Perhaps a more salient point is that these different exercise approaches may represent different stages on a training continuum. Patients may respond to different exercise protocols, depending on the stage of their disorder and factors such as their level of pain, disability, and muscle impairment. For example, there is some preliminary evidence that gentle low-load exercise produces a superior immediate hypoalgesic effect than higher-load exercise.<sup>53,55</sup> Accordingly, low-load exercise may be a better approach to management in the initial stages of rehabilitation when pain is a key issue.

Apart from avoiding the aggravation of symptoms, there appear to be other benefits of commencing exercise programs of specific cervical muscle groups at low load. Gentle low-load exercise has the added benefit of permitting the patient to train in a manner that facilitates the coordinated action of the deep and superficial cervical muscles,<sup>33,55</sup> which, based on the evidence presented previously, may be vital in patients with MNP. It has previously been shown that exercise at low load (20% maximal voluntary contraction [MVC]) facilitates a more selective activation of the deeper cervical muscles compared to exercise at moderate (50% MVC) and maximal (100%

MVC) intensities, in which the superficial muscles markedly increase their activity.<sup>54</sup> In accordance, training at lower intensities has been shown to translate to greater changes in the coordination between the deep and superficial cervical muscles compared to higher-load programs.<sup>33,55</sup> This is not to say that exercise at higher load is not important. Patients whose lifestyle demands higher-level endurance and strength conditioning of muscles will require exercise to be progressed towards these outcomes. Exercise programs utilizing higher-load endurance and strength protocols have shown superior gains in cervical muscle strength, endurance, and fatigability compared to low-load programs.<sup>17,55</sup> The point is that higher-load conditioning of muscles, when indicated, should be commenced as soon as possible and done within the capabilities (and within symptom tolerance) of the patient, and only when an acceptable baseline of control at low load has been achieved.

## How Soon Following Injury Should Training Commence?

There is sound support within the literature that attention to muscle function should be given early following injury. Impairment of cervical muscle function occurs early following injury to the neck,<sup>66</sup> and experimental pain studies suggest that pain has an immediate effect on the behavior of muscles.<sup>15</sup> It is, therefore, suggested that exercise to address observed impairment of muscle function be commenced early in rehabilitation and in a pain-free manner.

## Does It Matter If Exercise Is Painful?

It is logical that exercise that is provocative of pain may be counterproductive, with the knowledge of the detrimental effects that pain has on motor control.<sup>15</sup> This is consistent with our clinical observations in patients for whom exercise was commenced at too high a level, or progressed too quickly. Provoking the patient's symptoms with overzealous exercise could result not only in compliance issues to an exercise program, but in fur-

ther alterations of cervical neuromuscular control.<sup>15</sup> In the initial stages of rehabilitation the dosage of exercise prescribed should reflect a volume permitting stimulus of muscle performance but remaining short of symptom reproduction. As rehabilitation is progressed to a dosage reflecting higher-load strength and endurance protocols,<sup>5</sup> diligent monitoring of patients symptoms is recommended to ensure that any discomfort experienced during exercise associated with fatigue is not sustained between sessions, which may suggest accumulative and potentially injurious fatigue.

### Should Exercise Be Performed in Combination With Other Interventions?

The strongest evidence of efficacy for the management of subacute and chronic MNP from exercise is when it is performed in combination with manual therapy techniques.<sup>28,39</sup> Based on clinical observation, this would seem logical, as in many patient presentations muscle function appears to be hindered by painful or limited mobility of local tissues that seem to be improved with the administration of appropriate manual therapy techniques. The combined exercise and manual therapy approach is also superior to results found for manual therapy intervention alone.<sup>28</sup> It is logical that improvement in painful or limited mobility achieved with manual therapy techniques may be longer lasting if combined with exercise to facilitate muscle function and mobility in the region. It would appear that exercise and manual therapy are complementary to each other, providing additive benefits in terms of pain relief. Certainly, both appear to have pain-modulating properties that may have some neurophysiological basis.<sup>53,75</sup> Traditionally, improvement in neck pain following muscle training was considered to reflect enhancement of physical support for the cervical vertebral column due to demonstrated improvements in activation,<sup>33</sup> strength and endurance,<sup>79</sup> fatigability,<sup>17</sup> and proprioceptive acuity<sup>34</sup> of the cervical muscles and spine. However, specific cervical muscle training

has also been shown to have immediate pain-modulating effects<sup>53</sup> that interestingly differs to that observed for passive cervical manual therapy.<sup>75</sup> Passive cervical manual therapy has been shown to elicit immediate hypoalgesic responses both local and remote to the cervical spine, as well as concurrent sympathetic nervous system excitation suggestive of systemic pain modulation.<sup>68,75</sup> In contrast, specific cervical muscle training was shown to evoke a hypoalgesic response local to the cervical spine only, that was not associated with concurrent sympathetic nervous system excitation.<sup>53</sup> These differences in the pain-modulating properties of specific cervical muscle training and passive cervical manual therapy might in part explain the complementary benefits of these interventions when combined.<sup>39</sup>

## CONCLUSION

**A**SSESSMENT AND TRAINING OF cervical muscle function is a fundamental component of informed clinical practice when managing MNP. Underpinning this approach is a mounting body of evidence that implicates cervical muscle dysfunction as a feature of MNP and demonstrates training of cervical muscle function to be a beneficial intervention for the management of patients with MNP. While research progressively informs clinical practice, a clinician's capacity to optimally assess and retrain cervical muscle function is still largely dependent on astute clinical skill and a research-informed rehabilitative program that is relevant to the functional requirements of the individual patient. ●

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