SYSTEMATIC CRITICAL REVIEW

The assessment of the cervical spine. Part 1: Range of motion and proprioception

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Summary   Neck pain and headache of cervical origin are complaints affecting an increasing number of the general population. Mechanical factors such as sustained neck postures or movements and long-term ''abnormal'' physiologic loads on the neck are believed to affect the cervical structures and compromise neck function. A comprehensive assessment of neck function requires evaluation of its physical parameters such as range of motion, proprioception, strength and endurance/fatigue. The complicated structure of the cervical spine however, makes it difficult for any clinician to obtain reliable and valid results. The aim of the first part of this systematic critical review is to identify the factors influencing the assessment of range of motion and proprioception of the cervical spine.
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Clinical relevance of review findings

The assessment of neck range of motion and proprioception by researchers or clinicians can be influenced by many factors because of the complicated nature of the cervical spine. For this reason, examiners should use the same position (sitting or standing) for each subject, and should take care to control lumbar spine posture during any measurement. Torso stabilisation can overcome this problem. Ideally assessments should be performed after undertaking warm-up exercises and a full practice session at the same time of the day (preferably not early morning). For proprioception assessment, active movements give more information from muscle and joint receptors while fatigue and external influences such as noise and cutaneous stimulation should be avoided.

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PREVENTION & REHABILITATION — SYSTEMATIC CRITICAL REVIEW

Introduction

A comprehensive clinical evaluation of the cervical spine requires consideration of more than a single-factor and includes assessment of both symptoms and physical deficits. Pain is the primary complaint which has attracted the attention of most researchers and clinicians, however pain is only a symptom and not a cause. Also, pain, disability and other symptoms are subjective in nature and may depend on many other factors than the problem itself. The assessment of physical impairments of the neck has been proposed as a more objective measure for the diagnosis and prognosis of neck pain and headache as well as an essential part of their overall management (Strimpakos et al., 2005b; Jull et al., 1999; Hermann and Reese, 2001; Dumas et al., 2001; Nakama et al., 2003; Strimpakos et al., 2004; Strimpakos et al., 2005a; Strimpakos et al., 2006; Nordin et al., 2008; Vaillant et al., 2008).

Interest in the assessment and treatment of strength, endurance, range of motion and proprioception of the cervical spine has increased exponentially in the last two decades (Strimpakos et al., 2005b; Jull et al., 1999; Hermann and Reese, 2001; Dumas et al., 2001; Nakama et al., 2003; Strimpakos et al., 2004; Strimpakos et al., 2005a; Strimpakos et al., 2006; Nordin et al., 2008; Vaillant et al., 2008). To a large extent this appears to be linked to an increased incidence and recurrence of neck problems in combination with a growing dissatisfaction regarding the current methods of identifying the causative factors of cervical spine dysfunction. The objective assessment of several physical parameters has been proposed by many researchers and clinicians as important components of a thorough evaluation of the cervical spine that could possibly contribute to the ''cause and effect'' justification of neck disorders. It is widely accepted that structural pathology does not generally correlate with pain therefore many therapists have focused on restoring function. Strength, endurance, flexibility, proprioception and coordination are basic elements for performing activities of daily living (ADLs) such as sitting, carrying and posture therefore assessing and restoring their deficits have become a primary objective of many clinicians (Liebenson, 2002).

From a previous extended literature review, relevant studies demonstrated great diversity concerning the measurement tools, the methodologies undertaken and analysis of the data used (Strimpakos and Oldham, 2001). Unfortunately, many of these studies were shown to be methodologically flawed.

In order, therefore, to determine the best protocol for measuring physical deficits in the cervical spine this critical systematic review aims to identify the factors influencing their assessments and estimates. The first part of this review addresses the issues influencing ROM and proprioception measurements; and the second part, appearing in a subsequent paper, relates to the strength and endurance/ fatigue measurements.

A computerized search was performed through the Medline, EMBASE, CINAHL and AMED databases from 1966 to December 2008 using broad as well as specific key words — individually or in combination. They included: cervical spine, neck, function, reliability, validity, intra-observer, inter-observer, strength, endurance, fatigue, range of motion, flexibility, proprioception and kinaesthesia. This was followed by a search through references cited in the retrieved articles. Only English language articles were included. Reliability and validity studies were included if they reported at least one measurement tool concerning cervical strength, endurance, ROM and proprioception, regardless of whether the studies were in healthy or symptomatic subjects. Studies were excluded if measurements were limited to an individual vertebra or focused on a small portion of the cervical spine, such as the upper cervical spine.

Range of motion

Measurement of cervical ROM has been used to evaluate the severity of impairment or disability in patients with work-related cervical disorders and whiplash injuries (Hagen et al., 1997; Hermann and Reese, 2001; Klein et al., 2001; Cagnie et al., 2007; Nordin et al., 2008). It has also been used as part of the clinical criteria in disease classification (Headache Classification Commitee of the International Headache Society, 1988) as well as to evaluate the efficacy of a rehabilitation programme (Hagen et al., 1997; Jordan et al., 1998; Huston et al., 2000; Wang et al., 2003; Nordin et al., 2008). Many systematic reviews on neck pain and headache have demonstrated that range of motion is the most frequently reported objective outcome measure in published trials (Aker et al., 1996; Borghouts et al., 1998; Kjellman et al., 1999; Nordin et al., 2008).

Although the terms range of motion (ROM) and flexibility have been considered synonymous by many authors they are not exactly the same (White and Panjabi, 1990); (Kriviskas, 1999). In this review flexibility is expressed in terms of ROM (passive or active). ROM is muscle and joint specific and is influenced by many factors such as age, gender, temperature and even the race of the individual (Kriviskas, 1999).

Furthermore, the present review reveals that measurements of neck function can be affected by intrinsic factors such as the joint complexity and diurnal variation of ROM. It may also be influenced by factors arising during the measurement procedure such as the position and posture of the subjects, the use of active or passive movement, whether the subjects have open or closed eyes, the use of stabilisation and isolation of the cervical spine. The importance of each of these factors and their influence in neck ROM assessment is discussed below.

Factors influencing range of motion measurements and estimates

Joint complexity and range of motion

Reliability of measuring ROM is specific to the action measured and to regional structure and function. For example, measurements of the elbow, generally considered a simple hinge joint, show less day-to-day variation in ROM than measurements of the wrist, the movement of which is affected by multiple joints and numerous muscles (Gajdosik
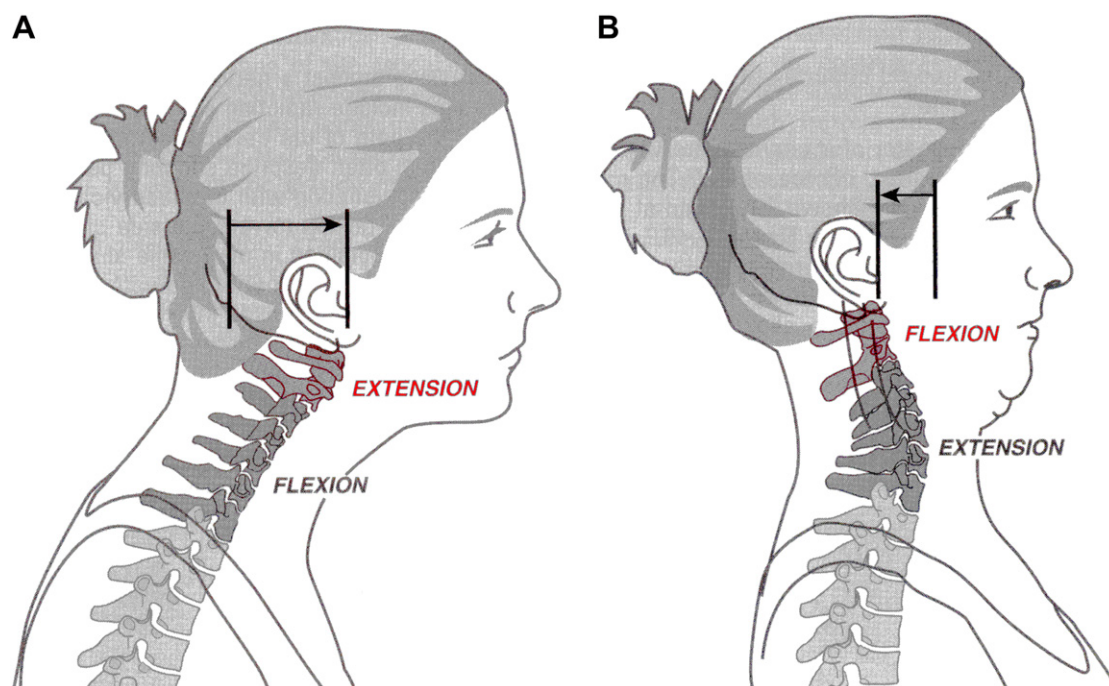
Figure 1 Change in posture of the head affects the relationship of the upper and lower cervical spine and consequently the neck ROM (From Neumann, 2002, with permission).

and Bohannon, 1987). Many authors have demonstrated that even complex movements can be measured reliably when the measurement procedures are controlled. Clinicians and researchers must recognise the complex anatomy of the cervical spine and the greater normal variation in comparison with other joints of the body. During the assessment of neck flexion and extension motion occurring in both the upper and lower regions of the cervical spine must be controlled as much as possible if the full potential of cervical flexion or extension is to be reliably assessed. Furthermore, the usual slump position that many individuals adopt in everyday activities (especially in sitting) leads to a forward head posture and affects greatly the kinematics of the cervical spine (White and Sahrmann, 1994) (see Figure 1). Lack of such control in addition to the wide variety of instruments and lack of standardised procedures may be responsible for the wide range of reported values for normal neck motion (Chen et al., 1999; Solinger et al., 2000).

Neutral position, half cycles or full plane motions

Neutral head position, defined as the anatomical position, has been commonly used but poorly controlled for in most studies (Chen et al., 1999; Solinger et al., 2000; Cagnie et al., 2007). In some reports, the initial head position was adjusted by the examiner using anatomic landmarks, a bubble level or a single inclinometer (Chen et al., 1999). Many other studies used a target in front of their subjects or simply asked them to look straight ahead and to put their head subjectively in a neutral position. The ability to reliably assume the same neutral head position relative to the thorax is essential in measuring half-cycle ROM or assessing

asymmetry accurately and precisely. On the other hand, studies have suggested that the inability of a patient to resume their neutral head position may serve as an additional indication of spinal pathology. Therefore, clinicians and researchers assessing cervical ROM have to be able to standardise and reproduce the head and body posture in each test session in order to have reliable and valid motion estimates.

Stabilisation effect

To assess the range of motion of muscles that cross more than two joints, the body or segments of the body have to be positioned appropriately, stabilising them to ensure validity and reliability (Mellin et al., 1991; Kriviskas, 1999). The lack of isolation of the cervical spine from the rest of the body can affect both the reliability estimates as well as the normative cervical ROM values. Many studies however, did not isolate adequately the cervical spine jeopardizing the validity and reliability of their results (they used manual stabilisation or stabilised only the lumbar spine or asked the subjects to hold a handle) (Christensen and Nilsson, 1998; Lantz et al., 1999; Petersen et al., 2000). The use of sophisticated instruments which are able to record motions only from the cervical spine (e.g. 3D electromagnetic or ultrasound-based devices) can overcome this limitation although in practice the problem is not completely solved (Strimpakos et al., 2005b; Solinger et al., 2000; Dvir and Prushansky, 2000; Petersen et al., 2000). The need therefore for a firm stabilisation of the torso (even when the above instruments are employed) as well as the use of a specially constructed seat adjustable to each subjects' height are essential for repeatable assessments and for recording true ROM values (see Figure 2).

Figure 2   Operator with stabilisation frames.

Initial position effect

The initial body position (namely supine, sitting or standing) could affect the values of the measurements (Nitz et al., 1995; Lantz et al., 1999). Results of recent experiments showed that both initial standing and sitting positions yielded high reliability estimates with standing being slightly better in most movements (Strimpakos et al., 2005b). A probable cause for these discrepancies could be the change of the normal spine curvatures when different initial positions are utilised resulting thus in different ROM values. It seems therefore that it does not matter if measures are made in sitting or standing providing the same position is adopted in subsequent measures.

Active or passive motions

Another issue concerns whether the measurement should be made actively or passively (Nordin et al., 2008). Chen et al. (1999) and (Jordan, 2000) identified some investigations in which passive motion gave greater range of motion values than active movement and also higher reliability estimates. In trying to explain the differences between active and passive motions some authors noted that active ROM may be more idiosyncratic and therefore more difficult to interpret than those using passive ROM techniques, particularly when end-range asymmetry information is considered to be of primary clinical importance (Wong and Nansel, 1992). Passive movement has been considered thus

by some to be a more suitable option for cervical ROM estimation than active movement (Dvorak et al., 1992; Morphett et al., 2003). On the other hand, the advantage of active ROM assessment is the fact that coupled-motion sequences can be better represented and everyday physiologic motions can be measured (Castro et al., 2000). Additionally, measurements of active ROM are not vulnerable to over-pressure variations among different examiners. Despite the above inconsistencies however, no protocol seems to be significantly superior over the other, suggesting that both can be used in clinical settings (Strimpakos et al., 2005b; Nordin et al., 2008).

Open or closed eyes

The influence of vision on cervical ROM has not been examined extensively in the literature with most studies examining cervical ROM with subjects' eyes open (Dvir and Prushansky, 2000; Irnich et al., 2002; Dvir et al., 2002). Some authors have found that passive end-range values were much more variable if goniometric assessments were performed with the subjects' eyes open (Wong and Nansel, 1992). Dvir et al. (2002) suggested that elimination of visual stimulation would allow a clearer delineation of the factors involved in ROM reliability measurements as subjects may use vision to attain higher reproducibility. In a recent study however, both procedures yielded reliable values (Strimpakos et al., 2005b).

Direction effect

The examination of differences in reliability according to a specific direction reveals that in most studies the best correlations were obtained for lateral flexions and axial rotations. Flexion and extension movements seem to be the least reliable. This fact may be related to the position of the trunk relative to the seat. Since the lumbar spine's convexity was not precisely controlled in most of the studies, the initial position could be different with repeated measures. This could result in a different head versus thorax inclination and hence could lead to a larger measurement error (Dvir and Prushansky, 2000). Another explanation is that motion in the sagittal plane involves the upper and lower cervical spine with the larger number of elements giving rise to a larger error. Sterling et al. (2002) suggested that the lower reliability in flexion could be attributed to an order effect as flexion was always the first movement being measured in their study (Sterling et al., 2002). This explanation is rejected however from the results of other studies which assessed other movements first and still found flexion to be less reliable (Lantz et al., 1999). Differences in reliability also exist between sides although there is no specific trend in favour of the right or left direction (Normand et al., 2007).

With regard to normal ROM values, there is general agreement that transverse plane motion displays larger motion ranges as compared to flexion-extension and lateral flexion. Some studies have shown an asymmetry between right and left axial rotation in normal subjects (Chen et al., 1999; Dvir and Prushansky, 2000) and have attributed these differences to hand dominance. More possible however, is the explanation that the inability of most studies to control

the reproduction of the neutral head position could lead to false asymmetries between sides. This is yet another area requiring further investigation.

Warm-up and range of motion

In addition to elevating core temperature, warm-up exercises are used to increase the range of motion about a joint (Smith, 1994). Increases in core temperature whether due to muscle contractions or a passive heat source, enhance the extensibility of the tissues around a joint (Kriviskas, 1999). This effect is evident only while the temperature remains elevated (Enoka, 2002). Cold muscles are stiffer and possibly more predisposed to injury (Best et al., 1997). Frequently no distinction is made between warm-up exercises and those designed to increase flexibility. Differences in flexibility between joints and individuals are due to long-term adaptations, not the changes that take place after a set of warm-up activities (Enoka, 2002; Zakas et al., 2006; Beedle and Mann, 2007). Cervical spine studies have suggested that warm-up exercises which simulate the actual testing procedure increase the compliance of neck soft tissue and minimise the process of creep associated with repetitive measurements (Troke et al., 1996, 1998). Practice of the real tests would also allow the examiner to correct possible incorrect performances from the subjects and it is generally accepted that in any future developments a warm-up session should be included.

Diurnal variation and range of motion

Ranges of motion are not stable with time (Bogduk, 1994; Reilly et al., 2007). Lumbar spine studies have shown that ROM increases during the day (Adams et al., 1987; Wing et al., 1992; Ensink et al., 1996). Moreover, forward bending movements subject the lumbar spine to higher bending stresses in the early morning compared with later in the day (Adams et al., 1987). It is clear however, that for a measurement to be reliable it is important to investigate ROM at the same time of day (Ensink et al., 1996; Reilly et al., 2007) and normative data should encompass diurnal changes. In addition, to overcome the initial stiffness of the spine all measurements are better carried out at least 2 h after arising in the morning (Mannion and Troke, 1999).

Implications for clinicians and researchers regarding neck ROM assessment
The assessment of neck ROM requires awareness of the complexity of this body region. More specifically, the examiner has to use the same subject position (sitting or standing) and has to take care with their lumbar spine posture (forward/backward inclination). Stabilisation of the torso could overcome this problem. All assessments should be performed after undertaking warm-up exercises and a full practice session at the same time of the day and preferably not early morning. The use of active or passive movements with open or closed eyes is left to the choice of the examiner as long as the same protocol is retained in subsequent assessments. Finally, it is essential when assessing the ROM in one particular plane (e.g. left or right side flexion) to ensure a standardised neutral head position.

Proprioception

Proprioception is a term commonly used to describe the complex interaction between afferent and efferent receptors that control the position and movement in space of the body or part of the body (Newcomer et al., 2000). Many authors have stated that proprioception encompasses the sensation of joint movement (kinaesthesia) and joint position (joint position sense) (Lephart et al., 1997; Swinkels and Dolan, 1998; Brumagne et al., 1999; Newcomer et al., 2000). Perception of the orientation of the head in space as well as on the trunk demands not only the contribution of vestibular and visual cues but also proprioceptive information from the cervical spine (Taylor and McCloskey, 1988; Revel et al., 1991). This information comes from many structures around the cervical spine such as muscles, joints and skin (McCloskey, 1978; Taylor and McCloskey, 1988; Hogervorst and Brand, 1998). Conscious proprioception is essential for proper joint function in sports and activities of daily living or work-related tasks. Deficits in motor performance arise when the reliance on proprioceptive feedback is abolished either experimentally or because of a disorder (Gandevia and Burke, 1992; Lephart et al., 1997; Loudon et al., 1997; Karjalainen et al., 2003; Malmstrom et al., 2007; Sjolander et al., 2008; Field et al., 2008; Sandlund et al., 2008; Armstrong et al., 2008) although some studies showed little evidence of impaired cervicocephalic kinaesthetic sensibility in neck pain patients (Rix and Bagust, 2001; Dumas et al., 2001).

Sources of proprioception

The word 'joint' in 'joint position and movement sense' should not be interpreted as meaning that the receptors responsible for these sensations are located solely in the joints. These receptors can be found in different structures such as joints, muscles, tendons, capsules and skin which function as transducers converting the mechanical energy of physical deformation into the electrical energy of a nerve action potential (McCloskey, 1978; Taylor and McCloskey, 1988; Barrack et al., 1994; Hogervorst and Brand, 1998). Mechanoreceptors (muscle spindles, Golgi tendon organs, Pacinian corpuscles, Ruffini endings, free nerve endings) can be classified as either rapidly adapting or slowly adapting. Rapidly adapting receptors such as Pacinian corpuscles are associated with detection of acceleration, deceleration, or any sudden change in deformation of the mechanoreceptor (Barrack et al., 1994; Lephart et al., 1997). Slowly adapting receptors such as Ruffini end organs and Golgi organs are sensitive to the position of the body in space and to a slow change in position, since they exhibit a differing rate of impulse generation throughout the range of motion rather than a sudden burst of impulses typical of rapidly adapting receptors (Barrack et al., 1994; Lephart et al., 1997).

Afferent information from tendon organs contributes to joint position and movement sense under active conditions, but has little or no proprioceptive role when muscles are relaxed (Goodwin, 1976; Colebatch and McCloskey, 1987). Static (predominantly secondary) muscle spindle endings and dynamic (predominantly primary) muscle spindle

endings may have a greater role in joint position sense and joint movement sense respectively. The contribution from muscle spindle receptors to joint position and movement sense may be substantially augmented during even lightly resisted muscle contractions.

Approximately 80% of all muscle and joint afferents stem from free nerve endings (Heppelmann et al., 1988; Loben-hoffer et al., 1996). Since most mechanoreceptive free nerve endings in normal joints are only stimulated by extreme joint movements, they are probably not normally significant sources of position and movement sense. However, as with muscular free nerve endings, when there is inflammation, a large proportion of the free nerve endings are sensitised by the milieu of chemical substances produced during the inflammatory process (Grigg et al., 1986; He et al., 1988). In turn, this may result in abnormal joint position sense.

A majority of cutaneous receptors are also free nerve endings (and hair follicle receptors in hairy skin). Slowly adapting skin receptors, especially Ruffini endings, play a significant part in the perception of finger joint positions and movements; but because of the specialised function and innervation of the human hand, it cannot be assumed that skin receptors have a similar proprioceptive role elsewhere in the body including the cervical spine (Perl, 1996; Craig and Rollman, 1999).

In summary, studies suggest that muscle, joint and skin mechanoreceptors usually contribute to joint position and movement sense to a varying extent dependent on the test conditions and the region being examined. All proprio-ceptors are most active near the limits of joint movements, and it is widely believed that muscle receptors are of greatest importance. Comprehensive accounts of the sources of proprioception have been reported (McCloskey, 1978; Gandevia and Burke, 1992; Lephart and Fu, 2000; Proske et al., 2000).

Tests of proprioception

In general there are different ways in which to evaluate proprioceptive capabilities: histological, neurophysiolog-ical and clinical. In the clinical environment most authors apply the threshold for detecting joint motion or a position sensation test during movement to evaluate kinaesthesia and the angle of reproduction capability (active or passive) for measuring joint position sense (Jerosch and Prymka, 1996; Marks, 1998; Rozzi et al., 2000; Kristjansson et al., 2004; Swait et al., 2007; Juul-Kristensen et al., 2008). These tests utilise a number of measurement tools ranging from visual estimation to sophisticated computerized instruments (Lincoln et al., 1998; Bruton et al., 1999; Strimpakos and Oldham, 2001; Strimpakos et al., 2006). The threshold of perception test requires customised motor-driven apparatus to produce low velocity movements. Each subject is usually required to listen to white noise or music through headphones to block out noise from the motor, and a pneumatic sleeve is placed around the proximal and distal joint segments to minimise extraneous skin stimulation (MacDonald et al., 1996; Stillman, 2000). These precautions are at best inconvenient for routine clinical assessments of some joints, and impractical for many others which limit the ability to establish normality, to quantify severity, or to demonstrate changes over time. This is especially so with respect to mild disorders, or assessments which simulta-neously involve more than one joint such as in the cervical spine. On the other hand, research has shown little corre-lation between performances with the position sensation test during movement and the cervical joint position test raising questions as to their validity (Swait et al., 2007).

In the subsequent paragraphs this review aims to present the most important factors capable of affecting the results of neck proprioception assessment in both clinical and research environments. More specifically, factors such as the cutaneous receptors involved in skin contact and stretch, memory and distraction, the position of the subjects, the speed of the test movement, the existence of fatigue, the number of repetitions, the learning effect, the active or passive assessment and the direction of the movement all have to be considered in any assessment.

Factors influencing proprioception measurements

Cutaneous influence

The possibility that skin contacts might influence joint position sense assessment is suggested by findings from a wide variety of clinical and laboratory experiments (Ferrell and Smith, 1989; Barrack et al., 1994; Stillman, 2000). For the purposes of moving a joint to and from different test positions, and when it is necessary to support any body part during maintenance of a test position, the examiner should keep contact with whatever surface(s) is/are the most convenient using a comfortable grip with the minimum necessary pressure. Care should be taken to avoid skin stretch or a combination of stretch with relaxation. Most importantly, whatever method of manual contact is chosen, it should be comfortable for the patient, conve-nient for the examiner and consistent between measure-ments. In active tests, employing mid-range movements is a way to avoid skin stretch and thus reduce the influence of cutaneous receptors. Direct contact with clothes should also be avoided in order to eliminate their contribution to the outcome especially in the cervical spine where should be evaluated without a shirt or wearing only a T-shirt.

Memory and distraction

The effect of memory and distraction on proprioceptive acuity has been examined in several studies with inconsistent results. It has been found that less than a 12 s delay between successive tests, with or without accompanying distraction, significantly increases joint position sense accuracy, and minimally effects reliability (Williams et al., 1969; Laabs, 1973; Stillman, 2000). It has also been found that a 60 s delay between passive tests and ipsilateral matching responses produces significantly worse results than a 15 s delay (Kaplan et al., 1985). Conversely, Horch et al. (1975) found that a 45 s delay between passive tests and contralateral matching responses had no effect on their results (Horch et al., 1975).

The time delay which would normally occur during uninterrupted joint position sense tests with ipsilateral

matching responses (less than 6 s) is unlikely therefore to have any discernable effect on results (Leonard and Milner, 1991; Sandlund, 2008). Wells et al. (1994) found that when subjects concentrated on their position sense task they presented higher accuracy in the joint position matching than with the addition of a distractive task.

For all patients, but especially those with poor memory, inattention or emotional lability, the time interval between test and response should be kept to a minimum, and distractions avoided (Leonard and Milner 1991; Wells et al., 1994). As a matter of principle, clinicians should abort and recommence all assessments whenever there is a possible source of distraction between the start of a test and completion of the associated response.

Speed of the movement

The speed of the movement is also an additional factor which can affect measurements and requires a high level of concentration particularly in neck proprioception testings. No speed instructions were mentioned in most of the reviewed articles and this seemed to be in accordance with low back studies (Swinkels and Dolan, 1998; Brumagne et al., 1999) although some researchers asked their subjects to perform three repetitions within 60-s (Loudon et al., 1997; Newcomer et al., 2000; Koumantakis et al., 2002). Therefore, uniformity remains to be established for the utility of speed instructions in proprioceptive measurements as well as for the time the subjects have to stay on the target location in order to memorize the movement and position of the cervical spine.

Fatigue and proprioception

Several human clinical studies have found abnormal position and movement sense associated with muscle fatigue (Saxton et al., 1995; Voight et al., 1996; Brockett et al., 1997; Carpenter et al., 1998; Taimela et al., 1999; Rozzi et al., 2000; Bjorklund et al., 2000). Only one study has evaluated the effect of fatigue on neck proprioception acuity (Wong et al., 2006) and until future research clarifies this issue clinicians and researchers have to avoid multiple repetitions during assessments and should suggest to their subjects that they avoid any strenuous activities for one or two days before the tests.

Active and passive joint position sense

Another point which has provoked controversy is the use of passive or active movements for reproduction of the desired position (Loudon et al., 1997; Strimpakos and Oldham, 2001; Kristjansson et al., 2001). Research has shown that sensory inputs may differ depending on whether the head is moving actively or passively (Cullen and Roy, 2004). Marks (1998) stressed that passive positioning cues are considered less sensitive than active positioning cues or constrained movements, and may produce an underestimate of a subject's actual positioning ability. Most studies use the active relocation of their target. Although investigation of passive movements could give useful information on proprioceptive sensations it seems more rational to examine active head

excursions since these stimulate both joint and muscle receptors and provide a more functional assessment of the afferent pathways.

Test position and joint position sense

Although it is often stated that joint position sense assessments may be influenced by the choice of test position, this view has been based on a limited and less than systematic study of only a few joints, movements and pathologies (Lonn et al., 2000). There is no information regarding the cervical spine and thus the question may be asked whether in current clinical practice the choice of test positions is always based on physiological and pathological considerations, or whether examiner convenience is more often the determinant. For example, some clinicians who chose to test right-angled joint positions, may do so because right-angles can be easily judged subjectively by the examiner, and not because they have particular clinical relevance for the patients. Gray and Regan (1996) have shown that right-angles (and 0° and 180°) are the only angles which can be accurately judged subjectively (Gray and Regan, 1996).

At the physiological or pathological limits of joint movement, stretch of articular and periarticular tissues on one side of a joint, and compression on the other, may be proposed as the reason why end-range test positions might produce different joint position sense assessment results compared to mid-range positions. Some other factors which might contribute to significantly different results at different test positions especially in the cervical spine include the variation in the lengths and tensions of muscles overlying the examined joint at different joint positions (Refshauge and Fitzpatrick, 1995; Refshauge et al., 1995, 1998), the variation in gravitational resistance of the contracting muscles during active tests at different joint positions, particularly the proximity of the test position to the gravitational horizontal and vertical (Papaxanthis et al., 1998), the variation in the capacity of subjects to relax with the joint in different positions and the amplitude of movement required to bring the joint to the chosen test position (Wells et al., 1994).

Finally, it is probable that the effect, if any, of adjacent joint positions on the results from active and passive joint position sense assessments will vary at different joints depending on the particular multiarthrodial muscle biomechanics at each joint (Refshauge et al., 1998). It is therefore recommended that clinicians keep both the examined joint positions and adjacent joint positions constant during repeated assessments to minimise possible variations in the obtained results caused by different biomechanical test conditions. This requires a stabilisation system capable of isolating the joint or joints under investigation from the rest of the body which in the case of the neck proprioception measurements seems to have been forgotten (see Figure 2).

Number of test repetitions and learning effects

Although some brief explanation is almost mandatory when subjects are to be asked to perform joint position sense

tests for the first time, most published studies of joint position sense make no reference to any preliminary explanation or practice having taken place (Skinner et al., 1984; Clark et al., 1995). In the clinical environment, the amount of initial practice and the number of formal repetitions at each test position must take into account the attention span and compliance of the patients, each patient's propensity to fatigue, how many test positions need to be examined, and at how many joints. Also, consistency of instructions and the tone of voice are important for obtaining more reliable results (Troke et al., 1998; Juul-Kristensen et al., 2008). Undoubtedly, clinicians will also be concerned about the total time required to gather and process the data.

Due to the lack of extensive investigations on neck proprioception none of the above considerations have been examined in any of the reviewed studies. Concerning the possible influence of preliminary practice and the number of test repetitions, a more extensive practice and/or an increased number of formal test repetitions per target position might lead to less variability in the obtained results (Swait et al., 2007; Pinsault et al., 2008). However, the protracted assessment might equally cause deterioration in the performance of some patients as a consequence of reduced compliance or fatigue.

Direction effect

Only a few studies have presented separate reliability values for each side or direction tested (Kristjansson et al., 2001; Strimpakos et al., 2006; Lee et al., 2006). However, in most cases any observed differences between left and right directions were not statistically significant. The same conclusion was drawn by most other studies which did not find any significant difference between repositioning accuracy in the horizontal plane or the vertical plane (Revel et al., 1991; Heikkila and Astrom, 1996; Loudon et al., 1997; Rix and Bagust, 2001). Any further studies could therefore take the summation of both directions into account.

Implications for clinicians and researchers regarding neck proprioception assessment

There is no consensus concerning the best method of assessing neck proprioception in the current literature. Whatever the assessment of proprioception however, some precautions to ensure valid results have to be taken. According to present knowledge, all subjects should be examined without a shirt or wearing only a T-shirt and avoiding end-range movements. Fatigue should be eliminated because of its possible effect on proprioception measurements. Any factor that could distract the attention of the subjects should also be eliminated. More than three repetitions seem to be needed in order to reduce variability of the results but less than ten to avoid fatigue and noncompliance of the subject. A full practice session is also important. Active assessments give more information about muscle and joints and are more functional. Finally, the test position has to be kept constant between measurements and torso stabilisation could help in this way. The direction and the speed of the movement have not been proven to have any effect on test results.

Conclusion

It is obvious from the above that despite the widespread clinical use of cervical ROM and proprioception assessment the scientific literature reflects little agreement regarding the instruments as well as the methodologies utilised. The anatomical, biomechanical and physiological considerations in the assessment of physical parameters presented so far in this review have revealed the complicated nature of the cervical spine and the multiple issues a clinician or researcher has to take into account throughout its evaluation. Maintaining consistent procedures by isolating the cervical spine movement, by the use of a stabilisation frame, the avoidance of fatigue, the undertaking of a warm-up and a full practice session before measurements are all essential for reliable and valid results in both neck ROM and proprioception assessments. Furthermore, any external influences such as noise or sensory information from clothes have to be controlled when assessing neck proprioception.

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PREVENTION & REHABILITATION — SYSTEMATIC CRITICAL REVIEW