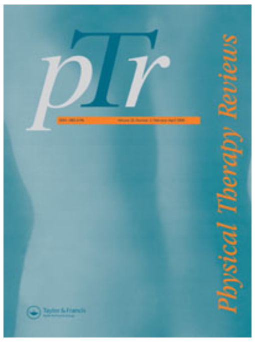

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Functional rehabilitation of the neck

Chris Worsfold

MSK Research Unit, University of Hertfordshire, Hatfield, Hertfordshire, UK

ABSTRACT

Introduction: Spinal pain is a leading cause of disability worldwide and there is convergent epidemiological data describing neck pain as a recurrent and episodic condition. Recent work suggests that addressing sensorimotor impairments (e.g. proprioception, oculomotor control or postural stability) and impairments in muscle performance (e.g. neck strength training) may improve outcomes in neck pain but there appear to be two main problems facing such active rehabilitation strategies: Firstly, contemporary surveys of clinical practice demonstrate poor translation of research findings to the clinical setting – with passive modalities dominating the clinical picture - and secondly, there appears to be a disinclination to progress rehabilitation of the neck beyond the 'treat what you find' impairment stage, in both the clinical and research setting.

Purpose: The aim of this paper is to delineate functional rehabilitation of the neck and it will focus upon; (i) existing impairment-based sensorimotor approaches to neck pain, (ii) a critique of impairment-based approaches, (iii) consideration of the utility of a functionally orientated and task-based rehabilitation and (iv) an attempt to define functional rehabilitation of the neck.

Implications: Evidence suggests that outcomes from neck pain treatment may be improved by means of impairment-based interventions. The proposal in this paper is that by addressing function of the neck throughout rehabilitation - as would readily occur in rehabilitation of a peripheral condition such as an ankle sprain for example – outcomes and perhaps patient compliance would be improved. High quality randomised controlled trials are needed to evaluate the role of functional rehabilitation in the management of this challenging condition.

KEYWORDS
cervical spine; physical therapy; rehabilitation; neck pain; function

The neck sub-serves the specialised sense organs of the head; the eyes, the ears, the nose and the tongue, and moves over 600 times per hour [1] with a total sagittal plane excursion approaching 1,000,000° per day [2]; no other part of the articular system is in such a state of constant motion.

Neck pain has an estimated one-year incidence of between 10% and 20%, with a mean one year prevalence of 23% [3]. At an individual level, the course of neck pain is episodic and recurrent and it has been stated that 'most people with neck pain do not experience a complete resolution of this problem' [4].

Neck pain is associated with considerable economic and personal burden: neck and back pain combined are the leading global cause of disability and with respect to health care spending spinal pain has been estimated to be the third-largest condition in the US costing more than $85 billion per annum [5].

Reflecting on these data, Walton and Elliott have suggested that research into the prevention and management of neck pain over the past 25 years appears to have had little effect on the relative overall global burden of this problem [6].

A potential step forward in improving outcomes has been provided through work identifying muscle and sensorimotor deficits – such as reduced neck muscle activity [7,8], muscle strength [9], and sensorimotor control [10] – in individuals with neck pain. There is some evidence that both assessing [11–13] and addressing these specific impairments can lead to improvements in pain and disability [14,15] but clinicians appear reluctant to utilise such active management strategies in their day to day work.

For example, recent surveys of contemporary clinical physiotherapy practice reveal a predominance of passive approaches to neck pain, with pain relieving modalities such as TENS and acupuncture and postural advice the most commonly administered interventions [16]. 'Cervical stabilisation exercises' and sensorimotor approaches are consistently utilised by less than half of survey respondents [17,18]. Comparable surveys of peripheral joint

CONTACT Chris Worsfold c.worsfold@herts.ac.uk The Tonbridge Clinic, 339 Shipbourne Road, Tonbridge TN10 3EU, UK.

problems report nearly 100% utilisation of strengthening exercises in physiotherapy practice [19,20].

Alongside evidence of poor utilisation of active rehabilitation approaches in day to day clinical practice there appears to be a reluctance both to progress rehabilitation interventions in neck pain beyond the impairment level and to consider cervical spine *function* during rehabilitation; this impairment-focussed 'treat what you find' approach appears to have constrained both research and clinical practice to a surprising degree.

Examples of impairment based approaches are found in Treleaven's [10] ground breaking sensorimotor clinical vignettes where for example, balance impairments are treated with balance exercises and oculomotor control impairments are treated with oculomotor exercises.

In a recent text, Jull et al. [21] recommend assessing what they term 'dynamic tests' such as 'a timed 10 metre walk with head turns', but only in the presence of specific sensorimotor symptoms e.g. 'if the patient complains of dizziness when walking, loss of balance or falls' (p. 137). Likewise, management with 'dynamic balance training' is 'particularly indicated in patients who report functional difficulties such as feeling light headed or unsteady when walking or moving quickly' (p. 227).

With respect to managing neck pain Jull et al. [21,22] describe staging the progression of 'three phases of exercise for the muscle system' from cranio-cervical flexion training (phase 1), to isometric holds, cervical extension and scapular control (phase 2) to strength and endurance training involving head lifts against gravity and cervical extension against resistance band (phase 3). Again, the exercise progressions described appear to begin and end at the impairment stage only, focus exclusively upon uniplanar neck motion (i.e. flexion/extension only) and there is scant reference to functional activities, except in passing and only specifically with respect to disturbed sensorimotor control.

Additionally, research studies consistently utilise impairment level interventions only [14,23] with large pragmatic multi-centre trials also utilising uniplanar exercise only [24]; in the case of the MINT whiplash intervention trial [25], the only neck muscle exercise prescribed consisted of a 'motor control exercise' in *one direction only*; i.e. upright cranio-cervical flexion. In the periphery, a comparable approach might be 'non-weight bearing ankle dorsiflexion' as the only exercise in the management of ankle sprain.

As noted previously, such impairment-only based approaches contrast strongly with both clinical and research practice in the rehabilitation of peripheral joint problems. Here functional activities are introduced as early as possible into the management pathway: for example squatting, sit to stand, one leg balance, lunges and step ups in rehabilitation of the knee [26]. Jull [27] has been one of the few authors who has recently drawn attention to the apparent 'discord' in approaches to rehabilitation between spinal and extremity disorders.

Have clinicians and researchers alike failed to acknowledge the neck as a functional, multi-planar and sensorimotor organ? We move our neck to 'smell the coffee', to observe the movement of traffic as we cross a road and to look at a pair of shoes in a shop window as we walk down the street, maintaining our gaze and head position in space, often whilst our body moves beneath. Such movements occur through three dimensions and are goal orientated and it follows that specific functional activities should be considered early in rehabilitation of the neck in much the same way that functional activities are considered early in lower limb rehabilitation. Viewed in this way impairment level only assessment and intervention could be regarded as abstract and disengaged from everyday functional neck activity.

The proposal here is that a functionally orientated rehabilitation follows an inherently logical course and is unifying - 'closing the loop' on pain, disability, impairment and function as seen in peripheral rehabilitation - with impairment based interventions viewed as building blocks towards specific and goal orientated neck related functional activity.

The starting point for this paper comprises a summary of current evidence based recommendations with respect to impairment-level sensorimotor assessment and rehabilitation of the neck. The argument for, and the reasoning that underpins inclusion of a functional approach to neck pain in rehabilitation is then developed. Finally, functional approaches to neck pain are described.

Sensorimotor impairment in neck pain

Clinically, dizziness and unsteadiness are commonly associated with whiplash injury and less frequently atraumatic neck pain and may indicate sensorimotor disturbance [28,29]. It is hypothesised that the afferent output from the cervical spine (e.g. from muscle spindles and/or mechanoreceptors) is impaired in neck pain and injury, and this in turn can lead to mismatches between the cervico-ocular and vestibulo-ocular reflexes, manifesting as unsteadiness, dizziness and vision related disturbance. Thus, cervical proprioception, eye movement control, postural stability and movement velocity/trajectory of the head are impaired in neck pain, to a lesser or greater degree [28–31].

Sensorimotor impairment testing therefore involves assessing proprioception ('joint position

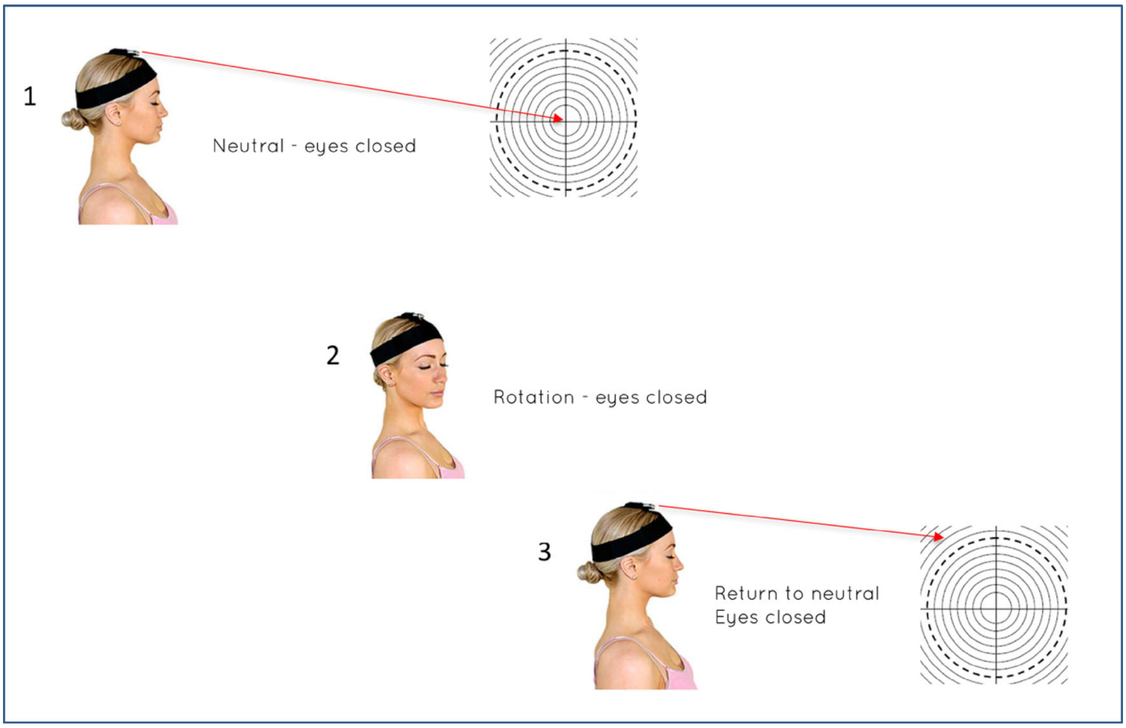

Figure 1. Testing proprioception. Source: www.rehabmypatient.com.

error' or JPE), oculomotor control, postural stability and speed of head motion.

Proprioception: cervical joint position error tests measure an individual's ability to accurately relocate their head to the same point in space with the eyes closed (Fig. 1). Evidence suggests that cervical JPE measured with a laser and target in the clinical setting has acceptable validity (compared with laboratory based electromagnetic tracking e.g. Fastrak system) and reliability (ICC > 0.75) and can discriminate between healthy controls and subjects with neck pain [32–35]. Recent systematic reviews demonstrate impaired proprioception in neck pain [36,37].

Oculomotor tests: the smooth pursuit test involves the patient sitting and following a moving object with their eyes whilst keeping their head still. The object – usually the clinician's finger – is panned slowly, taking 5 s to cross an arc 30° either side of the patient's mid-line (Fig. 2). Onset of pain, dizziness or increased effort suggests sensorimotor impairment. The smooth pursuit test has good inter-rater reliability and has been shown to discriminate between healthy controls and subjects with chronic neck pain [38].

If the smooth pursuit test deteriorates - i.e. leading to increased effort, pain, dizziness - when the neck is "torsioned" 45° to one side, by rotating the trunk beneath the neck so as not to disturb the vestibular system, this implicates the cervical spine as a source of sensorimotor symptoms (Fig. 3). This latter assessment is termed the 'smooth pursuit neck torsion test' (SPNT) and demonstrates high specificity and sensitivity (>90%) for diagnosing individuals following whiplash injury who complain of dizziness [39].

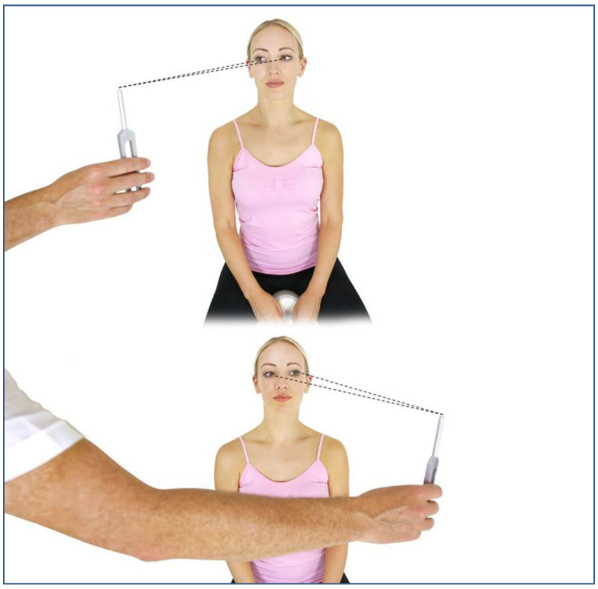

Figure 2. Smooth pursuit test in neutral. Source: www.rehabmypatient.com.

There is evidence that gaze stability testing is also impaired in neck pain and this involves the subject maintaining their gaze upon an object and moving their head through a physiological plane e.g. rotation (Fig. 4) or flexion-extension [31,40]. Studies consistently show deficits in eye movement control following whiplash injury [41].

Postural stability: tests of postural stability include comfortable, narrow and tandem (heel-toe) standing, tested with both eyes open and eyes closed. The test is often timed to 30 s' maximum.

Figure 3. Smooth pursuit neck torsion test right side. Source: www.rehabmypatient.com.

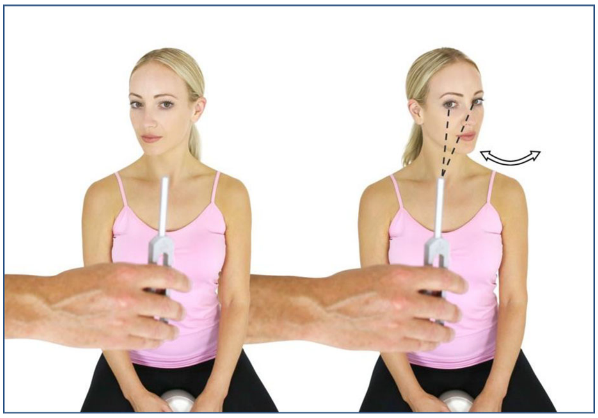

Figure 4. Gaze stability test (rotation). Source: www.rehabmypatient.com.

The patient 'fails' the test if they step or require support during the test [42]. Disturbances of postural stability have been consistently demonstrated in individuals with neck pain and following whiplash injury [43]. Gait disturbances have also been demonstrated in neck pain, specifically decreased step width, step length & speed [44].

Why functional rehabilitation?

Impairment has been defined as 'disturbances at the organ level i.e. abnormalities of body structure and appearance and organ or system function resulting from any cause' [45]. As an example - with respect to neck pain - reduced proprioception would be considered an impairment.

As discussed above, the impairment-based - 'treat what you find' - model clearly dominates neck pain musculoskeletal research and practice, but this focus may have limitations. Bove et al. [46] have stated with respect to rehabilitation 'optimal performance of daily tasks requires adequate strength; joint motion and endurance; and the integration of cognitive, perceptual, and motor skills. Impairment-based exercise approaches do not address all factors involved in daily function. Consequently, we must develop alternative training strategies to enhance the effect of therapeutic exercise on task performance' (p. 548). There is some evidence to support this view: research into rehabilitation of osteoarthritis of the knee suggests that reductions in impairments may not correlate with functional improvement and may have limited positive effects on the performance of specific functional tasks [47,48].

There also exist interesting parallels between musculoskeletal and neurological rehabilitation with respect to functional task-specific intervention. Snodgrass et al. [49] have stated that although the musculoskeletal therapist is working with patients with a 'non-lesioned brain', the 'neuro-biological basis of neuroplasticity and potential for motor learning is the same as for the person with brain damage such as stroke' (p. 615). The authors note that 'interventions with the best evidence in stroke rehabilitation are intensive repetitive practice and task-specific training' (p. 615). For example, a systematic review of treatment for paresis suggests that greater benefit occurs in programmes in which functional tasks are directly trained, with less benefit if the intervention is impairment focussed [50]. Snodgrass et al. [49] conclude that 'introducing the functional context of movement early in musculoskeletal rehabilitation may lead to greater movement gains and earlier cortical recovery' (p. 616).

Van Vliet and Heneghan [51] in a narrative review of the role of cortical plasticity and task specificity in musculoskeletal rehabilitation have also highlighted how practice of 'part of a task' such as wrist extension 'may not activate the same neuronal network as practice of wrist extension within the whole task such as reaching' (p. 211). The authors conclude by suggesting that 'functionally oriented exercise be incorporated as early as possible in rehabilitation, rather than after many repetitions of component parts of movements' (p. 211).

Whilst it is acknowledged that there is evidential support specifically for 'novel motor skill training' such as deep neck flexor training in pain [14,52] and that addressing impairments appears to lead to some improvements in pain and disability [15] from a reasoning perspective the impairment-based approach perhaps fails to address both important and specific aspects of motor skill learning, namely a) the goal orientated nature of functional movement b) the focus of attention during tasks and c) that training gains are task specific.

These factors are discussed further below with the proposal being that a functional approach to rehabilitation emphasises more readily the above specific aspects of motor skill learning compared to an approach that focusses solely upon impairment. It is not the suggestion here that impairment-based approaches are replaced by functionally orientated ones, but simply that function is viewed and utilised as an early goal of rehabilitation of the neck.

I. *The goal orientated nature of movement*

Our bodies are the only interface through which we can intentionally act upon the external world that surrounds us; they are the 'instrument' or 'frame' that serves us to achieve our goals [53]. 'Goals' - in the cognitive psychology literature - have been defined as 'intended' or 'desired' states of affairs [53] and we perform movements, i.e. segments of bodily activity for the sake of such goals that lie beyond the movements themselves. Relevant here is that the physical response in trying to achieve the goal is a whole body event; it is not specific to a particular joint or muscle (Lederman [54] citing Hughlings-Jackson [55]).

There is experimental evidence supporting the proposition that goals take the lead over movements (for a review see Prinz [53]). Prinz [53] considers the example of using a screwdriver to drive a screw into a beam of wood. Here, attention and intention explicitly refer to the distal goal i.e. motion of the screw as it is driven into the beam by the screwdriver. The movements of the hands and arms operating the tool are 'out of focus'. Thus, it is seen that distal goals lead to proximal movements. This has been termed backward planning [53]. There is also evidence that motor learning may be enhanced when learner's attention is directed towards distal goals rather than to a specific feature of proximal movement [56].

Thus, distal goals take the lead over proximal movements and it is the distal *functional* goal that leads to the proximal (i.e. impairment level) movement; the concept of 'backward planning' therefore provides some support for the inclusion of functional day to day goals in rehabilitation of the neck.

II. *Focus of attention*

Instructions with an external focus (directed at the movements effect) appear to be more effective than those promoting an internal focus (directed at the performer's body movements) [57]. It is thought that an external focus facilitates both movement automaticity and efficiency.

Wulf [58] further states that studies demonstrate that instructions directing attention to performers' movements of their fingers, hands, hips or head,

Figure 5. 'Mirror twist': on the spot maintain gaze and head stability whilst rotating body beneath. Source: www.rehabmypatient.com.

Figure 6. 'The Pedestrian': walk forwards maintaining gaze and head stability whilst rotating body beneath. Source: www.rehabmypatient.com.

inducing an 'internal focus' of attention are not only relatively ineffective, but also constrain the motor system thus disrupting automatic control processes. By contrast, directing attention to the *effects* of the individual's movements on the environment (e.g. an implement) – inducing an 'external focus' – generally results in more effective and efficient performance and learning.

Wulf [57] uses the example of a standing balance task, whereby instructions directing attention to the support surface (external focus) rather than the feet (internal focus) consistently result in enhanced performance and learning. Supporting this view, electromyographic (EMG) activity for the same task (basketball throws) has been found to be reduced when subjects adopt an external focus (basket), in

Figure 7. 'Crossing the road': walking the length of a room, alternately focussing upon the left and right side walls. Source: www.rehabmypatient.com.

Figure 8. 'Walk Past': look at a point on the wall, maintain eye and head stability whilst walking to comfortable end range cervical rotation, then turn and walk back in the opposite direction. Source: www.rehabmypatient.com.

Figure 9. 'Washing Hair - Extension': extend head and neck and touch back of head with both hands. Source: www.rehabmypatient.com.

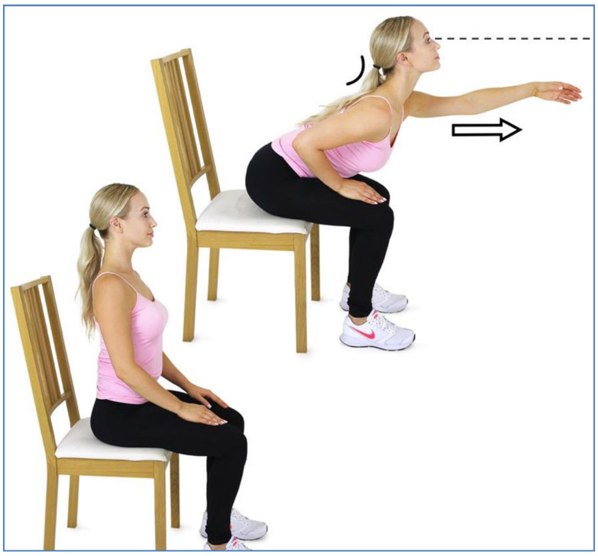

Figure 10. 'Sit and Reach': reach forward in sitting. Source: www.rehabmypatient.com.

contrast to the internal cue of 'wrist motion', thus indicating enhanced movement efficiency [59].

In the case of neck rehabilitation by directing attention during movement to the body part itself – for instance when assessing cervical rotation range of motion with the request to 'turn your head to the left' - will be less successful in inducing effective performance than an instruction that utilises an external cue (and is in turn a functional activity) such as 'look over your left shoulder'.

Thus, cueing externally on distal goals inevitably leads to a greater 'functional bias' to the performed movement.

III. *Training gains are task specific*

When a new skill is learnt, there is an experience specific pattern of plasticity across the motor cortex and spinal cord [60] and the adaptation that occurs is specific for that task. Furthermore, training gains are task-specific, and do not appear to transfer to activities that are dissimilar: e.g. sprinting performance improves through single leg horizontal jumps but not by vertical jumps using both limbs, such as jump squats; vertical jumps are improved by training in vertical but not sideways jumps [54,61,62].

In the context of rehabilitation of the neck and in line with the concept of task specific training gains, the suggestion is that 'practicing' task specific impairment level exercises e.g. oculomotor smooth pursuit exercises will only result in improvements in performance of that specific exercise and they will not carry over or will carry over poorly into day to day functional activities such as crossing a busy road, for example.

In summary, a functionally orientated approach to rehabilitation may facilitate effective performance by a) focussing attention on the goal itself b) focussing attention on an external cue and c) ensuring the exercise mirrors as closely as possible the intended functional activity i.e. emphasises task specificity.

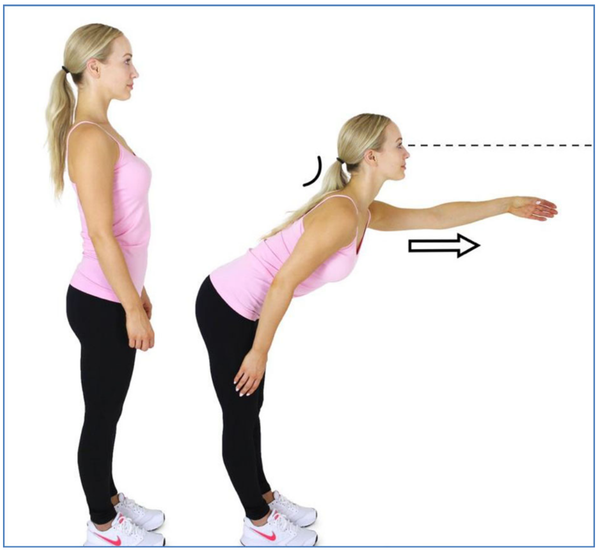

Figure 11. 'Stand and Reach': reach forward in standing. Source: www.rehabmypatient.com.

Toward functional rehabilitation of the neck

As discussed above, impairment-based approaches appear to have some utility and effectiveness in the assessment and management of neck pain. The above narrative review highlights that current approaches to neck pain may be falling short of providing a functional approach as utilised in rehabilitation of the sprained ankle or following anterior cruciate ligament reconstruction, for example.

So, how can we define what movements to use in functional rehabilitation of the neck?

There are two possible methods that can be employed: the first draws on studies that have monitored neck movements during day to day activities and the second relies upon observing the way we use our head and neck in everyday life, to identify direction specific functional activities that can be utilised in rehabilitation.

Which movements of the neck do we commonly carry out during day to day function? Analysis of range of motion of the neck using a portable device measuring continuous neck kinematics during normal daily living indicates that flexion/extension is the primary neck motion, with most movement about all axes being less than 15° [2].

Figure 12. 'Walk Past - Extension': look at a point where the wall and ceiling meet, maintain eye and head stability whilst walking to comfortable end range combined cervical extension and rotation, then turn and walk back in the opposite direction. Source: www.rehabmypatient.com.

Figure 13. 'Washing Hair - Flexion': flex head and neck and touch back of head with both hands. Source: www.rehabmypatient.com.

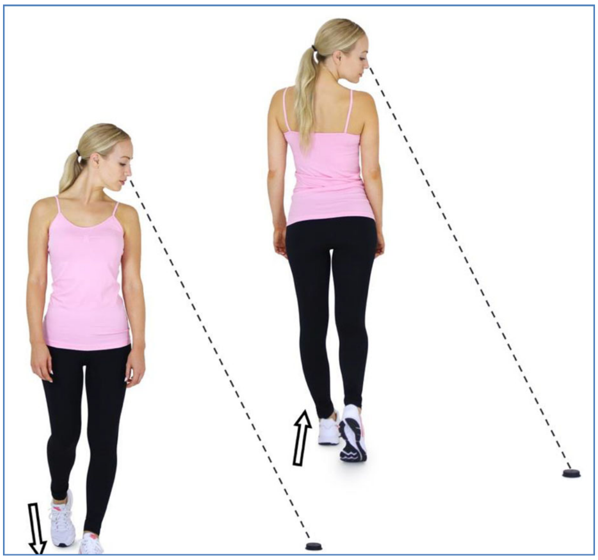

Figure 14. 'Walk Past - Flexion': look at an object on the ground maintain eye and head stability whilst walking to comfortable end range combined cervical flexion and rotation, then turn and walk back in the opposite direction. Source: www.rehabmypatient.com.

Figure 15. 'Smell the coffee': sitting cervical protraction. Source: www.rehabmypatient.com.

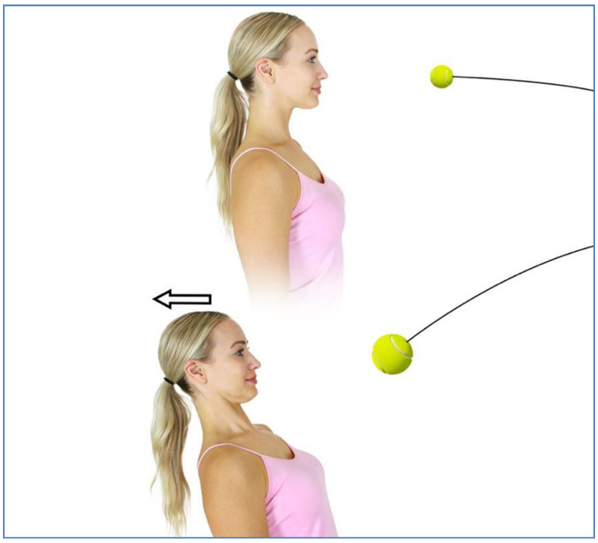

Figure 16. 'Avoid': standing cervical retraction. Source: www.rehabmypatient.com.

In a study investigating cervical range of motion maximal excursion during simulated activities of daily living using a goniometer attached to the subject's head, functional tasks requiring the greatest cervical mobility were: reversing a car, 67.6° rotation; tying shoes in a seated position, 66.7° flexion–extension; crossing a road, 54.3° rotation and 22.2° side bending; washing the hair in the shower, 42.9° flexion– extension [63]. It was also noted that coupling of side bending and rotation occurred in various tasks [63].

Of all the activities of daily living evaluated by Bible et al. [64] using an electrogoniometer and torsiometer, the greatest sagittal plane motion occurred reversing a car, 32°; picking up a 2 lb object, placed on the ground 8 inches from the subject - either by bending at the waist, 30°or squatting at the knees, 29°; and when washing hair, 27°. Greatest axial rotation occurred whilst reversing a car 92° and during personal hygiene activities such as shaving 34° and applying make-up 34° [64].

Interestingly, Bible et al. [64] also concluded that only a small percentage of available active range of motion is required to carry out many activities of daily living, suggesting that functional rehabilitation activities, with the exception of 'reversing a car' do not require excursion to anywhere near full range of motion.

Defining functional neck rehabilitation

Combining the empirical data above with observation of neck motion during activities of daily living leads to the identification of direction

Table 1. Example impairment level sensorimotor components of functional activities.

Direction	Description of functional activity	Cervical physiological motion	Sensorimotor components	Illustration
Rotation	The Mirror: stand in front of a mirror or object at head height. Keep your gaze on the mirror or object and keep your head still as you rotate your body underneath you, turning your body to the left and then the right by stepping around as far as is comfortable.	Trunk on cervical rotation	Gaze stability, proprioception, dynamic postural stability.	fx1
Extension	Walk Past - Extension: fix your gaze and head on a point on the wall to one side and above head height. Walk forwards whilst keeping your gaze and head directed at the object. When you have walked as far as you can turn your head, turn your body and walk back in the other direction. Keep looking at the object at all times.	Cervical extension and rotation	Gaze stability, head and eye follow, proprioception, dynamic postural stability.	fx2
Flexion	Walk Past - Flexion: put a small object on the floor in front of you. Walk towards the object keeping you gaze and head directed at the object as you walk past and over the object to one side of your feet.	Cervical flexion and rotation	Gaze stability, head and eye follow, proprioception, dynamic postural stability.	fx3
Retraction	Avoid it! Retraction. Move your head and neck backwards as if avoiding an object.	Cervical retraction	Smooth pursuit, proprioception, dynamic postural stability.	fx4

Figure 17. 'Crossing the road with step': walking the length of a room, alternately focusing upon the left and right side walls, stepping over a step. Source: www.rehabmypatient.com.

specific functional activities. Some examples are illustrated with respect to: rotation (Figs 5–8), extension (Figs 9–12), flexion (Figs 13–14), retraction and protraction (Figs 15–16). Some examples of the physiological motion and impairment level components of the functional exercises are presented in Table 1.

These 'functional categories' of extension and flexion etc. are arbitrary and combinations often occur e.g. combined rotation and extension: looking to the right side at the point where the ceiling meets the wall, whilst walking the length of the room. An example of a progression of a functional activity is illustrated in Fig 17.

Conclusion

Neck pain remains a leading cause of disability and recent work suggests that active rehabilitation approaches such as proprioceptive training or strengthening of the neck have potential to improve outcomes. In contrast to rehabilitation of peripheral joint conditions such as ankle sprain or anterior cruciate ligament reconstruction for example, rehabilitation of the neck in practice appears to be dominated by passive modalities and in both practice and research appears to stall at the impairment 'treat what you find' stage. Thus, an attempt has been made to describe both the theoretical underpinnings and the specific movements required to undertake 'functional rehabilitation of the neck'. It is proposed that the inclusion of functionally orientated exercises in neck pain rehabilitation 'closes the loop' on all phases of rehabilitation (disability – impairment – function). High quality randomised controlled trials are needed to test the hypothesis that integrating function into the management of this challenging condition improves outcomes further.

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Disclosure statement

I affirm that I have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript. There are no conflicts of interest.

Notes on contributor

Chris is a Physiotherapist specialising in neck pain & Visiting Lecturer in Physiotherapy at the University of Hertfordshire where he mainly contributes to the MSc in Advanced Neuromusculoskeletal Physiotherapy programme. He divides his time between the clinic, teaching, blogging & research. His research is focussed upon developing a functional approach to rehabilitation of the neck. He lectures internationally, has represented the Chartered Society of Physiotherapy in Parliament & appeared on BBC Radio, TV & in the National press discussing neck pain.

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