Charlotte Giuliani

MSc Advanced Professional Practice (Paediatric Musculoskeletal Health) 2012-2013

Musculoskeletal Health in Infants

Dr. Joyce Miller

Date of submission 05-07-2013

Word count 2467

I certify that

· this is my own original piece of work and that all other peoples academic work has been acknowledged
· the word count recorded is accurate
· that confidentiality in accordance with the guidance in my student programme handbook has been maintained

Signature.................................................. Date 14-06-2013
How does the cervical spine contribute and participate in head righting and how might a cervical functional deficit influence the ability to right the head? A review of the literature.

Introduction

Head righting reflexes (HRR) are a complex group of reactions that combine inputs from the vestibular, visual and somatosensory systems to make postural adjustments when the body becomes displaced from its normal vertical position (Goldberg et al. 2012). The purpose of these reflexes in humans is to stabilize the head especially during unpredictable movements.

Since the HRR reflects functional integration of visual, vestibular and proprioceptive stimuli (Nandi and Luxon 2008), it has been proposed as an assessment tool for cervical dysfunction in infants expressing postural asymmetry of the neck (Sacher 2004). Subsequently it has been adopted by some chiropractors in clinical practice as part of examination procedure of infants with functional asymmetry of the neck (figure 1). However, the theoretical basis of this interference of aberrant cervical function on HRR remains to be described. The purpose of this assignment is, therefore, to investigate and explore how the cervical spine contributes and participates in head righting and how cervical functional deficits might influence the ability to right the head.

Methods

A computer search of the PubMed and AECC search (includes PubMed, Index to Chiropractic Literature, MEDLINE (full-text), AMED, Alt-Health-Watch, Cochrane Library, Best Bets) databases using the following key phrases: “head righting reflex”, “head righting reaction”, “vestibulocollic reflex”, “cervicocollic reflex” and the Boelean term “OR”, yielded 91 studies, of which 15 were relevant. Searching amongst the relevant citations of references amongst these articles, resulted in 6 further articles. A further manual search of relevant textbooks resulted in 3 further references.
Figure 1. The lateral head righting reaction
The infant is held around the waist and tilted 45 degrees in the horizontal plain and the righting of the head is observed. Afterwards the opposite side is tested in a similar manner. The procedure is repeated twice on each side.

Results

What are the "head righting reflexes?"
Head righting reflexes are a complex group of reactions which rely on input from multisensory modalities. Aside from the vestibular system, it also involves proprioceptive input, exteroceptive impulses and visual stimuli (Campbell 2013). Although head control relies on all these multisensory modalities, the study of the individual reflexes in isolation and their interaction allows us to probe nervous system function (Goldberg et al. 2012).

Even though visual input has been shown to have great importance in postural regulation (Goldberg et al. 2012), the postural reflexes involving vision will not be covered in this assignment. Recognizing that visual input plays a part in the vestibular antigravity response, the focus of this assignment is on the function of the remaining two reflexes and their interaction.

The Vestibulocollic Reflex and Cervicocollic Reflex.

Two collic reflexes activating the cervical musculature are thought to be of particular importance in head righting: The vestibulocollic reflex (VCR) and the cervicocollic reflex (CCR) receiving afferent input from respectively the vestibular and mechanoreceptors of the upper cervical spine. The function of the VCR is to stabilize head in space, whilst the function of CCR is to maintain alignment between head and trunk (Goldberg and Cullen 2011).
The VCR has mainly been studied by fixing the head position with respect to the trunk during whole-body rotation, isolating its function by removing any proprioceptive feedback from the neck (Reynolds et al. 2008). Passive rotation of the whole body stimulates semicircular canal afferents that reflexively activate neck muscles that produce opposing angular head and neck movements. Likewise the CCR has been studied with whole-body rotation under a fixed stationary head, thus removing any vestibular feedback (Goldberg et al. 2012).

Seen in isolation from other contributing factors, the combined function of the VCR and CCR is thus a linear combination of their individual functions. Whether the reflexes support or oppose each other depends on the position of the head and trunk in space and the direction of the perturbation (Goldberg and Cullen 2011). In case of angular movements in the frontal plane when the head is free to move, such as in the lateral head righting response test, the functions and the mechanisms of action are dynamically opposed (figure 2.). The resulting head movement depends on the relative gains and strengths of each of the reflexes (Reynolds et al. 2008).

---

**Fig. 2 Vestibularcollic reflex and cervicocollic reflex evoked by rotations in the horizontal plane.**

Upward arrows represent increases in the neck muscle activity induced by stimulation of labyrinthine (white arrows) and neck receptors (black arrows). Dashed and continuous lines represent the head/body longitudinal axes and the medial sagittal plane respectively.

A) rotation to one side with neck fixed to body, stimulates the labyrinthine on opposite side.

B) Rotation of body to one side with head fixed to sagital line, stimulates the neck muscles on opposite side.

C) Rotation of the head with a stationay body, stimulates both the labyrinthine and neck muscles on the opposite side.

D-F) illustrates the activity from neutral position (d), with the activation of the labyrinthine when rotating to opposite side (e) and as the head tilts to the side of labyrinthine activation, the neck receptors on the opposite side (f) is activated.
However, outside a research setting such a linear relation presents an oversimplification. In a model proposed by Peterson et al. (1985), the feedback systems of VCR and CCR are combined with voluntary head movements and the passive mechanics of the head and neck (Fig 3). The passive behavior is characterized as the moment of the inertia, viscosity and elasticity of the tissues (Goldberg and Cullen 2011).

![Diagram of head-neck plant](image)

**Figure 3. A block diagram of head-neck plant.**

a. Block diagram of head–neck plant including input from trunk re space (Ψ) and output, head re trunk (neck, Θ). Two reflexes (VCR and CCR) sum with voluntary motor commands (VOL) to result in muscle activation (EMG), which is transformed to torque by a low-pass torque converter (T). Head re space (H) is the sum of Ψ and Θ. Head inertia (I) and passive plant mechanics (P).

b. In the absence of trunk movements (and ignoring the CCR), the diagram is that of a conventional negative-feedback system with a single input, a voluntary motor command (VOL). The possibility that the VCR is partially cancelled during active head movements is depicted by subtracting VOL from the VCR input, leaving deviations from desired head movement as the error signal driving the VCR.
In humans the VCR is found to be suppressed during voluntary head motion (Goldberg and Cullen 2011). Certain neurons, the so-called vestibular-only neurons (VO) have been found to have an inhibitory effect on the VCR during active head movement. Furthermore the VCR cancelation during active head movements can be accomplished by the inhibition sent from “the efference copy”; a copy of the anticipated sensory consequences of a motor command. In this way, the nervous system can distinguish sensory inputs arising from external sources and those resulting from self-generated movements (Goldberg et al. 2012).

Most studies of these reflexes have been conducted on animals (Reynolds et al. 2008). To reduce the complications introduced by voluntary movements, reflexes have often been studied in reduced preparations such as decerebrate (Goldberg et al. 2012). However the clinical applicability to humans is limited because of the differences in neurophysiology between the upright biped and the experimental quadruped (Goldberg et al. 2012) and the efficacy of the reflexes varies across species (Goldberg and Cullen 2011).

In humans, postural head control has been investigated by methods where various manoeuvres were done to eliminate visual (Woollacott et al. 1987) and somatosensory reafference (Goldberg et al. 2012). Since there is no way to eliminate vestibular reafference, the influence of vestibular afference is studied in labyrinthine-defective patients (Bunday and Bronstein 2008). Studies employing a computerised posturography, where the subject stands on a computer-controlled movable platform containing pressure transducers to monitor postural sway, offer a particular controlled situation, providing information of the individual contributions (Goldberg et al. 2012; Hedberg et al. 2005). Use of this paradigm has lead to the development of the “Sensory Weighting Hypothesis”: the ability of the postural control system to re-weight sensory information to optimize postural stability. This implies that the “gain” of a sensory input will depend on its accuracy, and as sensory input from one sense becomes less reliable, the other sensory cues will be weighted more heavily (Oie et al. 2002).

An important part of interpreting sensory information is the presence of an internal representation or body scheme providing a postural reference frame (Shumway-Cook and Woollacott 2010). Not only does the postural body scheme provide an internal framework for maintaining upright posture, but is also serves as a stable internal
representation of biomechanical properties to guide and organize anticipatory postural adjustments and voluntary motor movements.

Role of cervical proprioception:

The Cervicocollic Reflex is a stretch reflex resulting from activation of muscle proprioceptors of specific cervical muscles (Goldberg et al. 2012). The role of these cervical proprioceptors in postural control have commonly been studied, inducing activation of muscle spindle receptors by applying vibration to both normal subjects and those with specific neurological deficiencies (Morningstar et al. 2005). A study investigating reaction to vibration in patients with cervical dystonia (Bove et al. 2004), showed an unpredictable reaction to vibration compared with normal subjects, suggesting an altered central interpretation of the proprioceptive information. This observation is supported by studies of whiplash patients and in patients with muscular fatigue (Morningstar et al. 2005). Interestingly, a study demonstrated that the head tilt associated with spasmodic torticollis can be significantly reduced at least temporarily, when subjected to cervical vibration for 15 minutes. This finding led the authors to conclude that the muscular spasm associated with spasmodic torticollis may be the result of aberrant afferent input relaying head position to the central nervous system (Petersen et al. 2013).

When vibration is applied to upper cervical musculature, the postural compensation is greater compared to that occurring from lower cervical vibration (Morningstar et al. 2005). This greater role in postural regulation might be a reflection of the higher density of muscle spindles in the deep portions of the suboccipital muscles (Liu et al. 2003).

Besides the proprioceptive input from cervical musculature, mechanoreceptors in the facet joint and capsule, spinal ligaments contribute an extensive amount of sensory input for postural control (Morningstar et al. 2005). These structures have been shown to directly provide afferent postural input throughout the higher centers in the brain, amongst others to the vestibular nuclei. Some studies therefore suggest that afferent information from these structures might, at least partially, be responsible for mediating the reflex activity of associated muscle spindles (Sjölander et al. 2002) and might even dominate over vestibular apparatus in the maintenance of static posture (Morningstar et al. 2005). The high numbers of free nerve endings and lamellated
corpuscles found within the facet joint capsules have shown importance in the rapid adaptation of changes to cervical spine position (Treleaven et al. 2003). Furthermore, noxious afferent input produced by injury or pathology to the upper cervical spine has been shown to interfere with postural control (Morningstar et al. 2005).

Discussion

The cervical spine is a virtual warehouse of postural afferent input and, as the results of the search clearly show, the cervical spine is a major contributor to postural regulation in general and head control in particular. The neurological structures of the cervical spine contribute to head righting both through direct reafference from proprioceptors to the CCR (Goldberg and Cullen 2011), indirectly through connections from the proprioceptors to higher neurological pathways involved with postural control (Goldberg et al. 2012) and through widespread connections throughout the central nervous system from other mechanoreceptors from other cervical spine anatomical structures, such as ligaments and facet joints (Morningstar et al. 2005).

An aberrant somatosensory input attributed by cervical dysfunction might therefore influence head righting response in numerous ways. However, the complexity of the nervous system, the immense overlap found in many neurological processes and its connections to the biomechanical structures make any attempt to outline specific pathways of head control a gross oversimplification. Nevertheless, it is now known that multisensory inputs combine and contribute to a multitude of functions ranging from reflexes like head righting to more complicated motor strategies and spatial perception (Goldberg and Cullen 2011).

Although appreciating the oversimplification, modeling studies of the interaction of the VCR and CCR have considerably improved our understanding of their combined functions with respect to the head movements they produce (Reynolds et al. 2008). The resulting head movement depends on the relative gains and strengths of each of the reflexes.

Aberrant cervical function is likely associated with muscle contraction: mechanoreceptors sensitised with acute inflammation may excite muscle activity at reduced stimulation levels through a gamma-coactivation. Accordingly birth trauma, or injury caused by intrauterine constraint could produce muscle contraction in conjunction with pain (Petersen et al. 2013). An increased muscle contraction
associated with a cervical dysfunction could potentially accentuate the gain of the CCR in respect to the gain of the VCR, resulting in the production of head movements that were less compensatory with respect to the direction of whole-body rotation. (fig. 2).

Simultaneously an increased muscle contraction from a cervical dysfunction could potentially decrease the viscoelasticity of the tissues and therefore affect the passive behavior, resulting in an increased resistance to movement according to the model proposed by Peterson et al. in 1986 (fig. 3).

Conversely, according to the “Sensory Weighting Hypothesis”, the somatosensory input from an aberrant afference is likely disregarded as unreliable and out-weighted by an increased gain of the other sensory input, decreasing the impact on head movement (Oie et al. 2002; Reynolds et al. 2008). However, studies investigating the effect of altered cervical proprioception in whiplash patient and patients with cervical dystonia (Morningstar et al. 2005), have found alteration of afferent information from cervical proprioceptors to still disturb head orientation in space and relative to the trunk (Petersen et al. 2013). Perhaps the ability to weight sensory information, and thus keep the postural control system in equilibrium, depends upon the extent of disturbance, the state of the remaining senses and how well developed the internal representation of body scheme is!

Indeed, the latter point is especially interesting in the case of children, where cortical function is not yet fully developed. An important part of interpreting sensory information is the presence of an internal representation of body schema providing a postural reference frame (Shumway-Cook and Woollacott 2010) and studies have shown that the ability to adapt sensory information for postural control (Woollacott et al. 1987) is incomplete under the age of 7.

The head righting reflexes are most responsive between 4 and 10 months of age, subsequently they are gradually modulated by developing central inhibitory influences, cerebellar control and central adaptation (Nandi and Luxon 2008). The effect of an altered afferent input might therefore be profoundly different in infants where central processing and the establishment of a body scheme is incomplete. The lack of an internal reference frame, enables the infant to modulate sensory input and the head righting reflexes are left practically uninhibited.

An interesting question is, how aberrant cervical function is perceived and processed by the higher level neural centers if present from birth. Most studies investigating how multisensory input combine and interact, are conducted on subjects where an
alteration of a normal somatosensory input has occurred. However, if aberrant somatosensory input is present before higher level processes essential for mapping body scheme has developed, then the perceptual processes of organizing and integration of visual, vestibular and somatosensory systems might perceive the aberrant input as normal, and, if uncorrected, potentially influence the anticipatory and adaptive aspects of postural control. In such cases, one might even expect the feedforward mechanism of efference copy to reinforce the impact of a cervical dysfunction on head righting.

**Conclusion.**

Cervical proprioception plays a central part in head righting reactions. Not only directly through the CCR, but also indirectly through reafference to other reflexes and numerous central connections. Aside from these direct interactions with the nervous system, the increased muscle contraction associated with a cervical dysfunction, might influence head righting by decreasing the viscoelastic properties of the neck. According to the “Sensory Weighting Hypothesis”, the somatosensory input from an aberrant afference is outweighted by an increased gain of other sensory input. However, in infants, where the immaturity of the nervous system and hence a lack of an internal reference frame, enables the infant to modulate sensory input and the head righting reflexes are left practically uninhibited. Based on these facts it is not only possible, but likely that cervical dysfunction can be reflected in the head righting test.
References


