LECKEY

HEAD CONTROL IN CHILDREN WITH CEREBRAL PALSY

The importance of head control

Head control is something that, for typically developing children, we rarely give much thought. It proceeds gradually and seamlessly, and after a few short months, children are sitting up, crawling and walking.

However, for children with a neurological delay such as cerebral palsy, gaining head control may be harder to achieve. As a result, the emergence of head control takes on much more of a developmental significance and may become a therapeutic goal.

But what exactly *is* head control? What influences head control and what is the impact of a delay? And, most importantly, if head control is delayed, what can we do about it?

Searching for the answers

To answer these questions, key research databases were searched to identify published literature referring to the development of head control in children with cerebral palsy. The searches were carried out as detailed below:

Database	Search Term(s)	Hits	Dedupe & Limit*	Review	Final no. of papers
Google Scholar	head control head control AND cerebral palsy children with cerebral palsy AND head stability development of head control	13	13	13	13
OVID: Medline PsychInfo AMED Embase EBM Reviews	head control (using AND with other search terms yielded no results)	867	333*	35	26
Other	Reference lists				7
				TOTAL	**46**

*Articles were limited to those published between 2007 and the present, except where relevant earlier articles were identified in reference lists. Articles were also required to be in English. However, the Google Scholar search was not limited, and all relevant papers were included.

What is head control?

Surprisingly, "head control", although the earliest stage of development, and a key goal of therapy, is not clearly defined within the literature. Following the retrieval of almost 50 papers, not a single stand-alone definition of head control could be located.

Some researchers borrowed definitions from assessment procedures. For example, Butler et al (2007) considered a child to have functional head control if "*he/she can be supported at the chest in upright sitting and maintain the head in midline for 10 seconds*". This an extract from the Gross Motor Function Measure (GMFM), for determining the development of sitting ability. Bentzley et al (2015) defined head control in 12-week-old infants as the ability to lift their head 90^0 while in prone (tummy lying) and keep their head and trunk aligned while being pulled-to-sit, movements which are considered developmental norms for three-month-old babies. Other researchers constructed individual definitions in relation to their research, for example, in two studies investigating the development of postural control, Dusing et al (2013, 2014) considered the onset of head in the midline when infants could hold this head position when back lying (supine) for at least 50% of the experimental time of five minutes. Similarly, Tas & Cankaya (2015) required infants to hold their heads upright for 10 seconds in supported sitting, determined as a simple "yes" or "no".

Whilst perhaps surprising that head control receives so little attention in research, the *development* and *purpose* of head control receives much greater attention.

The typical development of head control

The first head movements can be seen in the womb at 7.5-8 weeks pregnancy when sideward bending of the head occurs. Forward, rearward and rotational movements appear by 11 weeks (Einspieler et al, 2008; Lee & Galloway, 2012). These early movement patterns remain apparent for the first few weeks after birth, despite the vastly different environment new-borns find themselves in (Einspieler et al, 2008). This can be seen in spontaneous head movements, the rooting reflex (searching for the nipple), and in attempts to follow visual stimuli (de Lima-Alvarez et al, 2014).

In back lying (supine), new-borns predominantly turn their head to the side because of the size of their head in relation to their body, and they have weak neck muscles. Interestingly, this head turn is predominantly to the right. Between two and eight weeks old infants hold their head midline more often when crying, because crying increases the activity of the neck muscles (de Lima-Alvarez et al, 2014).

The level of head control dramatically changes between two and three months old when there appears to be a major adaptation to the environment. Muscle power increases leading to better control of the head against gravity (Einspieler et al, 2008, de Lima-Alvarez et al, 2014); and a host of other skills appear, including chin tuck in supine (de Lima-Alvarez et al, 2014), visual attention, binocular vision, social smiling, and pleasure vocalisation. These late adaptations to the world outside the womb are thought to exist because of the relatively short human gestation period. Human babies have rapid brain development and need subcutaneous white fat for body temperature regulation (fat deposition in utero is unique to humans and presumably an evolutionary response to the loss of fur), both of which place a high metabolic demand on the mother (Einspieler et al, 2008).

Lee and Galloway (2012) describe how the upright, midline head position when a three-month-old infant is held upright has clinically been considered a basic level of head control which continues to develop throughout the first year and beyond, while Saavedra et al (2010) report that the "full repertoire" of head stabilisation strategies is not utilised by children until after eight years of age.

Purpose of head control

The purpose of head control is widely considered to be its pivotal role in the development of postural control to enable other skills (de Lima-Alvarez et al, 2014; Butler et al, 2007; Dusing et al, 2014, 2012; de Saldanha Simon et al, 2014; Lee & Galloway, 2012). Gaining postural control is well-documented in research as an extremely complex process, which depends on the nature of different postural tasks, and whether the balance and stability needed for each are internally generated (a desire to move) or externally generated (a response to being moved). Additionally, in children without neurological impairments, the process starts with the development of head control, and does not fully mature until after adolescence (de Graaf-Peters et al, 2007b).

Head control therefore provides a stable frame of reference for movement of other body parts (Einspieler et al, 2008; Saavedra et al, 2010) which Saavedra et al (2012) explain further,

> "*The task for the young infant is to stabilise the head in space over an inherently unstable, multi-segmented column [spine] using an array of overlapping muscles*." (p. 2215).

Head control must also come before the development of visual hand regard, intentional reaching, grasping, and the visually controlled manipulation of objects (de Lima-Alvarez et al, 2014; Einspieler et al, 2008; de Saldanha Simon et al, 2014); oral-motor skills (Lee & Galloway, 2012); sitting (Butler et al, 2007; Einspieler et al, 2008; de Saldanha Simon et al, 2014; and walking (Einspieler et al, 2008).

Due to the location of the eyes and vestibular systems for balance in the head, head control is also considered critical for visual orientation and balance (de Saldanha Simon et al, 2014; Saavedra et al, 2010).

What influences head control and what is the impact of a delay?

There is limited evidence about *why* head control is impaired, as well as the factors involved (Lee and Galloway, 2012). Given the obvious motor development of head control, and the weight placed by therapists on the severity of movement skills in children with cerebral palsy, it seems logical to assume that neuromotor skills (nervous system and muscles) have the greatest impact on the development of head control.

However, limited though it is, the research suggests a complex range of influences on the development of head control, with internal and external factors playing significant parts (Lee and Galloway, 2012). Rachwani et al (2013) sum this up:

> "*…motor development is not only a result of neural maturation, but is a dynamic process involving interaction between environmental constraints and sensorimotor systems."* (p. 2).

Lidbeck et al (2015) agree and suggest that even though the processes are not fully understood, perceptual and sensory systems affect gross motor development. Therefore, while each factor impacting on the development of head control is fundamentally reliant on the other factors, for this document, we have attempted to look at each separately.

a) Neuromotor development:

Typically developing babies are considered to reach a neuromotor developmental milestone around three months of age, a phenomenon which has been described as the *"the three-month transformation of neural functions"* (Prechtl (1984) quoted by Einspeiler et al, 2008, p148) due to its role in helping infants adapt to life outside the womb. At this stage, neck muscles increase in strength (de Lima- Alvarez et al, 2014; Einspieler et al, 2008), which in turn, leads to an ability to 'chin tuck' in supine (bring the chin closer to the chest in midline), improving alignment between head, neck and trunk. Around the same time, there is also an inhibition of the head righting reflex (when the head is turned to one side, the body log rolls to the same side), which allows for more independent movement to develop (de Lima- Alvarez et al, 2014).

Bentzley et al (2015) found that in preterm babies (24-34 weeks gestation), head lag and poor ability to lift the head whilst in prone beyond four months of age were associated with poor motor outcomes later. Therefore, because delays in neuromotor development at this very earliest stage of development are likely to have a negative influence on the development of subsequent neuromotor skills, they should also provide an early red flag for intervention.

b) Sensory development:

Research evidence about sensory perception is lacking in children with CP (Saavedra et al, 2010), and according to Bertenthal & von Hofsten (1998), little is known about the influence of head control on visual tracking. However, with the eyes located in the head, it makes sense that vision and head control are linked. Typically developing new-borns tend to track with eye movements as far into the periphery as possible before head turn occurs, but this is thought to relate to poor head control, as infants at one month old can visually track when their heads are supported for them (Bertenthal & von Hofsten, 1998).

The three-month transformation of neural functions is also considered to apply to the emergence of visual attention and binocular vision (Einspieler et al, 2008) and Bertenthal & von Hofsten (1998) describe visual tracking as "*more flexible and efficien*t" by three months old (p. 517). Porro et al (2005) explain that equally, head control plays an important role in the development of vision in terms of fixing, focusing and following – gaze control; and the development of vision is important for controlling the head in space.

Gaze control is a dynamic process involving the coordination of eyes, head and object, during which the object, head, or both may be moving. The eye movements must be able to follow the object (pursuit function of gaze control) as well as counteract for changes in speed and direction of the head and/or the movements of the object (compensation function of gaze control) (Bertenthal & Hofsten, 1998). Both pursuit and compensation functions are controlled by the vestibular-occular reflex (Masuda & Kaga, 2014).

The opposite situation, where impaired vision may affect head stability, may also occur because the opportunities to practice pursuit and compensatory gaze control movements are reduced (Saavedra et al, 2010). The complexity of these manoeuvres in typically developing children is described by Bertenthal & Hofsten (1998):

> *"Successful reaching involves a nested hierarchy or eyes, head, and trunk organised in such a way that the hand is guided toward the target object. The location of the object is initially given in retinal coordinates, but this information must also be transformed into head and shoulder coordinates to ensure the co-ordination participation of the different body segments. Moreover, the relation between the different body segments and the object is continuously changing during a reach. For this reason, reaching for distal objects is necessarily a dynamic process demanding mutual and reciprocal processing of the relevant perceptions and actions. It is quite remarkable that infants develop the capacity for successful reaching at such a young age when considered from the perspective of such a complex system of interacting behaviours"* (p. 519).

As well as the development of the visual-motor sensory skills, there may be additional visual limitations for children with CP. According to Porro et al (2005), approximately 48% of children with CP have some dysfunction of their visual system, compared to 5% of typically developing children. This may be responsible, in part, for postural compensations such as head tilt, face turn, or upper body adjustments seen in some children with CP – postures which are considered unusual, but which are used to obtain better visual awareness or maintain a central visual field with one eye. Porro et al (2005) hypothesise that children with CP use their available eyesight and ability to move to find the best postural compensation for their specific visual impairment.

Sensory development applies to more than the visual system. It includes the somatosensory (light touch and temperature), vestibular (balance and movement), proprioceptive (deep touch and body awareness) and auditory senses, which are triggered, controlled, integrated and regulated by the central nervous system (Porro et al, 2005). Einspieler et al (2008) highlight that the three-month developmental age is a further significant time for the proprioceptive system, when it is "recalibrated" in order to prepare infants for later fine motor development.

Motor and sensory delays can also have an impact on function. Tas & Cankaya (2015) found a direct relationship between poor head control and increased drooling in children with quadriplegic CP. Nutrition and swallowing disorders were also found to be increased, and weight and BMI were lower in these children. To process food successfully, the movements of the tongue, lips and jaw must co-ordinate, and the foundation for this is head control (Redstone & West, date unknown).

c) Cultural and environmental norms:

Lee and Galloway (2012) suggest that the three-month developmental milestone of head control is biased towards Western cultures where supine (back lying) positioning is favoured. In contrast to Western cultures, East African infants sit, stand and walk earlier, while Chinese and Japanese infants who are heavily swaddled are more delayed (Ratliff-Schaub et al, 2001).

A reduction in prone positioning (tummy lying) opportunities occurred in Western cultures when supine sleeping was widely recommended to reduce the incidence of sudden infant death syndrome. While such a reduction has been achieved, there has been concerns about the impact on the development of motor skills. Ratliff-Schaub et al (2001) found that head control was more advanced in preterm babies who were placed in a prone position. They suggest additional “awake” positioning strategies should be used to prevent delays. Other researchers report similar findings. Perez-Machado and Rodriguez-Fuentes (2013) found a direct positive relationship between the amount of time spent in an awake prone position and the level of head control at three months of age.

Lee and Galloway (2012) showed that in typically developing infants from one month old, the development of head control could be advanced by a combination of increased opportunities for upright or prone positioning (for example, using a front carrier); “active handling” (reduced passive support of the head), which has been shown in cross-cultural research to advance head control; and through increased social interaction which they speculated arose during different positions and active handling sessions.

Therapy for head control

As with other areas of research on head control and CP, the literature is sparse about therapy and head control. Only three studies were found which specifically addressed the effect of therapeutic intervention on improving head control. Studies which investigated the effect of therapy on postural control were excluded.

In the most recent study located, Curtis et al (2017), compared segmental training with conventional physiotherapy for improving gross motor function for children with moderate to severe CP. Segmental training (or targeted trunk control training) is a biomechanical approach which aims to improve head and trunk control in a top-down fashion using specially adapted standing frames. The study did not find any statistical differences between the segmental training group and conventional physiotherapy group, but forward-backwards head sway was found to be clinically significantly reduced in the group of children receiving targeted training. The authors attribute the results, in part, to difficulties with measuring outcomes. In addition, the clinical difference in head sway was not found at six-month follow-up, suggesting that intervention needs to be ongoing for benefits to last.

In the second study, de Saldanha Simon et al (2014) investigated the activation of neck and upper body muscles of children with severe CP during facilitated side lying, and in tummy lying over a wedge, using the hips as a key point of control. Using neurodevelopmental treatment (NDT, also known as the Bobath approach), they found that muscle activity was higher for all children in both positions, but as the muscles of children with slightly milder CP were activated more in the prone position, they concluded that side lying may be a better treatment position for more affected children, and prone for less affected children. However, how this translates into positive treatment outcomes was not investigated as part of this study.

In the final, much older study, Leiper et al (1981), investigated improving head control in children with CP by using auditory feedback. Wearing a specially designed helmet, a signal was emitted when their head angle dropped to prompt a corrective response, and the aim was to teach children to self- correct their head position.

The authors found that all children improved their ability to control their head using the auditory feedback, but out of five, only three children learned to self-correct their head position. The other two children were more severely impaired and continued to require verbal prompts to correct their head position.

So, what can we do if head control is delayed?

The lack of research on head control means there is also a lack of guidance available on how we can intervene to improve things. However, evidence-informed practice means inferring what we can from the available research, combining this with clinical knowledge, and considering the experience and values of families of children with CP, to make the most informed recommendations (Woodbury & Kuhnke, 2014).

The following recommendations are based on this evidence-informed approach.

Recommendations for addressing delays in head control

1. **Assess the extent of head control in more detail (see attached checklist)**

If we don't understand the extent of head control limitations, the earliest developmental milestones (for example, chin tuck, integration of reflexes) may have not been reached and head control work in other positions may remain very challenging.

Assessment should also recognise the relationships between the sensory systems and head control, (particularly eyesight and hearing) and the impact deficits may have on the development of head control. Obtaining information on sensory impairments may involve liaising with a wider range of multi-disciplinary team members than usual, such as vision and hearing specialists.

2. **Practice the skills at the appropriate level**

Practising skills may involve treatment sessions with a physiotherapist, occupational therapist, or through family-centred intervention carried out by families with their child at home. Regardless of the age of a child, floor work in supine (back lying) may need to be revisited before attempting a more upright position. Bearing in mind the reciprocal arrangement between the development of head control and sensori-motor development, activities in supine or semi-reclined positions should also include visual and/or auditory stimuli.

Opportunities for awake prone (tummy lying) positioning and active handling are also very important. This might be over an exercise ball, wedge, over a parent's knee or semi-reclined against their chest. These positions should be presented little and often and be accompanied by visual and auditory stimulation. Reclined against the chest is a super way to achieve this, as there are no better visual and auditory rewards for a child than a familiar adult's face and voice.

The development of head control is difficult to treat, and it can take a long time to see results (Curtis et al, 2017; Leiper et al, 2016). The progress also depends on the severity of CP and its distribution. Some children with severe quadriplegic CP may make very slow progress due to the impact of their condition on their motor and sensory systems. If a child becomes very fatigued or distressed during head control work, it may be worth alternating head control work with appropriate postural supports which help to compensate for motor and sensory impairments.

3. **Use appropriate postural supports and use them appropriately**

For severely affected children, or older children where active handling is neither physically achievable nor age appropriate, a range of postural supports including floor-based systems, seating systems, standing frames and night-time positioning systems can be used, both to facilitate postures which encourage the development of head control and to provide support in the absence of head control.

Floor-based and/or or night-time positioning systems may provide additional opportunities for supine work on head movements (left to right, focus and following, chin tuck) using the reduced demands of gravity in this position. However, children or young people with reduced vision or hearing may have difficulty achieving the full range of movement as they seek to use their available sensory functions to the best of their ability.

The requirement for understanding the impact of sensory deficits is also important when using postural support equipment with head supports. Head supports are commonly used to enable and sustain an upright or semi-reclined position of the head in special seating systems and standing frames. However, children with visual or hearing impairments may choose to hold their head tilted or turned away from the midline to gain the best functional use of the vision or hearing they have. Therefore, it is worth bearing in mind that insisting on a midline head position for these children has the potential to be detrimental to their function. The same is true for the semi-reclined seating position. This is a common strategy for providing relief from fatigue and preventing head drop in the upright position, but it limits the sensory experience of the child (Butler et al, 2007).

In addition, the level of trunk support provided by the overall system must match the child's level of abilities. Too much support when it is not required, and the quality of available movement is impaired (da Costa et al, 2017) suggesting that functional performance could be further inhibited.

The position of the head has an impact on other functional abilities such as feeding, where head falling forward can increase drooling, while a reclined position can impact negatively on safe swallow, and increase the risk of aspiration, chest infections and poor nutritional status (Tas & Cankaya, 2015). The key is getting the balance right, and guidance should be sought from speech and language therapy colleagues.

Conclusion

The development of head control remains somewhat of a neurological mystery. No one really knows how to address, or even define, head control in children with neurological impairments, despite it being the foundation for subsequent movement patterns, sensory, cognitive, perceptual and functional abilities.

The research is limited, and studies tend to have small sample sizes of children with less involved cerebral palsy. The literature that does exist is difficult to unpick, as there are many parallel layers. The motor, sensory and environmental influences involved are completely interconnected, making it a complex topic, which is not easily addressed.

However, there appears to be a tendency amongst clinicians to skip past this small, but vital, part of development, and look straight to equipment for the answers. While undoubtedly, equipment plays a fundamental role in the practical and functional management of a child with poor or absent head control, it can bring issues of its own, if the whole picture of sensory-motor abilities is not taken into consideration.

The key messages for clinicians are therefore to slow down and take greater stock of head control from the outset, liaise with a wider range of multi-disciplinary colleagues to understand the multisensory challenges faced by children with cerebral palsy, provide early and continued intervention and/or equipment to plug the gaps, and focus on individual need.

With a more holistic approach to understanding and addressing head control, each child has a greater chance of reaching their potential.

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