Australian College of Chiropractic Paediatrics

2017

Chiropractic Evidence-Based Management of Deformational Plagiocephaly

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ACCP

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Chiropractic Evidence-Based Management of Deformational Plagiocephaly **2017**

Authored by Braden G. Keil & Christian J. Fludder

Summary of Key Action Statements in this Document

1. When evaluating an infant or child with deformational plagiocephaly, the chiropractor should be aware that the presence of plagiocephaly may have a negative developmental effect on the infant, pre-schooler and school-aged child.

2. The chiropractor should understand the neurological benefits and impact of the chiropractic adjustment, as there may be significant functional changes occurring at the cerebellum and prefrontal cortex. Normalisation of afferentation by correcting dysfunctional spinal joints plays an important role in the restoration of proper spinal motion and aid appropriate neurological development.

3. The chiropractor should be aware that deformational plagiocephaly may be the sign of an underlying condition, either pathological or non-pathological. While being able to diagnose specific conditions is not ultimately the objective of this guideline, recognition of a condition requiring appropriate referral is critical.

4. The chiropractor should be the primary point of assessment for cervical spine joint dysfunction in infants and children with deformational plagiocephaly to assist with early identification and preventative treatment. Early intervention is associated with better outcomes.

5. Management of deformational plagiocephaly can vary depending on the severity of the presentation:

   Mild cases are able to be managed by the chiropractor.

   Moderate cases are able to be managed by the chiropractor with co-management by appropriate health professionals. Co-management is determined on a case by case basis.

   Severe cases are able to be managed by the chiropractor with co-management by appropriate health professionals. Co-management is determined on a case by case basis.

6. The chiropractor should be regularly examining and monitoring development of the degree of deformational plagiocephaly, as well as ensuring proper and expected neurological and physical development.

1. Introduction

Deformational Plagiocephaly, otherwise known as posterior or positional plagiocephaly, is a common disorder affecting infants and children. Posterior deformational plagiocephaly primarily affects the occipital bone or the back of the head with visible flattening on one side. Commonly associated with deformational plagiocephaly is a flattening or a retrusion of the contralateral frontal region of the skull. A subset of infants and children experience midline occipital bone flattening.

Deformational plagiocephaly may be associated with cosmetic issues and correction is important to restore facial symmetry and allow symmetrical development of the orbits and the upper and lower jaw. Deformational plagiocephaly is also associated with increased neurodevelopment issues affecting the visual system, the auditory system, motor development and cognitive development. Deformational plagiocephaly is associated with increased levels of gross motor developmental delay in infants, increased gross and fine motor issues in pre-schoolers, as well as increased gross motor issues, fine motor issues and learning difficulties in primary school aged children. Studies typically report learning difficulties in 33-40% of primary school aged children with a history of deformational plagiocephaly.

Deformational plagiocephaly is associated with considerable costs to the health care system as well as considerable costs to the education system. Recognition of the neurodevelopmental impact of deformational plagiocephaly among health care professionals as well as the greater community is poor with many still considering deformational plagiocephaly as being only a minor cosmetic issue which affected children will grow “out of”. Research indicates that this is not the case.

Chiropractors play an important role in the diagnosis and management of this common paediatric condition and are well trained to provide optimal management as part of an extended health care network. This will enable infants and children with deformational plagiocephaly to achieve the best possible neurodevelopmental and functional orthopaedic outcomes.

Key Action Statement – Scope of the Problem

When evaluating an infant or child with deformational plagiocephaly, the chiropractor should be aware that the presence of plagiocephaly may have a negative developmental effect on the infant, pre-schooler and school-aged child.

2. The Scope of the Problem

Head asymmetry or plagiocephaly is apparent in about 13% of healthy neonates and 56% of twins (Peitsch, Keefer, LaBrie, & Muliken, 2002). This head asymmetry appears to be the result of intra-uterine pressure moulding of the foetal head and in most cases resolves rapidly within two to three weeks after delivery. However, in some cases the deformational plagiocephaly persists.

Deformational plagiocephaly that requires intervention is either apparent at birth and does not resolve as expected, or arises post-delivery typically becoming apparent to the caregiver at 4 to 8 weeks of age.

The incidence of plagiocephaly is 16% at 6 weeks, 19.7% at 4 months, 9.2% at 8 months, 6.8% at 12 months, and 3.3% at 24 months (Hutchison, Hutchison, Thompson, & Mitchell, 2004). More recently the incidence of plagiocephaly in infants at 7 to 12 weeks of age was 46.6% (Mawji, Vollman, Hatfield, McNeil, & Sauve, 2013). There is a natural tendency for the head asymmetry to improve particularly as the infant becomes able to roll and spend less time sleeping supine.

> "The incidence of plagiocephaly is 16% at 6 weeks, 19.7% at 4 months, 9.2% at 8 months, 6.8% at 12 months, and 3.3% at 24 months."

The incidence of deformational plagiocephaly has most likely increased as a result of the "Back to Sleep" program which was developed to prevent Sudden Infant Death Syndrome (SIDS). It is now recognised that most infants with deformational plagiocephaly have abnormalities of their neck range of motion (ROM); however, this association is not well defined or widely known (Stellwagen, Hubbard, Chambers, & Lyons Jones, 2008).

2.1 The Natural History of Deformational Plagiocephaly

There is significant improvement in the appearance of deformational plagiocephaly in most cases with time particularly once the infant starts to roll and sleep on their side or back. More severe cases do not typically spontaneously resolve (van Vlimmeren, et al., 2008).

In a landmark study, families reported that 25 of the 63 children (39.7%) with persistent deformational plagiocephaly had received special help in primary school including: special education assistance, physical therapy, occupational therapy, and speech therapy generally through an Individual Education Plan. Only 7 of 91 siblings (7.7%), serving as controls, required similar services (Miller & Clarren, 2000). This was the first study suggesting that plagiocephaly was more than a cosmetic issue and was associated with significant neurodevelopmental issues later in life.

2.2 Evidence of Developmental Delay in Infants with Plagiocephaly

A study found that 33% of 42 infants with deformational plagiocephaly exhibited psychomotor delay suggesting that developmental issues were apparent within infancy in a significant proportion of plagiocephaly cases (Panchal, et al., 2001).

This was supported by an additional study that observed that 26% of 110 infants with deformational plagiocephaly tested using the Bayley Scales of Infant Development–II demonstrated psychomotor delay (Kordestani, Patel, Bard, Gurwitch, & Panchal, 2006).

Infants with deformational plagiocephaly had significantly more abnormal muscle tone than non-plagiocephalic infants, with the tone being either increased or decreased, in a study of 49 infants with an average age of 8.1 months (Fowler, et al., 2008). Muscle tone changes, either increased or decreased, tend to be associated with developmental issues in infants and children.

"An important study of 287 infants with a median age of 22 weeks found that in infants with plagiocephaly, 36% had one or more developmental delays. In those with a neck dysfunction, 41% had one or more delays, compared to 29% of infants without neck dysfunction who had one or more delays"

An important study of 287 infants with a median age of 22 weeks found that in infants with plagiocephaly, 36% had one or more developmental delays. In those with a neck dysfunction, 41% had one or more delays, compared to 29% of infants without neck dysfunction who had one or more delays (Hutchison, Stewart, & Mitchell, 2009). Infants with neck dysfunction have greater risk of developmental delays. This study used passive and active range of motion assessment to identify the infants with neck dysfunction. The increased level of delays in infants with neck dysfunction agrees with other studies that had found altered afferentation and cortical activity associated with neck dysfunction (Lelic, et al., 2016).

In another study, 235 infants with deformational plagiocephaly (average age of 6 months) were assessed using the Bayley Scales of Infant Development (BSID-III). On average, infants with deformational plagiocephaly performed worse than control infants on all variables for all scales except the receptive language subscale. For each of the 3 BSID-III scales, a greater proportion of case subjects than control subjects scored in the delayed range (Speltz, et al., 2010).

This was reinforced in a repeat study of 27 infants aged 4 – 11 months that observed the presence of plagiocephaly was associated with developmental delay in both composite motor (22%) and language scales (11%) scored on BSID-III (Fontana, et al., 2016). Interestingly, the authors note that the severity of cranial deformity could not be used to predict the presence or the degree of developmental delay.

A study of 20 infants with deformational plagiocephaly aged between 4-11 months found infants with deformational plagiocephaly received lower scores on the cognitive and motor scales of the Bayley Scales of Infant and Toddler Development than infants without deformational plagiocephaly. Bayley Scales of Infant and Toddler Development motor scores were inversely associated with several brain shape measurements on MRI. An association between the severity of plagiocephaly present and degree of asymmetry at the cerebellar vermis and corpus callosum was observed (Collett, et al., 2012). More severe asymmetry was linked to worse developmental outcomes on the Bayley Scales of Infant Development.

In 2013, 21 infants with deformational plagiocephaly aged 5-12 months were assessed using the Bayley Scales of Infant and Toddler Development with the mean psychomotor index of development significantly lower than normal population estimates would predict (Knight, Anderson, Meara, & Da Costa, 2013).

2.3 Evidence of Developmental Delay in Pre-Schoolers with Plagiocephaly

A study of 129 children with deformational plagiocephaly were assessed as infants and 3-4 year-old children using the Ages and Stages Questionnaire (ASQ). This longitudinal study demonstrated 41% had one or more delays and 22% had two or more delays using the ASQ as infants. At follow-up only 11% had one or more delays and 4% had two or more delays (Hutchison, Stewart, & Mitchell, 2011).

In addition, a study of 227 toddlers at 18 months of age with a history of deformational plagiocephaly found the affected toddlers scored lower on average than did demographically similar unaffected toddlers on all scales of the Bayley Scales of Infant and Toddler Development. Toddlers with deformational plagiocephaly were also more likely to score in the "delayed" range of functioning than those without deformational plagiocephaly as defined by Bayley Scales of Infant and Toddler Development norms (Collett, et al., 2011).

In 2013, a study of 224 three-year old children found that deformational plagiocephaly cases scored lower than unaffected controls on the receptive language, expressive language, and fine motor subscales of the Bayley Scales of Infant and Toddler Development (Collett, et al., 2013).

2.4 Evidence of Developmental Delay in School-Aged Children with Plagiocephaly

In a landmark study suggesting that deformational plagiocephaly was more than a cosmetic issue and was associated with significant neurodevelopmental issues later in life, it was reported that 25 of 63 children (39.7%) with persistent deformational plagiocephaly had received a form of special help in primary school including: special education assistance, physical therapy, occupational therapy, and speech therapy generally through an Individual Education Plan. Only 7 of 91 siblings (7.7%), serving as controls, required similar services (Miller & Clarren, 2000).

A study in 2007 using a parent completed questionnaire found 34% of school aged children with a history of deformational plagiocephaly had received learning assistance, and 14% were in a special class (Steinbok, Lam, Singh, Mortenson, & Singhal, 2007).

> "A study in 2007 found 33% percent of school aged children with a history of deformational plagiocephaly had received learning assistance, and 14% were in a special class."

A parent-reported survey of 80 children with deformational plagiocephaly identified that developmental delay occurred frequently, with 21% having language difficulties, 28% having motor difficulties, and 15% requiring special education. Population averages for developmental delay are typically 5-6% of children. The side of pathology was related to these cognitive outcomes, with left-sided deformational plagiocephaly strongly related to the need for special education classes (27% versus 10%) and the observations of fine motor delay (41% versus 22%) and speech delay (36% versus 16%). There was no difference in language comprehension among patients by side of pathology (Shamji, Fric-Shamji, Merchant, & Vassilyadi, 2012).

"Left-sided deformational plagiocephaly strongly related to the need for special education classes (27% versus 10%) and the observations of fine motor delay (41% versus 22%) and speech delay (36% versus 16%)"

In one study of 68 children aged 7-9 years with a history of Congenital Muscular Torticollis (CMT) assessment revealed increased risk for developing a neurodevelopmental disorder; 57.9% of those who completed assessments were observed to have or were at risk for developing attention-deficit hyperactivity disorder (ADHD), developmental coordination disorder, language impairment, or autistic spectrum disorder. Furthermore, 60.5% had received developmental treatment during childhood (Schertz, Zuk, & Green, 2013).

Recently, the first systematic review examining the association between plagiocephaly and developmental delay was published. The review identified 19 studies that reported developmental outcomes in infants and children with plagiocephaly with most of the studies being rated as having moderate (11/19 studies) or strong (5/19 studies) methodological quality. The review concluded that a positive association exists between plagiocephaly and developmental delay with delays most commonly reported in motor domains followed by language, with 12 of the 19 studies showing an association, including 4 of the 5 studies with the highest methodological quality (Martiniuk, Vujovick-Dunn, Park, Yu, & Lucas, 2017). This systematic review supports previous findings in the review completed in 2005 by Collett *et al* (Collett, Breiger, King, Cunningham, & Speltz, 2005).

2.5 Evidence of Auditory and Visual Processing Delay in Children with Plagiocephaly

Visual field assessment can be used to demonstrate function of the visual association areas of the cortex. Changes to the visual field were observed in 35% of infants with deformational plagiocephaly, with constriction of one or both hemifields by at least 20 degrees (Siatkowski, et al., 2005).

When considering the impact of deformational plagiocephaly on receptive language, two studies have been performed to determine if the plagiocephaly would impact on auditory processing. One study demonstrated, for the first time, that central sound processing, as reflected by Event-Related Potentials (ERP), is affected in infants with deformational plagiocephaly (Balan, et al., 2002).

The second study showed contrasting results – that the presence of deformational plagiocephaly did not impact on central sound processing (Hashim, et al., 2014). Both of these studies used different case samples suggesting that the impact of central processing depends on the aetiology of the plagiocephaly.

Evidence of auditory and visual processing delay is minimal and contradictory, with further research needed.

Key Action Statement – Neurological Effects

The chiropractor should understand the neurological benefits and impact of the chiropractic adjustment, as there may be significant functional changes occurring at the cerebellum and prefrontal cortex. Normalisation of afferentation by correcting dysfunctional spinal joints plays an important role in the restoration of proper spinal motion and aids appropriate neurological development. Chiropractic spinal manipulation may improve cortical drive improving muscle tone.

3. Neurological Effects of Chiropractic Care

There has been a growing body of evidence to suggest that neural plastic changes occur following chiropractic spinal manipulation (Haavik & Murphy, 2012). Investigators have suggested that neuroplastic changes occur in structures such as the primary sensory cortex, primary motor cortex, prefrontal cortex, basal ganglia and cerebellum (Haavik-Taylor & Murphy, 2007a) (Haavik-Taylor & Murphy, 2007b) (Taylor & Murphy, 2008) (Taylor & Murphy, 2010) (Daligadu, Haavik, Yielder, Baarbe, & Murphy, 2013). A recent study has additionally shown that adjusting dysfunctional spinal segments alters early sensorimotor integration of input from the upper limb and shows that this change predominantly happens in the prefrontal cortex (Lelic, et al., 2016).

Research has also documented the impact of chiropractic spinal manipulation on the cerebellum and its impact on the motor cortex (Daligadu, Haavik, Yielder, Baarbe, & Murphy, 2013). The cerebellum is a plastic structure involved in motor learning and modulation of motor circuitry (Doyon, Penhune, & Ungerleider, 2003) (Bellebaum & Daum, 2007) (Thach, 2007). The cerebellum plays a major role in processing proprioceptive input, or the awareness of where the body is positioned, and has a major role in higher cortical function.

Altered proprioceptive input from the cervical spinal region has been associated with maladaptive sensorimotor integration, and by improving cervical spinal function there tends to be more appropriate and accurate processing and integration of this proprioceptive input (Haavik & Murphy, 2012). This was further demonstrated in a study that showed improved head repositioning accuracy after spinal manipulation (Palmgren, Sandström, Lundqvist, & Heikkilä, 2006). The impairments of proprioceptive input, be it from insidious causes or trauma-induced onset, not only results in altered cervical spine flexor activation but also can create an altered sensitivity of proprioceptive fibres within the cervical muscles themselves (Haavik & Murphy, 2012). This impairment of input then further disturbs how the central nervous system processes, interprets and transforms afferent information into motor commands (Haavik & Murphy, 2012). All of these changes of cortical somatosensory processing, motor control and sensorimotor integration reflect changes of central processing of proprioceptive afferent input (Haavik & Murphy, 2012).

The Neurological Effects of Chiropractic Care

Restoration of proper afferentation from dysfunctional spinal joints can have a significant effect on the cerebellum, influencing proprioception and cognition, as well as affecting the function of the cerebrum – namely in the prefrontal cortex – which may influence neurodevelopment.

Recent research looking at the effects of spinal manipulation on motor control and the recruitment pattern of motor units in both upper and lower limb muscles reported that

spinal manipulation leads to changes in cortical excitability without changes in spinal measures suggesting increased strength following spinal manipulation were due to descending cortical drive and could not be explained by changes at the level of the spinal cord. Spinal manipulation may therefore be indicated for the patients who have lost tonus of their muscles (Haavik, et al., 2017).

Chiropractic treatment of cervical spine joint dysfunction is important in restoring normal afferentation from the cervical spinal musculature, joints, and other soft tissues that then may assist in improving long-term outcomes in gross and fine motor, cognitive and language development, and importantly, proprioception (Palmgren, Sandström, Lundqvist, & Heikkilä, 2006) (Haavik & Murphy, 2012).

4. Clinical Examination for Deformational Plagiocephaly

The paediatric patient with head asymmetry should be comprehensively examined, including a neurological examination appropriate for age, to exclude any pathology associated with the head asymmetry.

Initial assessment of infants and children with suspected deformational plagiocephaly requires accurate visual examination from the anterior, posterior and vertex points of view of the skull in order to fully appreciate the involved side and degree of severity (Hylton-Plank, 2004). The examiner should note the side of occipital flattening, presence and side of frontal bossing, presence and side of anterior ear displacement, sutural patency assessment, as well as anterior fontanelle state and size measurement.

Regular head circumference measuring with plotting on appropriate charts such as WHO Anthro should be performed.

The gold standard for determining severity of deformational plagiocephaly is the transdiagonal difference (Glasgow, Siddiqi, Hoff, & Young , 2007). This measurement is the difference noted when measuring between two diagonals of the skull illustrated in Diagram 1. A head band is typically used to facilitate accurate reproducible placement of the calliper. When assessed using calipers, the transdiagonal difference measurement was found to have a high level of inter-examiner reliability (Skolnick, Naidoo, Nguyen, Patel, & Woo, 2015). There are a number of severity classification systems, including the two detailed below:

<u>McGarry, et al., 2008:</u>

1. Normal: <3mm difference
2. Moderate: 3-12mm difference
3. Severe: >12mm difference

<u>Looman & Kack Flannery, 2012:</u>

1. Mild: 3-10mm difference
2. Moderate: 10-12mm difference
3. Severe: >12mm difference

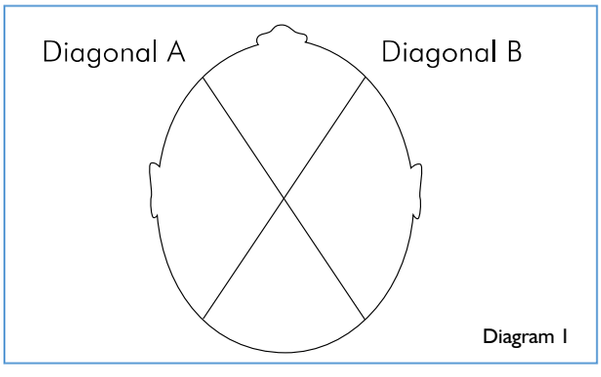


Diagram 1

While Looman and Kack Flannery state "there is no firm professional consensus on the best way to subjectively or objectively classify severity of plagiocephaly" (Looman & Kack Flannery, 2012), an anthropometric pilot study involving 401 children was able to provide an age and sex-

based table illustrating, among others, head circumference and Cranial Vault Asymmetry Index values in tabulated form (Wilbrand, et al., 2012).

Key Action Statement – Clinical Diagnosis

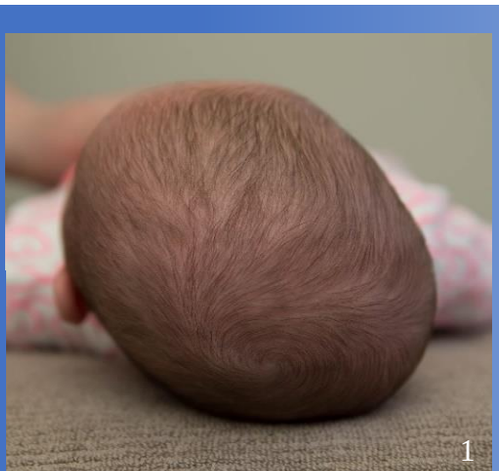
The chiropractor should be aware that deformational plagiocephaly may be the sign of an underlying condition, either pathological or non-pathological. While being able to diagnose specific conditions is not ultimately the objective of this guideline, recognition of a condition requiring appropriate referral is critical.

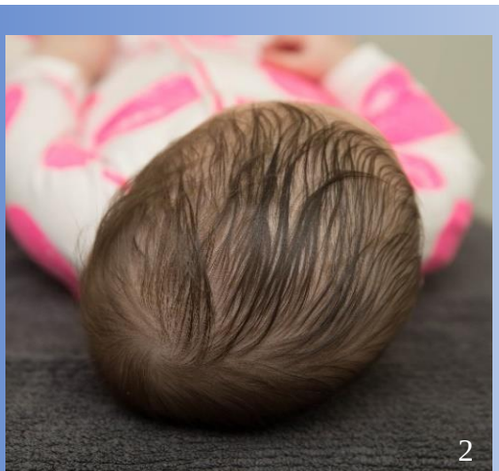
5. Clinical Diagnosis of Deformational Plagiocephaly

There are a number of possible underlying conditions which may present with occipital asymmetry which need to be considered by the chiropractor.

Examples of Deformational Plagiocephaly:

Image 1 (left) illustrates a left occipital plagiocephaly, image 2 (right) shows a right occipital plagiocephaly.





Lambdoidal Craniosynostosis - Deformational plagiocephaly needs to be differentiated from lambdoidal craniosynostosis which may also present with a flattened occiput (Hummel & Fortado, 2005) (Looman & Kack Flannery, 2012). Chiropractors are trained to detect lambdoidal craniosynostosis (O'Neil & Stewart, 2013).

The key differentiations between lambdoidal craniosynostosis and deformational plagiocephaly are:

1. Shape of the skull, with deformational plagiocephaly involving anterior displacement of the ipsilateral occiput with ipsilateral frontal bossing (parallelogram) compared to lambdoidal craniosynostosis which involves ipsilateral anterior occipital displacement with *contralateral* frontal bossing (trapezoidal),
2. Displacement of the ear, which occurs anteriorly on the side of occipital flattening in plagiocephaly compared to posteriorly in lambdoidal craniosynostosis, and
3. The presence of a palpable sutural ridge over the occipitomastoid area, which occurs in lambdoidal craniosynostosis only (Kalra & Walker, 2012).

Torticollis - A recent prospective case series determined that although more than 90% of infants with positional plagiocephaly were noted to have preferential head positioning with head rotational asymmetry (i.e., torticollis), only 24% of infants had been previously diagnosed as having, or had been treated for, torticollis, indicating that the incidence of torticollis is underreported and underdiagnosed in infants with positional plagiocephaly (Rogers, Oh, & Mulliken, 2009). A common cause of torticollis in infants and children is cervical spine joint dysfunction. Similar to plagiocephaly, the list of differential diagnoses for torticollis is extensive.

Cervical spine joint dysfunction (subluxation) – Chiropractors are able to accurately identify and correct cervical spine dysfunction in infants and children.

Infections

- **Grisel syndrome** – post-infectious or post-surgical atlanto-axial subluxation as a result of inflammation of atlanto-axial ligaments.
- **Retropharyngeal or Parapharyngeal abscess** – infection of the retropharyngeal or parapharyngeal lymph nodes resulting in neck stiffness, torticollis or refusal to move the neck.
- Other Infections – the development of a torticollis can be associated with various infectious conditions such as discitis or osteomyelitis.

Congenital Conditions

- **Congenital Muscular Torticollis** – a torticollis due to asymmetric length or tone of the sternocleidomastoid muscle.
- **Scoliosis** – including infantile idiopathic scoliosis, congenital malformations or various neuromuscular conditions such as cerebral palsy or syringomyelia.
- **Congenital vertebral anomalies** - such as Klippel-Feil syndrome, hemivertebrae, unilateral fusion of the atlanto-occipital joint or occipitalisation (in which the bony ring of the atlas is completely or partially fused to the base of the occiput).

Neuromuscular Conditions

- **Focal Motor Epilepsy** – or seizures causing turning of the head, as can occur in both focal and generalised seizures.
- **Developmental Abnormalities with asymmetric tone** – such as syringomyelia (the presence of a spinal syrinx that can cause scoliosis and absence of superficial abdominal reflexes), cerebral palsy, or torsional dystonia.
- **Ocular Torticollis** – resulting from either a strabismus or palsy of one or more ocular muscles.
- **Spasmus Nutans** – a congenital or acquired nystagmus with associated head nodding and abnormal posturing.
- **Benign Paroxysmal torticollis** – a self-limiting form of torticollis consisting of intermittent episodes of cervical dystonia.

Trauma

- Such as a clavicle fracture or brachial plexus neuropathy.
- **Asymmetric brain injury**.
- **Atlanto-axial subluxation** – a result of Down Syndrome, Juvenile Idiopathic Arthritis, Morquio Syndrome or other skeletal dysplasias.

Genetic syndromes

- **Crouzon Syndrome** – An autosomal dominant syndrome characterised by premature craniosynostosis.
- **Apert Syndrome** – An autosomal dominant syndrome with premature craniosynostosis associated with syndactyly of the 2nd, 3rd and 4th fingers.

- **Carpenter Syndrome** – An autosomal recessive condition with premature fusion often forming the kleeblattschädel deformity (clover leaf shaped head), syndactyly of the hands and feet, mental retardation, congenital heart disease, and angular changes to the hips and knees.
- **Chotzen Syndrome** – An autosomal dominant condition that results in craniosynostosis, ptosis of the eyelids, shortening and syndactyly of the fingers.
- **Pfeiffer Syndrome** – A genetic condition that tends to form a "cone-shaped" head, with short and broad great toes and thumbs

Others

- **Sandifer syndrome** – arching or turning of the head in association with gastroeosophageal reflux.
- **Tumours** – spinal tumours, such as neuroblastoma or osteoblastoma, or posterior fossa tumours (such as astrocytoma or medulloblastoma) may induce changes in head position and neurological function.
- **Arnold Chiari malformation** – cerebellar tonsillar herniation below the line of the foramen magnum that may cause neck pain and/or torticollis.
- **Vitamin D Deficiency** and other bone softening conditions.

This list is not exhaustive and other conditions may be associated with the development of plagiocephaly.

Chiropractors are required to detect and appropriately refer children with associated conditions which require medical assessment.

Causes of Plagiocephaly

- Joint Dysfunction
- Infection
- Congenital
- Neuromuscular
- Trauma
- Genetic
- Other

Key Action Statement – Cervical Spine Dysfunction

The chiropractor should be the primary point of assessment for cervical spine joint dysfunction in infants and children with deformational plagiocephaly to assist with early identification and preventative treatment. Early intervention is associated with better outcomes.

6. Assessment of Cervical Spine Joint Dysfunction in Infants

Due to the high association between deformational plagiocephaly and spinal joint dysfunction, all infants and children with deformational plagiocephaly should be examined by a chiropractor. Cervical spine gross active and passive range of motion (ROM) should be assessed in all infants (Persing, James, Swanson, & Kattwinkel, 2003). Assessment of passive and active ranges of neck motion in all three planes is necessary to detect restricted cervical spine function. Many less severe cases will remain undetected by examination unless cervical spine intersegmental motion is assessed at each level of the cervical spine by a suitably trained practitioner. The complex action of the Sternocleidomastoid muscle (SCM) and the difficulty in assessing neck ROM in newborns has led to an underestimation of torticollis and cervical spinal joint dysfunction in infancy (Stellwagen, Hubbard, Chambers, & Lyons Jones, 2008). Most studies have looked at lateral rotation of the neck in infants, chin to shoulder as is done in adults, which is inadequate to assess cervical spine function (Cheng, et al., 2001) (Hutchison, Hutchison, Thompson, & Mitchell, 2004).

Normal newborns can laterally rotate the head well past the shoulder, 100–110 degrees from the midline, and laterally flex their head 50–60 degrees towards the ear. Newborns with torticollis can have some limitation of lateral rotation, but this generally does not prevent the chin from reaching the shoulder (90 degrees). Lateral flexion of the neck (ear to shoulder) contralateral to the torticollis is much more likely to show restricted movement in the newborn with torticollis. Many newborns with limited neck ROM are missed because of an incomplete examination (Stellwagen, Hubbard, Chambers, & Lyons Jones, 2008). Indeed 16% of newborns were found to have torticollis when cervical spine ROM was assessed (Stellwagen, Hubbard, Chambers, & Lyons Jones, 2008).

Abnormal motion of the occiput on the atlas was reported in 591 of 649 (90%) of children with plagiocephaly and a significant correlation was found between the side of the plagiocephaly and the side of the occipito-atlantal joint dysfunction (Sergueef, Nelson, & Glonek, 2006). They conclude that occipital dysfunction associated with intrauterine posture or the stresses of the birth process will predispose the infant to a more preferred position of the head for sleeping and thus foster the development of posterior plagiocephaly.

Newborns who have restricted neck ROM are at risk of developing cranial deformations that could be prevented with early identification and preventative treatment (Hutchison, Hutchison, Thompson, & Mitchell, 2004) (Stellwagen, Hubbard, Chambers, & Lyons Jones, 2008).

In addition to cranial deformation, newborns with restricted neck ROM are also increased risk of motor asymmetries or motor delays due to congenital torticollis (Ohman, Nilsson, & Lagerkvist, 2009) (Watemberg, Ben-Sasson, & Goldfarb, 2016).

Key Action Statement - Management

Management of deformational plagiocephaly can vary depending on the severity of the presentation:

Mild cases are able to be managed by the chiropractor.

Moderate cases are able to be managed by the chiropractor with co-management by appropriate health professionals. Co-management is determined on a case by case basis.

Severe cases are able to be managed by the chiropractor with co-management by appropriate health professionals. Co-management is determined on a case by case basis.

7. Management of Deformational Plagiocephaly

The chiropractor is ideally trained to manage deformational plagiocephaly and improve outcomes. Early intervention has been associated with reduced treatment duration and improved cosmetic and neurodevelopmental outcomes (van Vlimmeren, et al., 2008) (Cabrera-Martos I. , et al., 2016).

Chiropractic management of deformational plagiocephaly includes but is not limited to correction of cervical spine dysfunction, positional management, cervical spinal muscle

stretching, physical growth monitoring (head circumference, weight and length), head asymmetry monitoring and neurodevelopment monitoring.

7.1 Chiropractic Management

In addition to the neurological benefits of chiropractic care listed in section 3, chiropractic management of deformational plagiocephaly has been associated with quicker restoration of normal head symmetry (Davies, 2002). This study demonstrated that 60% of infants under chiropractic care had an increase of one standard deviation in their head circumference in a review one week after their first adjustment. The primary locations for dysfunction in the spine were upper cervical spine (24%), pelvic ring (72%), or the glenohumeral joint (4%). This study needs to be replicated. Cranial asymmetry in infants has also shown to be significantly reduced with osteopathic care (Lessard, Gagnon, & Trottier, 2011).

Early chiropractic intervention for infants with deformational plagiocephaly may be crucial for improved head symmetry, reducing the severity of any spinal dysfunctions and preventing possible developmental delays.

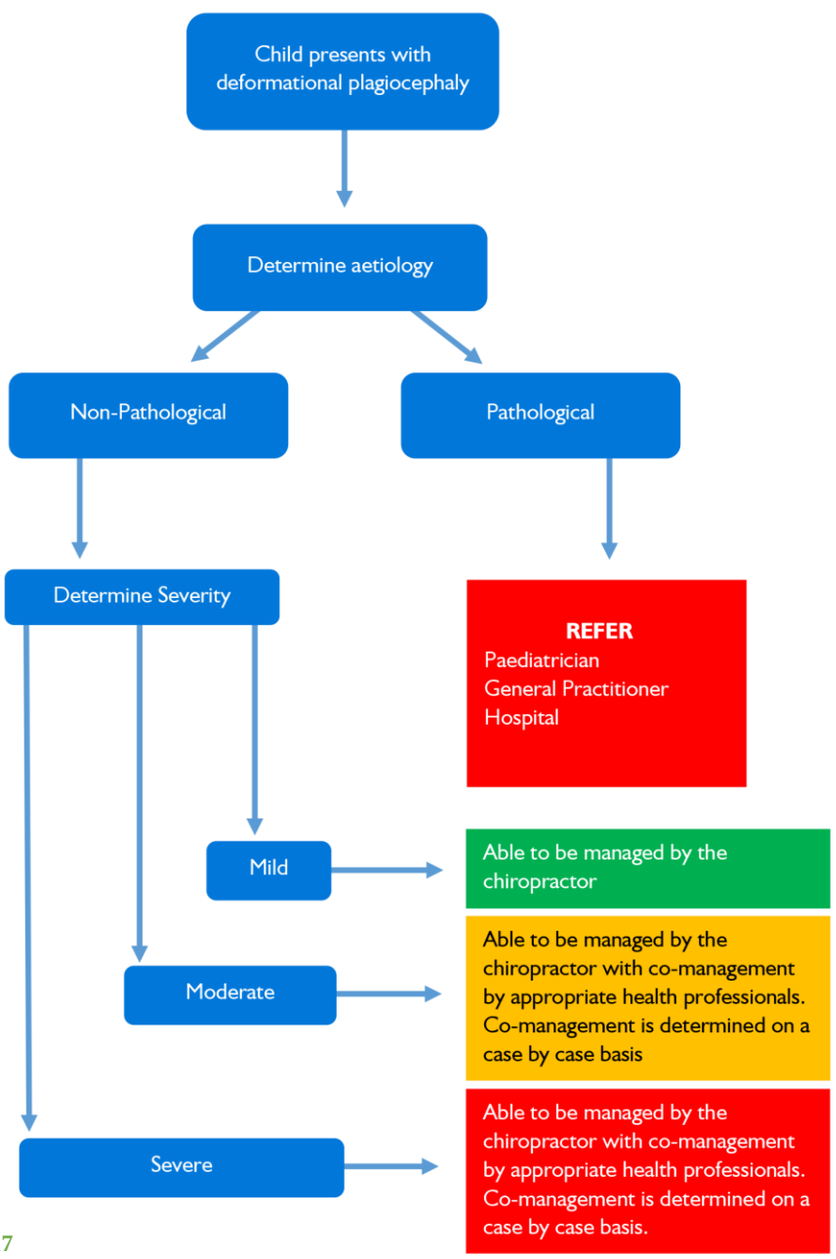
7.2 Cervical Spine Dysfunction Treatment

Chiropractors are able to accurately identify and correct cervical spine dysfunction using age and development appropriate techniques in a safe and effective manner (Davies, Chiropractic Pediatrics, 2010) (Anrig & Plaugher, 2013).

Medical training does not adequately train medical practitioners to assess cervical spine function in infants and children nor does medical training adequately train medical practitioners to treat cervical spine dysfunction of infants and children.

Chiropractors are highly trained in assessment and treatment of spinal intersegmental motion in all age groups. All infants and children with deformational plagiocephaly should be examined by a chiropractor and treated if appropriate. Chiropractors utilise multiple treatment approaches which are modified to suit factors such as the patient's size, age and presentation.

In regards to safety and adverse events, a 2015 systematic review summarises this topic as follows: "Published cases of serious adverse events in infants and children



receiving chiropractic, osteopathic, physiotherapy, or manual medical therapy are rare … no deaths associated with chiropractic care were found in the literature to date. Because underlying pre-existing pathology was associated in a majority of reported cases, performing a thorough history and examination to exclude anatomical or neurologic anomalies before applying any manual therapy may further reduce adverse events across all manual therapy professions" (Todd, Carroll, Robinson, & Mitchell, 2015).

"Chiropractors are able to accurately identify and correct cervical spine dysfunction using age and development appropriate techniques in a safe and effective manner"

7.3 Positional Management

Passive management of deformational plagiocephaly is aimed at encouraging movements to the side opposite that of the noted occipital flattening. Exercises that encourage the child to turn to the opposite side via visual or auditory stimulation (Kuo & Graham, 2014) or using a pillow or towel to restrict movement to the flattened side (Cabrera-Martos I. , Valenza, Extremera, & Valenza, 2013) can help promote changes to the motion of the neck and shape of the skull. Chiropractors are able to provide advice for promoting appropriate positional management.

7.4 Sternocleidomastoid (SCM) Stretching

SCM involvement in deformational plagiocephaly presents as contracture of the SCM without a palpable mass (muscular torticollis) or with a palpable mass (SCM tumour). Postural torticollis implies absence of SCM involvement. Postural torticollis, muscular torticollis and SCM tumour are often grouped as congenital muscular torticollis (CMT) however some reports exclude postural torticollis from CMT (Cheng, et al., 2001). The majority of cases of CMT present with a palpable tumour or lump within the SCM muscle evident in the first 4 weeks, or a thickening and tightening of the SCM muscle itself.

The incidence of CMT was found to be 16% of all births (Stellwagen, Hubbard, Chambers, & Lyons Jones, 2008). Chiropractors are able to palpate the SCM for the presence of a SCM tumour or tightening, in addition to cervical spinal restriction, to accurately diagnose CMT. If there is clinical doubt, then referral for ultrasound assessment of the tumour or lump is warranted.

Chiropractors are able to palpate the SCM for the presence of a SCM tumour or tightening, in addition to cervical spinal restriction, to accurately diagnose Congenital Muscular Torticollis

Management of CMT typically includes stretching exercises performed by practitioner and/or parents. Passive neck-stretching exercises are more difficult for child health practitioners to demonstrate to parents and equally difficult for parents to perform successfully at home. The recommendation for effective neck-stretching exercises is to hold each stretch for 30 to 60

seconds, to do 3 repetitions of each stretch, and to perform the series of stretches 6 to 8 times a day. Ideally, a stretching period should take approximately 5 to 10 minutes, depending on the cooperative ability of the infant (Kuo & Graham, 2014).

In cases of SCM involvement with a tumour stretching was associated with sudden giving way or snapping of the SCM in 8% signifying a possible tear or rupture of the muscle however need for surgical intervention was not increased in this group (Cheng, et al., 2001). Sudden giving way or snapping was more likely to occur under 1 month of age, if there was hip dysplasia, left sided involvement or a rotation deficit >15 degrees (Cheng, et al., 2001).

Median duration of treatment was 3.7 months for the SCM tumour group, 2.5 months for the muscular torticollis group and 1.4 months for the postural torticollis group (Cheng, et al., 2001). SCM stretching was effective treatment for SCM contracture in 95% of cases (Cheng, et al., 2001). Chiropractors are able to perform and teach parents stretching techniques when appropriate. A detailed description of the process and difficulties associated with stretching exercises with infants can be read by referring to Kuo & Graham, 2014.

7.5 Helmet Therapy

Cosmetic appearance of more severe cases may be improved with the assistance of helmet therapy which is typically used from 6-7 months of age onwards. Several studies suggest helmet therapy produces faster correction head asymmetry than positional management alone (Xia, et al., 2008) (McGarry, et al., 2008) (Lipira, et al., 2010) (Seruya, Oh, Taylor, & Rogers, 2013) (Dorhage, et al., 2016) (Ho, Mallitt, Jacobson, & Reddy, 2016) (Wilbrand, et al., 2016), while one randomised controlled trial demonstrated no difference in progression when compared to natural history (van Wijk, et al., 2014). Studies commencing treatment prior to 6 months of age were associated with improved outcomes regarding head asymmetry.

The use of helmet therapy has been shown by a number of studies not to improve the neurodevelopmental outcomes associated with deformational plagiocephaly (Miller & Clarren, 2000) (Steinbok, Lam, Singh, Mortenson, & Singhal, 2007). Furthermore, the presence of CMT can complicate progress, and treatment of the CMT is recommended to reduce potential forces that could cause the plagiocephaly to persist or return (Lee, et al., 2008).

Use of helmet therapy may be indicated prior to 6 months of age in severe cases (Freudlsperger, et al., 2016). There are a number of factors that can influence the use of helmet orthoses, and this decision to use helmets would be typically made by experienced orthotists.

It is recommended that severe cases of asymmetry identified by a chiropractor are referred to an experienced orthotist for evaluation.

Key Action Statement – Monitoring

The chiropractor should be regularly examining and monitoring development of the degree of deformational plagiocephaly, as well as ensuring proper and expected neurological and physical development.

8. Monitoring

8.1 Physical Growth Monitoring

Chiropractors are expected to routinely monitor skull growth and to measure any cranial asymmetry to ensure that proper growth is occurring and that any apparent cranial asymmetry is improving. In the instance that cranial asymmetry is not improving, regular monitoring of the cranial asymmetry will allow appropriate action to be taken (Siegenthaler, 2015).

Head circumference should be regularly measured and plotted against the appropriate WHO Anthro chart. Instructions on how to perform accurate head circumference measurements are available (Davies, Chiropractic Pediatrics, 2010) (Anrig & Plaugher, 2013).

Head asymmetry should be regularly measured using callipers and the diagonal difference calculated. For further detail refer to Section 4 – Clinical Examination for Deformational Plagiocephaly.

8.2 Neurodevelomental Monitoring

Chiropractors should monitor the neurodevelopment of paediatric deformational plagiocephaly using appropriate monitoring devices such as Parent's Evaluation of Developmental Status (PEDS) and/or Ages and Stages Questionnaire (ASQ).

Regular age appropriate neurological examination should also be employed by the chiropractor in order to monitor proper and expected development. Infants with neurodevelopmental concerns identified by the chiropractor may need to be referred to an appropriate health care professional such as a chiropractor with post-registration paediatric training or a paediatrician.

9. Referral to Other Health Care Practitioners

Chiropractors recognise the need to work with other health care practitioners in the management of paediatric deformational plagiocephaly and are able to identify when to refer for co-management to:

Paediatricians/General Practitioners
Speech Pathologists
Occupational Therapists/Physiotherapists
Educational Psychologists
Paediatric Orthopaedic Surgeons
Audiologists
Optometrists
Orthotists

10. Summary

Deformational plagiocephaly is a common condition with incidence rates of over 19% at 4 months of age.

Deformational plagiocephaly is associated with changes in gross and fine motor development, and may be associated with the development of learning difficulties at school ages.

Early intervention in cases of deformational plagiocephaly is associated with improved outcomes in head asymmetry and neurodevelopment.

Deformational plagiocephaly is commonly associated with torticollis due to cervical spine dysfunction and sternocleidomastoid muscle contracture.

The presence of cervical spine dysfunction is associated with cerebellar and cerebral cortex neurological changes which may result in neurodevelopmental delay.

Chiropractors are trained to detect and correct cervical spine dysfunction commonly associated with deformational plagiocephaly.

Chiropractors are trained to detect and appropriately manage infants and children with deformational plagiocephaly.

A small percentage of cases with deformational plagiocephaly are associated with pathology that requires identification by the chiropractor and medical management.

Appendix A

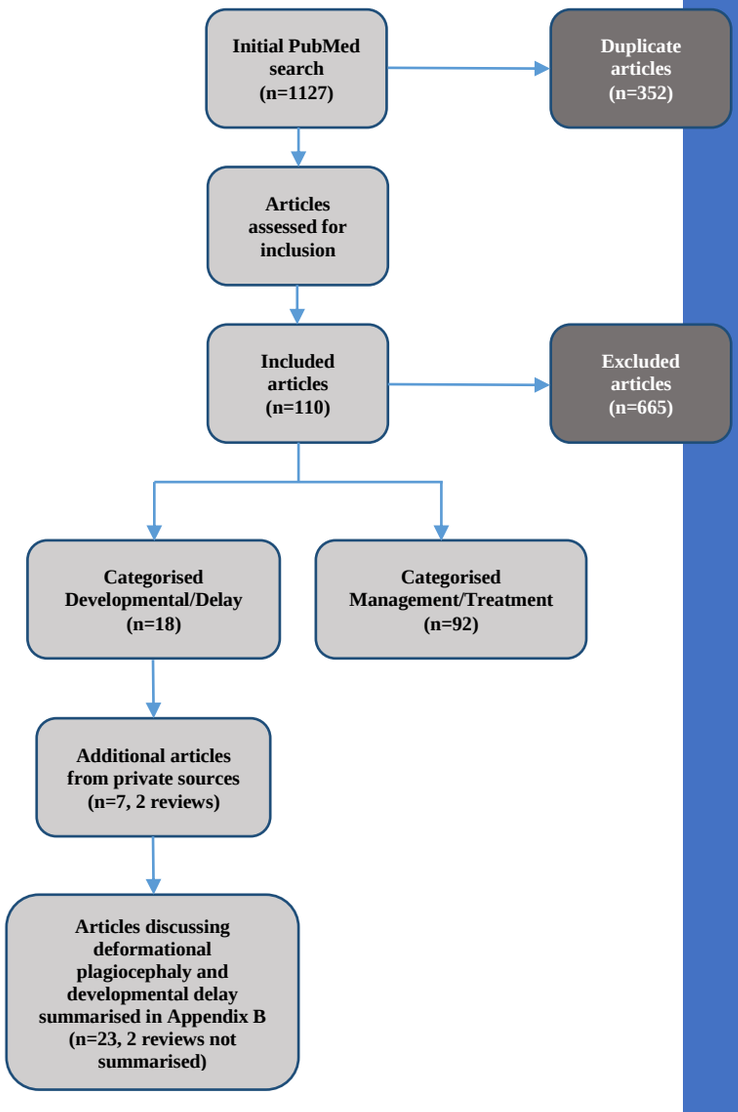
To obtain the highest-level evidence available regarding deformational plagiocephaly and developmental delay, as well as management of deformational plagiocephaly, a thorough search of PubMed was performed utilising the search terms:

[plagiocephaly AND treatment AND outcomes]
[plagiocephaly AND treatment]
[plagiocephaly AND stretching therapy]
[plagiocephaly AND helmet therapy]
[plagiocephaly AND language AND motor]
[plagiocephaly AND developmental delay]
[plagiocephaly AND delay]
[deformational plagiocephaly AND treatment AND outcomes]
[deformational plagiocephaly AND treatment]
[deformational plagiocephaly AND stretching therapy]
[deformational plagiocephaly AND helmet therapy]
[deformational plagiocephaly AND language AND motor]
[deformational plagiocephaly AND developmental delay]
[deformational plagiocephaly AND delay]

Initial number of papers selected using these terms was 1,127.

Initial exclusion parameters were set to exclude articles:

1. Not published in English,
2. based on craniosynostosis,
3. with presence of genetic disorders or syndromes,
4. following non-standard treatment or experimental treatment protocols,
5. focussed on frontal plagiocephaly,
6. dental or optical orientation,
7. not related to deformational plagiocephaly,
8. not on human subjects,
9. based on risks,
10. based on prevalence,
11. based on prevention management,
12. that were responses, replies or comments to previous publications,
13. that were cost studies,
14. that were duplicate search results or
15. that did not have an available abstract



1,017 studies were excluded on this basis.

Articles were split into categories of "Development/Delay" (n=17) and "Management/Treatment" (n=92). Additional articles that were identified as being appropriate from other sources were included in the "Development/Delay" category (n=8). Papers that commented on deformational plagiocephaly and development were summarised and listed in Appendix B (n=23, reviews excluded). Additional articles were manually searched for from references listed within included articles or reviews.

Articles within the "Management/Treatment" category were further evaluated for effectiveness, impact and benefit within the scope of this document.

Appendix B

Title	Sample Size	Age Tested	Test Used	Outcome
Miller & Clarren, 2000	63 families from 1980 to 1991.	Primary-school	Special Education required or not	"The families reported that 25 of the 63 children (39.7%) with persistent deformational plagiocephaly had received special help in primary school including: special education assistance, physical therapy, occupational therapy, speech therapy generally through an Individual Education Plan. Only 7 of 91 siblings (7.7%), serving as controls, required similar services."
Panchal, et al., 2001	21 subjects with non-syndromic synostosis, 42 subjects with plagiocephaly without synostosis	8-11 months old	Bayley Scales of Infant Development–II (BSID-II) for cognitive and psychomotor development	In regards to psychomotor development; "0 percent of the subjects in the craniosynostosis group were accelerated, 43 percent were normal, 48 percent had mild delay, and 9 percent had significant delay. 0 percent of the subjects in the group with plagiocephaly without synostosis were accelerated, 67 percent were normal, 20 percent had mild delay, and 13 percent had significant delay." In regards to Mental Development, the craniosynostosis group were "not statistically different", but in the plagiocephaly group: "0 percent of the subjects in this group were accelerated, 83 percent were normal, 8 percent had mild delay and 9 percent had significant delay."
Balan, et al., 2002		Infants	Event-Related Potentials at P150 and N250 responses to tone	"In the current study we demonstrated, for the first time, that the central sound processing, as reflected by ERPs, is affected in children with plagiocephaly."
Siatkowski, et al., 2005	40 infants with deformational posterior plagiocephaly	19-53 weeks old	Standardized binocular arc perimetry in the horizontal plane, 3-dimensional CT	"Thirty-five percent of infants with deformational posterior plagiocephaly had constriction of one or both hemifields by at least 20 degrees from established normal patients. Hemifield asymmetry of 20 degrees or more was found in 17.5% of infants tested. There was a significant difference in the worse hemifield values measured in each patient and the standard visual fields obtained from normative data ($P < 0.036$). A correlation between severity of hemifield constriction and % asymmetry on computed tomography was noted."
Kordestani, Patel, Bard, Gurwitch, & Panchal, 2006	110 infants	Infant	Bayley Scales of Infant Development-II	"…significantly different psychomotor development indexes and mental developmental indexes when compared with the standardized population ($p < 0.0001$; $p < 0.0001$)." "With regards to the mental developmental index scores, none of the infants with deformational plagiocephaly were accelerated, 90 percent were normal, 7 percent were mildly delayed, and 3 percent were severely delayed. With regards to the psychomotor development index scores, none of infants were accelerated, 74 percent were normal, 19 percent were mildly delayed, and 7 percent were severely delayed."
Steinbok, Lam, Singh, Mortenson, & Singhal, 2007	64 subjects	5-18.5 years old (mean age 8.9 years)	Parent completed questionnaire	"Thirty-three percent had received learning assistance, and 14% were in a special class. Long-term outcomes, as perceived by the parent or child, were no different between children with and without orthosis use."
Fowler, et al., 2008	49 infants	4-13 months (mean age 8.1 months)	Modified version of the Hammersmith infant neurologic assessment, Ages and Stages Questionnaires	"Infants with deformational plagiocephaly tended to score lower in all categories of the Ages and Stages Questionnaires." "There is a statistically significant difference in overall neurologic assessment scores of infants with deformational plagiocephaly vs their healthy peers ($P = .002$). This difference is predominately in tone, whereby infants with deformational plagiocephaly have significantly more abnormal tone than non-plagiocephalic infants ($P = .003$)."
Hutchison, Stewart, & Mitchell, 2009	287 Infants	Median age of 22 weeks	Ages and Stages Questionnaire (ASQ) Second Edition	"For 64% of the children, there were no delays on the ASQ, but one delay was seen in 17% of infants and two or more delays were seen in a further 19%; hence, 36% had one or more delays. In those with a neck dysfunction, 41% had one or more delays, compared to 29% of infants with no neck problem who had one or more delays ($p < 0.08$)" "The greatest number of delays was seen in the gross motor domain (18% of infants), followed by problem solving (17%), personal–social (15%), fine motor (14%), and communication (7%)"

Kennedy, Majnemer, Farmer, Barr, & Platt, 2009	27 infants and 27 matched controls	3-8 months old	Alberta Infant Motor Scale (AIMS) and the Peabody Developmental Motor Scales (PDMS).	"The mean percentile score on the AIMS was 31.1 ± 21.6 for infants with PP group and 42.7 ± 20.2 for infants in the comparison group, a difference that was not significant (p = .06)" "Five of the 27 infants with PP (18.5%) and one infant in the comparison group (3.7%) had scores below the 10th percentile on the AIMS." "The mean developmental motor quotient (DMQ) for the Peabody gross motor scale was 85.8 ± 9.9 for infants with PP and 88.0 ± 11.5 for infants in the comparison group, a difference that was not significant (p = .38). The mean DMQ for Peabody fine motor scale was 86.8 ± 11.4 for infants with PP and 89.3 ± 9.1 for infants in the comparison group, a difference that was not significant (p = .20)."
Speltz, et al., 2010	235 Case Subjects	4-11.7 Months (Average age of 6 months)	The Bayley Scales of Infant Development III (BSID-III)	"On average, case subjects performed worse than control subjects on all variables (*P* < .001 for all scales except the receptive language subscale, for which *P* = .010). For each of the 3 BSID-III scales, a greater proportion of case subjects than control subjects scored in the delayed range"
Hutchison, Stewart, & Mitchell, 2011	129 Children	Infancy, measured again at 3.25-4.75 years	Ages and Stages Questionnaire (ASQ)	"Of those who had both assessments, at the initial assessment [infancy] 41% had one or more delays on the ASQ and 22% had two or more delays. At follow-up only 11% of these had one or more delays and 4% had two or more delays."
Collett, et al., 2011	227 Children with deformational plagiocephaly	Infancy (mean age 7 months), measured again at 18 months	Bayley Scales of Infant and Toddler Development, Third Edition, scores.	"Children with DP scored lower than those without DP on all the BSID-III scales, with adjusted group differences of −1.6 to −3.9 raw score points on the BSID-III composite scales and −1.0 to −2.5 raw score points on the BSID-III subscales" "In categorical analyses, children with DP were 1.8 to 13.8 times as likely as those without DP to receive scores of less than 85 on the BSID-III composite scales" "children with DP and those without DP scored more similarly at time 2 than at time 1" "Toddlers with a history of DP scored lower on average than did demographically similar unaffected toddlers on all scales of the BSID-III" "Children with DP were also more likely than those without DP to score in the 'delayed' range of functioning as defined by BSID- III norms."
Collett, et al., 2012	20 Infants with deformational plagiocephaly	4-11 months	Measurements from MRI, Bayley Scales of Infant and Toddler Development-III (BSID-III)	"Infants with DP received lower scores on the cognitive and motor scales of the BSID-III than infants without DP." "BSID-III motor scores were inversely associated with several brain shape measures" "Asymmetry and flattening of brain structures were associated with worse developmental outcomes on the BSID-III."
Hutchison B. L., Stewart, de Chalain, & Mitchell, 2012	126 infants	<3-11.9months with follow up 3,6 and 12 months later	the Ages and Stages Questionnaire, Second Edition (ASQ-2)	"At the initial assessment, 30% had one or more delays. This rose to 42% at the 3-month assessment, then dropped to 33% and 23% at the 6- and 12-month assessments, respectively" "Compared with expected, over all four assessments there were marked delays in the gross motor domain"
Korpilahti, Saarinen, & Hukki, 2012	61 children (29 with deformational plagiocephaly, 32 with craniosynostosis)	3.3±0.3 years old	Speech pathologist administered Reynell Developmental Language Scales III	"25% of non- operated children with posterior plagiocephaly had severe problems in receptive language skills, showing a 10.31 times higher risk for this type of language delay when compared with the operated plagiocephalic subgroup" "risk of defective development of articulation and phonological skills … was 4.00 times higher when compared with the group of non-operated posterior plagiocephaly"

Shamji, Fric-Shamji, Merchant, & Vassilyadi, 2012	80 children	4-9 years	Parent questionnaire	"Among the 80 patients surveyed, parent-reported developmental delay occurred frequently, distributed as 21% having language difficulties, 28% having motor difficulties, and 15% requiring special education. This exceeds the population averages for developmental delay ($p < 0.01$), which occurs in 5-6% of children. The side of pathology was related to these cognitive outcomes as shown in Figure 2, with left-sided disease strongly related to the need for special education classes (27% versus 10%, $p < 0.05$) and the observations of fine motor delay (41% versus 22%, $p < 0.05$) and speech delay (36% versus 16%, $p < 0.05$). There was no difference in language comprehension among patients by side of pathology."
Collett, et al., 2013	224 children	4-11 months, reassessed at 3 years old	The Bayley Scales of Infant and Toddler Development, Third Edition (BSID-III)	"Cases scored lower on average than unaffected controls on all BSID-III composite scales. The largest differences were observed in language (adjusted difference = –4.4, 95% confidence interval [CI] = –6.8 to –2.0) and cognitive development (adjusted difference = –2.9 95% CI = –4.6 to –1.1)." "DP cases also scored lower than unaffected controls on the receptive language, expressive language, and fine motor subscales."
Knight, Anderson, Meara, & Da Costa, 2013	21 participants	5-12 months	the Bayley Scales of Infant Development, Second Edition (BSID-II)	"The mean MDI [mental development index] (mean, 97.1; SD, 7.7) of the infants with DP [deformational plagiocephaly] did not differ significantly from normative population averages ($P = 0.10$, $r = .36$). The mean PDI [psychomotor index of development] (mean, 91.0; SD, 13.2) was significantly lower than normal population estimates would predict ($P<0.01$, $r = .57$)."
Schertz, Zuk, & Green, 2013	68 infants with congenital muscular torticollis as infants	7-9 years old	Motor and cognitive outcomes at 1 year using the Alberta Infant Motor Scale and Cognitive Adaptive Test/Clinical Linguistic and Auditory Milestone Scale (CAT/CLAMS) assessment. On follow-up: the Movement Assessment Battery for Children 1st/2nd editions or the Bruininks-Oseretsky Test of Motor Proficiency, 2nd Edition–Short Form, MAASE test for language processing, and Developmental Coordination Disorder Questionnaire	"Medical assessment was performed on 37/38 (97.4%) children. Mild torticollis was found in 5 children, with 4 having left-side flexion and 1 right-side flexion. Of these 5 children, 1 was diagnosed with ADHD and another showed poor motor skills (7th percentile) on the Bruininks-Oseretsky Test of Motor Proficiency. Neurologic examinations were non-focal. Fourteen children (37.8%) (10 boys and 4 girls) were diagnosed as having ADHD based on examination at the time of the assessment, including 1 boy with epilepsy. Seven children at that time were receiving medication for ADHD, 1 developed an allergic reaction to methylphenidate, and 3 had medication recommended previously. One boy had autistic spectrum disorder and was receiving special education." "Complete results were available for 28 children tested by occupational therapists on the Bruininks-Oseretsky Test of Motor Proficiency. One child performed <5th percentile and 6 children between 5th and 15th percentiles (1 child performed at 18%) and 1 child for whom only the Visual Motor Control Subtests were administered performed below normal. Thus, 7/28 (25%) were below normal and 1 child demonstrated very low average performance." "Data on either motor test were available for 32 children, with 13/32 (40.6%) showing evidence of motor problems on clinical assessment; 5 (15.6%) of whom showed definite motor problems and 8 (25%) were at risk for significant motor problems (and a further 3 children showed very low average ability). This represents 19.1% (13/68) of the entire cohort of children with congenital muscular torticollis in this study showing movement problems and risk for developmental coordination disorder."
Cabrera-Martos I., et al., 2015	175 infants	Younger than 1 year	Assessment of motor development by physiotherapist and pediatric neurologist	"…the infants with plagiocephaly without torticollis acquired the motor skill of rolling over later than the infants with plagiocephaly and congenital torticollis. Crawling was achieved significantly earlier in the plagiocephaly and acquired torticollis profile compared with plagiocephaly without torticollis. Significant differences were also found between the infants with plagiocephaly without torticollis and the infants with plagiocephaly with congenital or acquired torticollis in standing without support."

Cabrera-Martos I., et al., 2016	46 infants	4-8 months	Motor development assessed using AIMS (Alberta Infant Motor Scale)	"It is important to mention that motor behaviour was not normal for any infant. In up to 56.52 and 47.83 % of the infants in the experimental and control groups, respectively, the motor behaviour was abnormal for their age" "…a progressive decrease in deformity level was noted in all the treated infants, indicating a lesser degree of observable deformity assessed with the Argenta scale" "Significant differences were found in the AIMS subscales with higher scores in the experimental group. However, motor behaviour was normal for all the infants at discharge"
Cabrera-Martos I., et al., 2016	52 children	3-5 years old	Pediatric Balance scale	"Balance assessment showed significant lower values ($P < 0.001$) in the plagiocephaly group" "…the results of this study show that children with previous history of non-synostotic plagiocephaly present head postural changes, muscle shortening and a poor balance when compared to control children at 3–5 years old"
Fontana, et al., 2016	27 infants	4-11 months	Bayley Scales of Infant and Toddler Development, Third Edition	"Three of 27 (11%) infants assessed using the composite language scale were delayed, and 5 of 23 (22%) were delayed on the scale measuring composite motor development, using the Bayley-III manual definition of delayed" "While motor skills were delayed more frequently than language or cognitive development, composite motor scores did not correlate with cranial deformity"

Appendix C

The initial draft was written by B.K. and C.F.

The draft was initially opened to chiropractors, including chiropractors with a special interest in paediatrics, to review the initial draft.

After this initial invite, a general invitation was sent to:

- Parents of children with plagiocephaly,
- General Medical Practitioners,
- Paediatricians,
- Paediatric Neurologists,
- Psychologists,
- Maternal and Child Health Nurses, as well as any other persons with an interest in paediatrics, chiropractic, or plagiocephaly.

An invitation to review the initial draft was also placed on the ACCP website (accp.asn.au).
All reviewers were asked to extend the invitation to review the initial draft to all contacts who may show interest in this area.

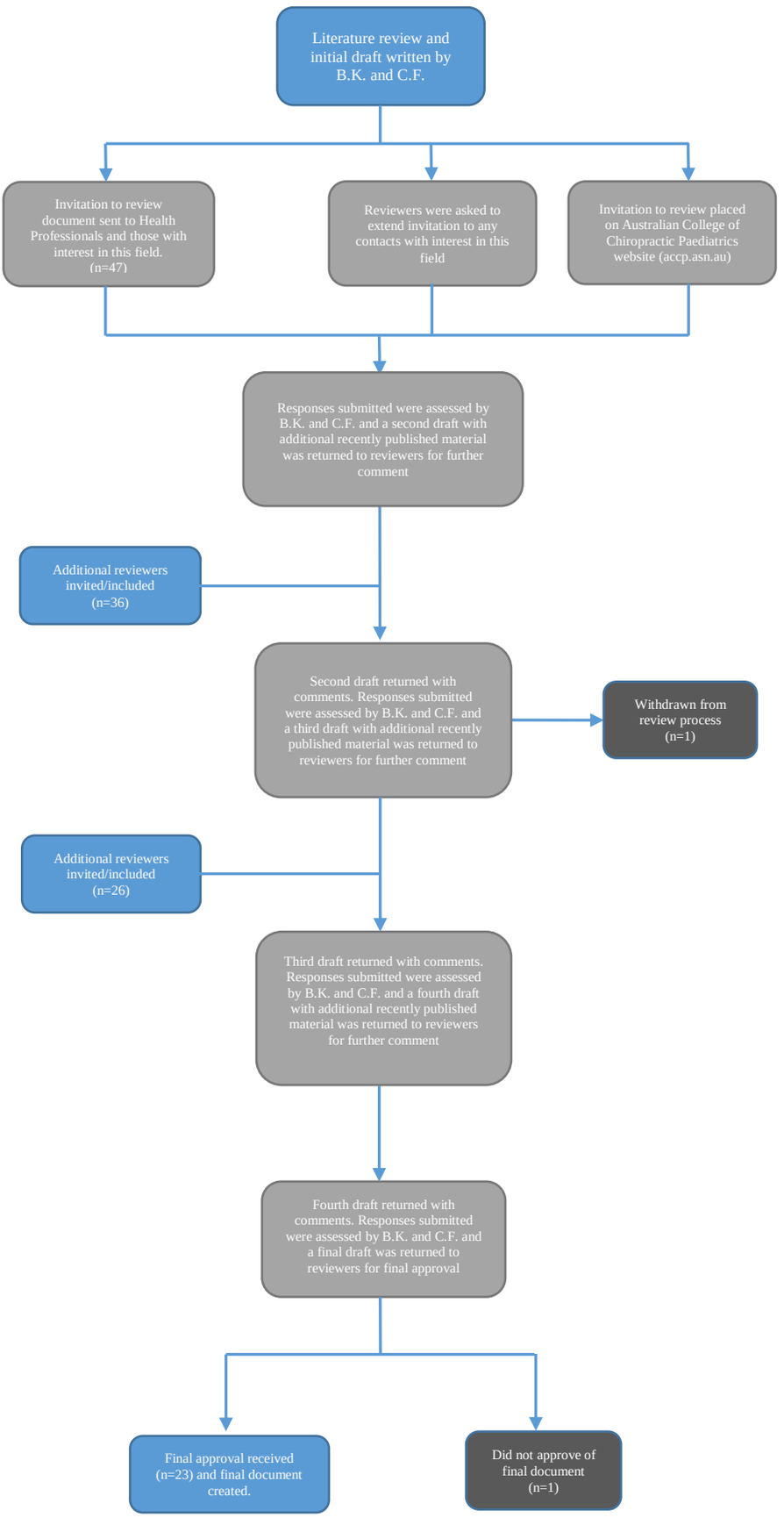
The responses submitted by the reviewers were assessed by BK and CF with agreed changes made to the initial draft.

The second draft was returned to all reviewers for comment. Additional reviewers were concurrently invited to join the review process at this stage.

Second draft was returned with comments. The responses submitted were assessed by B.K. and C.F. and a third draft with additional recently published material was returned to reviewers for further comment.

The third draft was returned to all reviewers for further comment. Additional reviewers were concurrently invited to join the review process at this stage.

The third draft was returned with comments. The responses submitted were assessed by B.K. and C.F. and a fourth draft was completed, and sent to reviewers for final approval.



Input was received by 26 reviewers. 24 reviewers responded with "Approve", 1 "Did not approve" and 1 did not respond to final approval.

Reviewers represented the following aspects of the healthcare sector:

- Chiropractic
- Chiropractors with a special interest in paediatrics
- Paediatric neurology
- Paediatrics
- Psychologist
- Maternal and Child Health
- Virology

The reviewers held the following qualifications: PhD (3), FRACP (1), PhD Candidate (1), Master (11), Bachelor (19), Diplomate of ACCP (DACCP) – a 2-year/800-hour post-graduate chiropractic paediatrics program (13).

The authors would like to acknowledge and thank the following reviewers for their contributions:

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Chiropractor
B.S., D.C., DACCP

Dr James Courtney
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