

Positional Plagiocephaly: Epidemiology, Risk Factors, Prevention, and Evidence-Based Management

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Abstract

Positional plagiocephaly (also termed deformational or non-synostotic plagiocephaly) is the most common cranial deformity of infancy, characterized by asymmetric occipital flattening secondary to prolonged external mechanical forces acting on a rapidly growing and malleable skull. Its prevalence rose markedly after the 1992 “Back to Sleep” campaign, reaching peak rates of approximately 16–22% at 6–8 weeks and 19–20% at 4 months of age, with subsequent spontaneous improvement to roughly 3–7% by 12–24 months in most cohorts. Major non-obstetric risk factors identified in a recent systematic review and meta-analysis include insufficient vitamin D intake (OR $\approx$ 7.15), preferential head positioning (OR $\approx$ 4.75), exclusive bottle-feeding (OR $\approx$ 4.65), reduced tummy time (OR $\approx$ 3.51), male sex, and delayed motor milestones. Differential diagnosis from true craniosynostosis relies primarily on clinical examination; imaging is rarely required. First-line management consists of parental education on counter-positioning, supervised prone play (“tummy time”), and pediatric physiotherapy, which demonstrably reduce the risk of severe deformity. Cranial orthoses (helmet therapy) are reserved for moderate-to-severe cases that fail to improve with conservative measures or present at older ages, offering faster early correction of asymmetry. This review synthesizes current international evidence from high-impact sources, including systematic reviews, randomized trials, and guidelines from the Congress of Neurological Surgeons (CNS) and the American Academy of Pediatrics (AAP), to support early recognition, prevention, and rational, multidisciplinary management that preserves safe-sleep recommendations while minimizing long-term craniofacial asymmetry.

Keywords: positional plagiocephaly; deformational plagiocephaly; infant; tummy time; cranial orthosis; ergonomics; preventive pediatrics

1. Introduction

Positional (deformational) plagiocephaly is defined as an acquired, non-synostotic cranial asymmetry resulting from sustained external molding forces applied to the infant skull during periods of rapid postnatal growth. Unlike true craniosynostosis, the cranial sutures remain patent and the deformity is potentially reversible with timely intervention.

The dramatic rise in prevalence followed the 1992 recommendation of the American Academy of Pediatrics that healthy infants sleep in the supine position to reduce the risk of sudden infant death syndrome (SIDS).¹⁰ While the “Back to Sleep” (later “Safe to Sleep”) campaign successfully lowered SIDS rates, it was accompanied by a several-fold increase in positional skull deformities. Contemporary prospective data indicate prevalence peaks of 16–22% at 6–8 weeks and approximately 19–20% at 4 months, declining spontaneously to 3–7% by 12–24 months of age as motor control and independent head movement improve.^[1,7]

Pathophysiologically, the infant skull is highly plastic in the first months of life. Prolonged pressure on one occipital quadrant produces progressive flattening, anterior displacement of the ipsilateral ear, and, in more severe

grades, frontal bossing and facial asymmetry (parallelogram deformity). Congenital muscular torticollis is a frequent and clinically important co-factor—present in a large proportion of infants with positional plagiocephaly—that perpetuates preferential head turning and amplifies the mechanical load; concurrent management of torticollis is therefore essential for successful correction of the cranial deformity.^[12,14]

Despite its frequency, positional plagiocephaly remains under-recognized in primary care and is sometimes incorrectly perceived as purely cosmetic. Emerging evidence suggests associations with delayed motor milestones and, in moderate-to-severe untreated cases, lower cognitive and academic scores at school age, although causality remains uncertain and the deformity may act as a marker of developmental risk.^[11] Consequently, early identification, parental education, and evidence-based conservative management constitute a public-health priority that must be balanced against the imperative of safe sleep.

2. Methodology

This narrative review with systematic elements was conducted by searching PubMed/MEDLINE, Embase, Cochrane Library, and Scopus

for publications from 1992 to 2025 using the terms “positional plagiocephaly,” “deformational plagiocephaly,” “non-synostotic plagiocephaly,” and related MeSH terms. Additional sources included guidelines from the Congress of Neurological Surgeons (CNS), American Academy of Pediatrics (AAP), Royal Children’s Hospital Melbourne, and Haute Autorité de Santé (France). Priority was given to systematic

reviews, meta-analyses, randomized controlled trials, and large prospective cohort studies. Risk factors were extracted preferentially from recent meta-analyses; diagnostic and therapeutic recommendations follow the 2016 CNS evidence-based guidelines (endorsed by the AAP) [3,4] and subsequent high-quality reviews.

Ref.	Study / Year	Design	Key contribution to this review
1	Hutchison et al., 2004	Prospective cohort	Age-dependent prevalence and natural history of plagiocephaly/brachycephaly
2	van Vlimmeren et al., 2008	RCT	Physiotherapy reduces risk of severe deformity (Level I evidence)
3	Flannery et al. (CNS), 2016	CPG / SR	Evidence-based guidelines for diagnosis and management
4	Laughlin et al. (AAP), 2011	CPG	AAP recommendations on prevention and management
5	Hillyar et al., 2024	SR + MA	Non-obstetric risk factors (vitamin D, tummy time, bottle-feeding, etc.)
6	Argenta, 2004	Clinical classification	Argenta Types I–V clinical grading system
7	Bialocerkowski et al., 2008	SR	Prevalence, risk factors and natural history synthesis
8	Steinberg et al., 2015	Comparative study	Effectiveness of conservative vs helmet therapy
9	Cabrera-Martos et al., 2016	RCT (pilot)	Manual therapy effects on duration and motor development
10	AAP Task Force, 2016	CPG	Safe-sleep recommendations (context for rise in prevalence)
11	Collett et al., 2019	Longitudinal cohort	Cognitive and academic outcomes at school age
12	Kaplan / Sargent et al., 2018	CPG (APTA)	Evidence-based management of congenital muscular torticollis
13	de Sousa et al., 2025	SR + MA	Helmet vs non-helmet short-term superiority (CVAI)
14	Kuo et al., 2014	Narrative review	Strong association between CMT and positional plagiocephaly
15	Dalla Corte et al., 2025	SR	Safety and efficacy of orthotic helmets in moderate–severe cases
16	Watt et al., 2023	Prospective validation study	Smartphone-based AI algorithm for automated diagnosis
17	Hashemi et al., 2024	SR	Predictive factors (age, severity, compliance) for helmet therapy success

Table 1: Summary of key evidence sources cited in this review

3. Results and Discussion

3.1 Epidemiology and Natural History

Point prevalence is strongly age-dependent. Representative figures from large perspective cohorts are: 16–22% at 6–8 weeks, 19–20% at 4 months, 6–9% at 8–12 months, and 3.3% at 2 years.^{1,7} Most mild cases resolve

spontaneously once the infant achieves independent head control and spends increasing time in varied postures. Positional brachycephaly (symmetric occipital flattening with increased cephalic index) frequently coexists or presents as a related phenotype and follows a similar natural history (Figure 1).

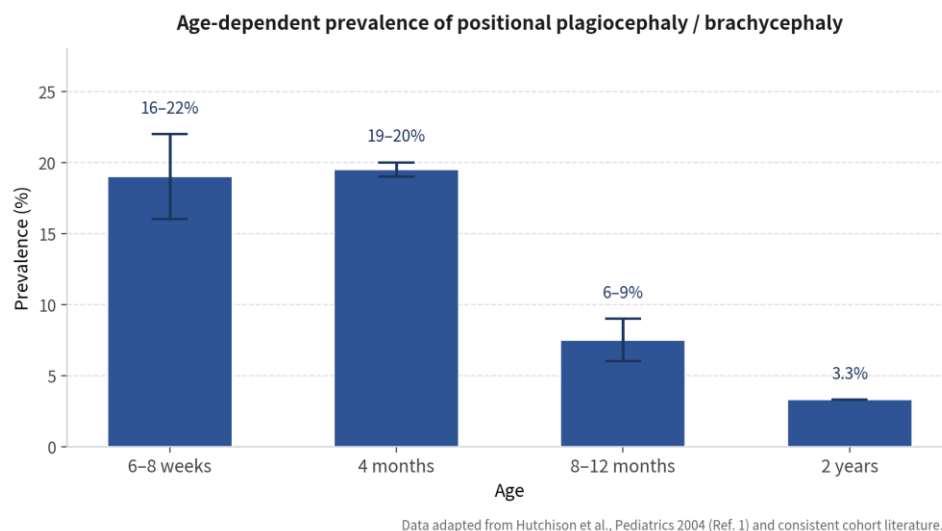


Figure 1: Age-dependent prevalence of positional plagiocephaly/brachycephaly. Vertical lines indicate reported ranges from prospective cohorts.

3.2 Risk Factors

A 2024 systematic review and meta-analysis of 19 studies (14,808 participants) identified 12 non-obstetric factors with statistically significant odds ratios. The strongest associations were insufficient vitamin D intake (OR 7.15, 95% CI 3.77–13.54), preferential head positioning (OR 4.75, 95% CI 3.36–6.73), exclusive bottle-feeding (OR

4.65, 95% CI 2.70–8.00), reduced tummy time (OR 3.51, 95% CI 1.71–7.21), and supine sleeping with limited variation. Male sex, delayed motor milestones, lower maternal education, and infant obesity also contribute. Prenatal and perinatal factors (male sex, primiparity, assisted delivery, prematurity, multiple gestation) further increase susceptibility (Figure 2).[5]

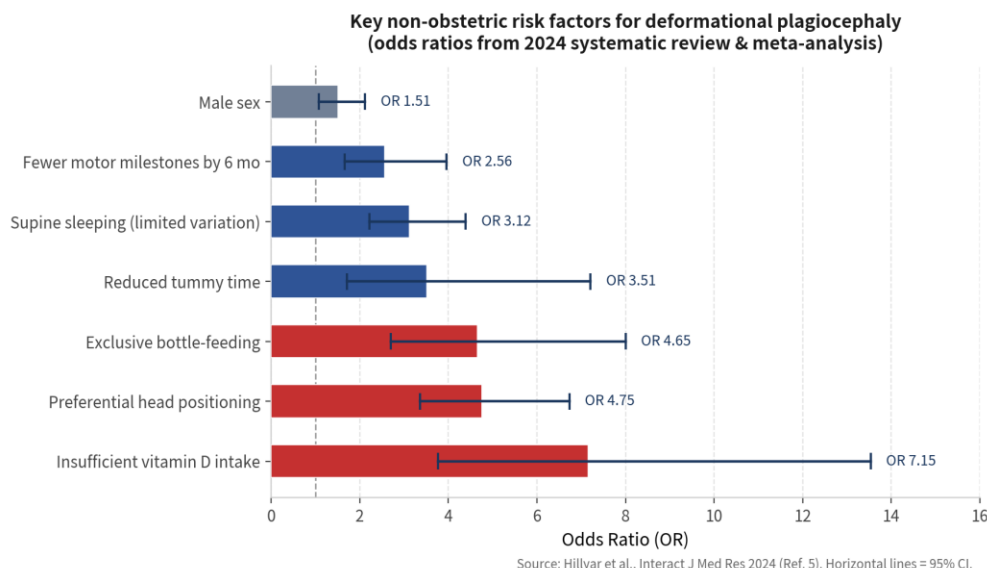


Figure 2: Selected non-obstetric risk factors with the highest odds ratios (horizontal lines = 95% confidence intervals).

3.3 Diagnosis and Classification

Diagnosis is clinical. Key features distinguishing positional plagiocephaly from lambdoid synostosis include a parallelogram (rather than trapezoid) head shape, anterior displacement of the ipsilateral ear, and absence of a palpable ridge over the suture. Imaging is rarely indicated; three-dimensional surface imaging or stereo photogrammetry may be used when clinical assessment is equivocal.

Recent advancements have explored the integration of artificial intelligence (AI) into clinical workflows to reduce the subjectivity of visual assessments. Watt et al.¹⁶ demonstrated that a smartphone-based

AI algorithm can accurately diagnose positional plagiocephaly with 85.39% accuracy, offering high sensitivity and specificity. This highly accessible technology can facilitate early screening in primary care settings, help guide specialist consultation, and enable longitudinal quantitative monitoring of the cranial shape.

Objective anthropometric measures complement clinical grading. The cranial vault asymmetry index (CVAI) and the diagonal difference (absolute difference between the longer and shorter oblique cranial diameters) are widely used in research and clinical decision-making for helmet therapy. A CVAI ≥ 3.5 –5% or a diagonal difference ≥ 6 –10 mm is

commonly considered clinically significant, although exact thresholds vary among centers.

The Argenta clinical classification (Types I–V) remains widely employed:⁶

- Type I – occipital flattening only;
- Type II – plus ipsilateral ear displacement;
- Type III – plus ipsilateral frontal bossing;
- Type IV – plus facial asymmetry;
- Type V – plus vertical cranial growth or temporal compensation.

3.4 Prevention and Conservative Management

Prevention centers on early parental counseling:

- Alternate the infant's head position during sleep while maintaining the supine position;
- Provide supervised tummy time for a cumulative 30–60 minutes daily as soon as possible after birth;
- Limit prolonged time in car seats, swings, and carriers;
- Encourage varied visual and auditory stimulation and address concurrent torticollis when present.

Randomized evidence demonstrates that structured pediatric physiotherapy initiated at approximately 7 weeks of age for infants with positional preference reduces the risk of severe deformational plagiocephaly by approximately 46% at 6 months and 57% at 12 months compared with usual care.^[2] Physiotherapy is superior to repositioning education alone (Level I recommendation, CNS guidelines).³ When congenital muscular torticollis coexists, targeted stretching, active range-of-motion exercises, and motor facilitation techniques should be integrated into the physiotherapy program, following evidence-based clinical practice guidelines for congenital muscular torticollis.^[12]

3.5 Helmet Therapy

Cranial molding orthoses are recommended (CNS Level II) for infants with persistent moderate-to-severe deformity after an adequate trial of conservative measures, or for those presenting at an advanced age (generally >6–8 months).³ Recent systematic reviews and a 2025 meta-analysis indicate faster and greater short-term improvement in cranial vault asymmetry index and related metrics with helmets compared with non-helmet approaches, although long-term superiority over conservative therapy is less clear once growth decelerates and study heterogeneity remains high.^{8,13,15} Treatment is typically initiated between 4 and 6 months and continued for 2–6 months, worn 23 hours per day. Parental adherence and timely initiation are critical determinants of success. This is strongly supported by a recent systematic review by Hashemi et al.¹⁷, which evaluated predictive factors affecting the success and duration of cranial remolding orthosis (CRO) treatment. The study confirmed that treatment success is primarily correlated with the patient's age at the initiation of treatment, the initial severity of the deformity, and parental compliance. Interestingly, factors such as gestational age and the presence of concurrent torticollis were not found to significantly limit CRO treatment success, reinforcing that early intervention and strict adherence to wearing protocols remain the absolute drivers of optimal outcomes.

3.6 Multidisciplinary Perspective and Long-term Outcomes

Optimal outcomes require collaboration among pediatricians, pediatric physiotherapists, craniofacial specialists, and, when indicated, orthotists. Parental adherence is the single most important modifiable determinant

of success. Although most mild-to-moderate cases resolve with conservative care, moderate-to-severe untreated deformity may leave residual cranial asymmetry and facial imbalance. School-aged children with a history of moderate-to-severe positional plagiocephaly have been shown to score lower on cognitive and academic measures than unaffected peers, although the association may reflect developmental risk rather than a direct causal effect of the deformity itself. ^[11] Long-term orthodontic or postural sequelae remain areas of ongoing investigation.

4. Limitations

This is a narrative review with systematic elements rather than a formal systematic review with registered protocol and exhaustive risk-of-bias assessment of every included study. Heterogeneity in diagnostic criteria, severity thresholds, and outcome measures across the literature limits direct comparison of some findings. The strongest risk-factor associations (particularly vitamin D) derive from a limited number of studies and warrant further confirmation. Finally, high-quality long-term developmental and psychosocial outcome data remain relatively sparse.

5. Conclusion

Positional plagiocephaly is a highly prevalent, largely preventable condition whose incidence rose as an unintended consequence of life-saving safe-sleep recommendations.^[1,10] Early recognition, parental education emphasizing tummy time and counter-positioning, concurrent management of torticollis when present, and timely physiotherapy constitute the evidence-based foundation of care.^[2,3,12] Helmet therapy remains a valuable second-line intervention for selected moderate-to-severe cases.^[3,13,15] Future research should focus on standardized severity metrics (including CVAI), long-term developmental and psychosocial outcomes, and implementation strategies that maximize adherence while fully preserving SIDS-prevention measures. Multidisciplinary, preventive approaches grounded in high-quality evidence offer the best prospect of minimizing residual asymmetry and supporting optimal infant development.

Declarations

Conflicts of interest: The authors declare no conflicts of interest.

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Author contributions: Both authors contributed to the conception, literature review, drafting, and critical revision of the manuscript and approved the final version.

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