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Development in Toddlers With and Without Deformational Plagiocephaly

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Abstract

Objective—To determine whether the heightened risk of developmental delays seen in infancy in patients with deformational plagiocephaly (DP) continues into the toddler years.

Design—Longitudinal study comparing the development of children with and without DP, with assessments in infancy (mean age, 7 months) and at age 18 months.

Setting—Infants with DP were recruited from a large craniofacial center, and unaffected infants were recruited from a research registry.

Participants—The study included 227 children with DP and 232 children without previously diagnosed DP.

Main Exposure—Diagnosis of DP by a craniofacial specialist.

Main Outcome Measures—Bayley Scales of Infant and Toddler Development, Third Edition, scores.

Results—Toddlers with DP scored lower than did unaffected children on all the scales of the Bayley Scales of Infant and Toddler Development, Third Edition. Motor score differences were smaller and cognitive and language score differences were greater than those observed in infancy.

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Conclusions—Toddlers with DP continue to exhibit evidence of developmental delays relative to toddlers without DP. These findings do not necessarily imply a causal relationship between DP and development because children with delays may be more likely to develop DP. Nonetheless, it seems that increased developmental surveillance is warranted in this population.

Deformational plagiocephaly (DP) refers to flattening of the infant skull secondary to external force. Although many clinicians consider DP to be an isolated cosmetic condition, accumulating evidence suggests that infants with DP are at heightened risk for developmental delays. This has been demonstrated in studies[1,2] comparing infants with DP with developmental test norms and, more recently, in studies[3–6] comparing the development of infants with DP with that of unaffected infants. In the largest study[6] to date, we studied the development of 235 infants with DP and 237 infants without previously diagnosed DP. Infants with DP scored lower than those without DP on all the scales of the Bayley Scales of Infant and Toddler Development, Third Edition (BSID-III),[7] particularly in motor development.

Published studies regarding this association have focused almost exclusively on infants younger than 12 months. Outcomes with older children are mixed. The findings from 2 retrospective studies[8,9] suggested that developmental delays persist in school-aged children. However, a more recent prospective study[10] did not reveal an increased rate of developmental delays in preschoolers with a history of DP.

In the present study, we sought to determine whether the differences observed between infants with and without DP in this sample at a mean age of 7 months (time 1) would persist to age 18 months (time 2), a point at which most toddlers are fully ambulatory and when more advanced cognitive and language skills are emerging.

METHODS

PARTICIPANTS

All the participants were enrolled after informed consent was obtained through procedures approved by the institutional review board at Seattle Children's Hospital, Seattle, Washington. This research was in full compliance with Health Insurance Portability and Accountability Act standards.

Infants With DP—Infants with DP were approached for participation at the time of their diagnosis in the Seattle Children's Hospital Craniofacial Center. Patients were eligible for participation if they had been diagnosed as having DP by a craniofacial specialist and were aged 4 to 11 months. The exclusion criteria were (1) a history of prematurity (<35 weeks' gestation); (2) diagnosis of a neurodevelopmental condition (eg, Down syndrome), a brain injury, or significant hearing or vision impairment; (3) the presence of a major malformation or 3 or more minor extracranial anomalies[11]; (4) diagnosis of craniofacial microsomia; (5) a non–English-speaking mother; (6) a history of adoption or out-of-home placement; and (7) the family planning to move out of state before project completion. We recruited 235 infants with DP between June 22, 2006, and February 9, 2009, representing 51.9% of all eligible individuals with DP. Two hundred three families (44.8%) declined to participate. Another 15 families (3.3%) consented to participate but could not be scheduled within the allotted time interval. Participants were similar to nonparticipants regarding age at diagnosis, family health insurance status (Medicaid vs private insurance or self-pay), sex, and DP severity.[6] Nonparticipants were less likely than participants to be nonwhite, non-Hispanic (23% vs 32%).[6]

Infants Without DP—Unaffected infants were eligible for participation if they had not been diagnosed as having DP or any other craniofacial condition and they did not meet any of the exclusion criteria listed for infants with DP. The first 8 infants without previously diagnosed DP were identified through pediatric practices. All the remaining infants in this group were identified from a pool of families who agreed to be contacted for research participation when their child was born. Families with a child in the target age range were contacted by telephone, and those expressing interest in the project were screened by telephone to determine eligibility. We selected infants without DP who were most similar to infants in the DP cohort in terms of age, sex, race/ethnicity, and family socioeconomic status. Two hundred thirty-seven infants without diagnosed DP were recruited between March 16, 2007, and February 18, 2009, representing 89.7% of those screened and determined eligible for participation. Twenty-seven families declined participation.

MEASURES

Severity of Cranial Deformation—Three-dimensional (3-D) cranial images were obtained for all the participants during their initial study visit (time 1) using the 3dMDcranial System (3dMD, Atlanta, Georgia) (imaging procedures are described by Speltz et al[6]). The 3-D images were deidentified, randomly sorted, and rated for severity by 2 dysmorphologists (C.L.H. and M.L.C.) who were unaware of DP status. A 4-point ordinal scale (none, mild, moderate, and severe) was used to rate the overall severity of cranial deformation. Interrater agreement for DP status (ie, presence or absence of DP) was 90% (κ = 0.80), and exact agreement for each of the 4 severity categories was 71% (weighted κ =0.72). The mean of the 2 raters' scores was used to represent the severity of each participant's cranial deformation.

The BSID-III—The BSID-III yields composite scores for cognitive, language, motor development, and parents' reports of the child's adaptive behavior. Gestational age was calculated using maternal report of due date and birth date. We corrected BSID-III scores for prematurity for children born between 35 and 37 weeks' gestation and for those born at 37 weeks' gestation but weighing less than 6 lb. The BSID-III was administered by trained infant/toddler psychometrists. To assess examiner reliability, assessments were videotaped, and approximately 10% were independently reviewed by one of us (B.R.C.). Scoring agreement on individual items was greater than 90% (κ = 0.84–0.90) for all the subscales. Mothers were asked to complete the BSIDIII adaptive development scale and to return the form by mail.

Medical and Intervention History—Semistructured interviews were completed with mothers at time 1 to document medical history and demographic characteristics. At time 2, an abbreviated interview was completed to document newly diagnosed medical conditions and to determine whether the child had received any intervention to treat DP or developmental delays.

ASSESSMENT PROCEDURES

Infants with DP were first assessed (time 1) within approximately 4 weeks of their diagnosis, at a mean age of approximately 7 months. We aimed to schedule participants' time 2 visit within 2 weeks of the child's 18-month birthday and set an upper age limit of 30 months if the child could not be seen earlier. Parents who could not participate in a full assessment completed the interview by telephone and were mailed the BSIDIII adaptive behavior scale. After testing, examiners indicated whether they considered the evaluation valid or invalid due to child behavior (eg, persistent noncompliance) or testing circumstances (eg, child illness). Invalid scores were dropped from the analyses.

DATA ANALYSES

Separately for children with and without DP, we summarized demographic characteristics by calculating means (SDs) or frequencies where applicable. To examine potential attrition bias between the time 1 and time 2 visits, we used descriptive statistics to compare these demographic characteristics and time 1 BSID-III scores for participants and nonparticipants (ie, those who were lost to follow-up or who withdrew from the study).

For analyses of group differences, we eliminated infants in the DP group who did not have discernible evidence of skull flattening or asymmetry and infants without diagnosed DP who had any posterior skull flattening or asymmetry based on their 3-D photographs at time 1. Linear regression analyses with robust standard errors were used to compare time 2 raw scores for children with DP vs unaffected children on the BSID-III cognitive, language, motor, and adaptive behavior composite scales and on subscales measuring receptive and expressive language and fine and gross motor development.

We also used general linear modeling to determine the relative risk of receiving standard scores of less than 85 on the BSIDIII composite scales for children with DP vs children without DP. We adjusted all the analyses for children's age (in months, corrected for birth at 35–37 weeks' estimated gestational age), sex, race/ethnicity (white and non-Hispanic vs nonwhite or Hispanic), and family socioeconomic status (continuous scores from the Hollingshead composite[12]). To evaluate whether time 2 group differences were affected by differences present in infancy, we refit the linear regression model of scores at the second visit, adjusting for time 1 BSID-III scores. We also tested whether these group differences were themselves different across the 2 time points by fitting an interaction term (DP status × visit). Because this analysis involved measures for individuals from 2 possible time points, we used a generalized estimating equation approach[13] with an unstructured correlation matrix, adjusting for age at each visit as a time-varying covariate.

In secondary analyses, we compared the BSID-III scores of subgroups of children with DP defined by the presence or absence of the following preceding events or conditions: (1) orthotic helmet or band treatment (further adjusted for ratings of DP severity), (2) developmental intervention, (3) torticollis, (4) neonatal intensive care, and (5) twin birth. We also compared children with mild vs moderate to severe DP. Finally, we compared time 2 BSIDIII outcomes for children without a previous diagnosis of DP who nonetheless had some degree of skull flattening or asymmetry vs those with no evidence of DP. Analyses were completed using a commercially available software program.[14]

RESULTS

Two hundred twenty-five children with DP and 230 without diagnosed DP were seen for a time 2 study visit that included administration of the BSID-III. For another 2 children with DP and 2 without DP, only parent interviews or BSID-III adaptive behavior scale data were available. Overall, partial or complete data were available for 96.6% of the original group of children with DP and for 97.9% of the original group without DP. Compared with participants, families lost to follow-up (8 children with DP and 5 without DP) had a lower socioeconomic status (69.2% Hollingshead categories III-IV compared with 28.0% among participants) and were more likely to be nonwhite or Hispanic (61.5% compared with 34.8% among participants). Participants and nonparticipants were similar in their mean time 1 BSID-III development scores and in DP severity.

Children with and without DP were predominantly male, of white race only, and of middle to upper socioeconomic status (Table 1). The mean age for both groups at time 2 was approximately 18.5 months. Based on parental report, children with DP were more likely

than those without DP to have a history of suspected or confirmed torticollis, to be a twin, or to have received care in the neonatal intensive care unit. Between time 1 and time 2, there were 80 children with DP (35.2%) who received orthotic helmet or band therapy. Eighty-four children with DP(37.0%) and 14 unaffected children (6.0%) participated in some form of developmental intervention, with the most common services being physical or occupational therapy. Finally, there were 2 children in the DP group (0.9%) with no discernible DP on 3-D imaging, 103 (45.4%) with mild DP, and 122 (53.7%) with moderate to severe DP. Of the children without previously diagnosed DP, 163 (70.3%) had no discernible DP, 67 (28.9%) had mild DP, and 2 (0.9%) had moderate to severe DP.

After enrollment in the study and completion of their time 1 visit, 7 children with DP and 2 without DP were diagnosed as having other medical conditions that could affect neurodevelopmental status. Specific diagnoses were a Chiari malformation in 2 children with DP and 1 child without previously diagnosed DP, cytogenetic anomalies in 3 participants with DP, neurofibromatosis type 1 in 1 child without previously diagnosed DP, an unspecified mitochondrial disorder in 1 child with DP, and cerebral palsy in 1 child with DP. (Both of the infants without previously diagnosed DP who were excluded due to significant medical conditions were also found to have discernible DP based on physician ratings of their 3-D cranial images at time 1.) Data for these participants were not included in group comparisons. We also excluded 69 children in the previously undiagnosed group whose clinician ratings of their 3-D cranial images at time 1 in infancy indicated some level of DP and 2 children in the DP group who had no discernible evidence of DP based on the same ratings. Examiners rated 1 or more scales of the BSID-III as invalid for 3 children with DP at time 1 and 3 with DP at time 2; these data were excluded from the analyses.

COMPARISON OF 18-MONTH DEVELOPMENTAL OUTCOMES IN CHILDREN WITH VS WITHOUT DP

For both groups, children's mean scores were close to test norm averages on all BSID-III composite scales and subscales (Table 2). 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 (Table 3). When further controlled for time 1 BSID-III outcome scores, the mean estimated differences at time 2 were only slightly reduced. 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 (Table 4).

Group differences at time 2 were larger than those observed at time 1 for most BSID-III scales. The gross motor scale was a notable exception: on average, children with DP and those without DP scored more similarly at time 2 than at time 1. Group differences on the composite motor scale and the fine motor and expressive language subscales were similar across time points.

SUBGROUP ANALYSES

After adjusting for DP severity, the presence or absence of orthotic treatment had little effect on BSID-III outcomes. Children with DP who participated in developmental interventions had slightly lower language, motor, and adaptive behavior scores than did those with no developmental treatment, as did children with moderate or severe DP vs mild DP. Other subgroup differences based on history of torticollis, twin birth, or neonatal intensive care unit stay were small or inconsistent across outcomes. Comparing children without previously diagnosed DP whose physician ratings confirmed the absence of DP vs those for whom the same ratings indicated at least mild posterior skull asymmetry, children in the latter subgroup received lower scores on all the BSID-III scales (adjusted differences of 2.2

to −3.7 raw score points on the composite scales and −0.3 to −0.9 raw score points on the BSID-III subscales).

COMMENT

Toddlers with a history of DP scored lower on average than did demographically similar unaffected toddlers on all scales of the BSID-III. The magnitude of these differences was clinically significant, ranging from one-third to two-thirds of a standard deviation. 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. Adjustment for time 1 BSID-III scores reduced group differences at time 2 only slightly, possibly due to instability in scores in the 2 assessments. Group differences in motor development were slightly attenuated in relation to those observed during the infancy assessment, [6] whereas differences on the other scales increased over time. Several investigators have theorized, with some supporting evidence, that early motor delays predict later problems in other areas of development. This might be due to either a shared biological substrate for these skills (eg, aberrant development of cerebellocerebral pathways affecting motor, speech, and cognitive development[15,16]) or opportunities for development that are missed when motor skills do not advance as expected.[17]

Thirty-seven percent of children with DP and 6.0% of children without previously diagnosed DP participated in some form of developmental intervention between times 1 and 2, such as physical or occupational therapy or speech-language therapy. Note that 6 of the 14 children in the non-DP group who participated in developmental interventions also had previously undiagnosed DP. As part of this study, parents had the option to receive feedback about their child’s performance on the BSID-III at both time points and to have a summary of the results sent to the child’s pediatrician. When a child’s development was delayed, we recommended follow-up with his or her pediatrician to determine the need for further assessment or intervention. Although this may have inflated the rate of services received, we used the same follow-up and recommendation criteria for families in both groups, making it unlikely that this would account for their disparity in service use. The small number of unaffected toddlers who received developmental services precluded a separate analysis of the potential interaction between DP status and intervention group (ie, whether the presence of DP affected children’s response to treatment).

Despite the group differences observed, most children scored within the typical range of normative BSID-III test scores regardless of their DP status. Moreover, few children in either group scored below the clinical threshold for developmental delay. These findings likely reflect the relatively high sociodemographic status of the sample (ie, most families were of middle to upper class) and the exclusion of infants with known medical risks (eg, those with identified neurodevelopmental conditions and those delivered at <35 weeks’ gestational age). There is also recent evidence suggesting that the BSID-III underestimates developmental delay in toddlers.[18] Both concerns underscore the methodological hazards of relying on test norms alone to estimate the relative status of children with DP rather than comparing them directly with unaffected children, as we have done herein.

As emphasized previously,[6] it should not be assumed on the basis of these results that DP causes developmental delays. Although we cannot rule out this possibility, it is equally or perhaps more plausible that developmental delays precede DP. For example, subtle neuromuscular problems may restrict infant movement, elevating the risk of skull deformation. Ultimately, DP may serve as an efficient biological marker of elevated developmental risk, evident long before other indications emerge that prompt clinicians to undertake developmental screening.

These results should be interpreted in light of a few potential limitations. Because we did not use population-based sampling, ascertainment bias may have affected both groups. Among children with DP, those referred to a tertiary care center may differ from nonreferred children in several respects. For example, community providers may be more likely to refer a child for an evaluation of DP if they also have concerns about his or her development. However, consistent with observations from infancy assessments, [6] toddlers without previously diagnosed DP who nonetheless had some posterior cranial flattening or asymmetry received lower BSID-III scores on average than did unaffected children. This suggests that referral or ascertainment biases in the DP group do not fully account for the association between DP and developmental outcome. Bias may have also affected the group of children without diagnosed DP because we recruited these participants using a registry of families who agreed to be contacted for research participation at the time of their child's birth. Although children in this group were demographically well matched to the DP group, parents in this registry may differ from others in ways that are not easily measured (eg, by intellectual curiosity or value placed on research or community involvement) that may also be reflected in a child's development. Further study using population-based ascertainment of infants with and without DP is needed to eliminate these potential biases. Finally, development is highly variable in early childhood, and it is essential that we determine whether developmental disparities in children with and without DP persist over time. We hope to observe this sample to school entry, enabling us to complete a more extensive neuropsychological assessment and to learn whether early developmental differences portend later difficulties in academic achievement and related outcomes.

In conclusion, toddlers with and without DP in this study continued to score within the average range of the BSID-III test norms. However, relative to demographically similar children without DP, those with DP showed evidence of developmental disadvantage that persisted from infancy to the toddler years. Delays in motor development, which were particularly evident in infancy, were slightly attenuated, whereas differences in cognitive and language skills were as large or larger than those observed in the same children in infancy. The ongoing study with this sample will clarify the long-term outcomes for children with and without DP. We continue to recommend close developmental surveillance of young children with DP.

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REFERENCES

1. Kordestani RK, Panchal J. Neurodevelopment delays in children with deformational plagiocephaly. Plast Reconstr Surg. 2006; 118(3):808–810. [PubMed: 16932202]
2. Panchal J, Amirsheybani H, Gurwitch R, et al. Neurodevelopment in children with single-suture craniosynostosis and plagiocephaly without synostosis. Plast Reconstr Surg. 2001; 108(6):1492–1500. [PubMed: 11711916]
3. Fowler EA, Becker DB, Pilgram TK, Noetzel M, Epstein J, Kane AA. Neurologic findings in infants with deformational plagiocephaly. J Child Neurol. 2008; 23(7):742–747. [PubMed: 18344457]
4. Hutchison BL, Stewart AW, Mitchell EA. Characteristics, head shape measurements and developmental delay in 287 consecutive infants attending a plagiocephaly clinic. Acta Paediatr. 2009; 98(9):1494–1499. [PubMed: 19548915]
5. Kennedy E, Majnemer A, Farmer JP, Barr RG, Platt RW. Motor development of infants with positional plagiocephaly. Phys Occup Ther Pediatr. 2009; 29(3):222–235. [PubMed: 19842852]

6. Speltz ML, Collett BR, Stott-Miller M, et al. Case-control study of neurodevelopment in deformational plagiocephaly. Pediatrics. 2010; 125(3):e537–e542. http://pediatrics.aappublications.org/cgi/content/full/125/3/e537. [PubMed: 20156894]
7. Bayley, N., et al. Manual for the Bayley Scales of Infant and Toddler Development. 3rd ed.. San Antonio, TX: Psychological Corp; 2006.
8. Miller RI, Clarren SK. Long-term developmental outcomes in patients with deformational plagiocephaly. Pediatrics. 2000; 105(2):E26. http://pediatrics.aappublications.org/cgi/content/full/105/2/e26. [PubMed: 10654986]
9. Steinbok P, Lam D, Singh S, Mortenson PA, Singhal A. Long-term outcome of infants with positional occipital plagiocephaly. Childs Nerv Syst. 2007; 23(11):1275–1283. [PubMed: 17551743]
10. Hutchison BL, Stewart AW, Mitchell EA. Deformational plagiocephaly: a follow-up of head shape, parental concern and neurodevelopment at ages 3 and 4 years. Arch Dis Child. 2011; 96(1): 85–90. [PubMed: 20880942]
11. Leppig KA, Werler MM, Cann CI, Cook CA, Holmes LB. Predictive value of minor anomalies, I: association with major malformations. J Pediatr. 1987; 110(4):531–537. [PubMed: 3559800]
12. Hollingshead, AB. Four Factor Index of Social Status. New Haven, CT: Yale University; 1975.
13. Liang KY, Zeger S. Longitudinal data analysis using generalized linear models. Biometrika. 1986; 73:13–22.
14. StataCorp. College Station, TX: StataCorp LP; 2007. STATA SE, Release 10.0.
15. Diamond A. Close interrelation of motor development and cognitive development and of the cerebellum and prefrontal cortex. Child Dev. 2000; 71(1):44–56. [PubMed: 10836557]
16. Gaysina D, Maughan B, Richards M. Association of reading problems with speech and motor development: results from a British 1946 birth cohort. Dev Med Child Neurol. 2010; 52(7):680–681. [PubMed: 20345953]
17. Iverson JM. Developing language in a developing body: the relationship between motor development and language development. J Child Lang. 2010; 37(2):229–261. [PubMed: 20096145]
18. Anderson PJ, De Luca CR, Hutchinson E, Roberts G, Doyle LW. Victorian Infant Collaborative Group. Underestimation of developmental delay by the new Bayley-III Scale. Arch Pediatr Adolesc Med. 2010; 164(4):352–356. [PubMed: 20368488]

Table 1

Distribution of Demographic and Clinical Characteristics of Young Children With and Without DP[a]

Characteristic	Children With DP (n=227)	Children Without DP (n=232)
Sex, No. (%)		
Male	148 (65.2)	138 (59.5)
Female	79 (34.8)	94 (40.5)
Age, mean (SD) [range], mo	18.6 (0.9) [17.3–23.3]	18.4 (0.8) [17.3–24.7]
Race/ethnicity, No. (%)		
White	155 (68.3)	144 (62.1)
Asian/Pacific Islander	13 (5.7)	12 (5.2)
Black/African American	0	6 (2.6)
Hispanic/Latino	25 (11.0)	29 (12.5)
Mixed/other	34 (15.0)	41 (17.7)
Familial socioeconomic status		
Mean (SD)	47.4 (12.4)	45.6 (12.5)
No. (%)		
I (high)	82 (36.1)	60 (25.9)
II	88 (38.8)	100 (43.1)
III	35 (15.4)	47 (20.3)
IV	16 (7.0)	20 (8.6)
V (low)	6 (2.6)	5 (2.2)
Torticollis, No. (%)		
Suspected	9 (4.0)	3 (1.3)
Confirmed	90 (39.6)	2 (0.9)
None	128 (56.4)	227 (97.8)
Twin, No. (%)		
Yes	27 (11.9)	2 (0.9)
No	200 (88.1)	230 (99.1)
Neonatal intensive care unit placement, No. (%)		
Yes	27 (11.9)	12 (5.2)
No	200 (88.1)	219 (94.4)
Missing	0	1 (0.4)
Orthotic helmet or band therapy, No. (%)		
Yes	80 (35.2)	0
No	147 (64.8)	232 (100)
Developmental interventions, No. (%)		
Physical or occupational therapy	77 (33.9)	6 (2.6)
Speech-language therapy	9 (4.0)	1 (0.4)
Birth-to-3 monitoring	8 (3.5)	6 (2.6)
Other	19 (8.4)	6 (2.6)
Any developmental interventions	84 (37.0)	14 (6.0)

Characteristic	Children With DP (n=227)	Children Without DP (n=232)
DP severity, No. (%)		
None	2 (0.9)	163 (70.3)
Mild	103 (45.4)	67 (28.9)
Moderate to severe	122 (53.7)	2 (0.9)

Abbreviation: DP, deformational plagiocephaly.

[a] Percentages may not sum to 100 because of rounding.

Table 2

Standardized Scores[a] on the BSID-III for Children With and Without DP[b]

BSID-III Domain	BSID-III Score, Mean (SD)	
	Children With DP (n=216)	Children Without DP (n=162)
Cognitive[c]	98.8 (11.9)	105.1 (11.10)
Language[c]	98.6 (15.7)	106.2 (14.6)
Receptive language	9.7 (3.4)	11.6 (3.2)
Expressive language	9.7 (2.6)	10.5 (2.5)
Motor[c]	98.4 (9.9)	103.9 (9.7)
Fine motor	10.4 (2.2)	11.4 (2.1)
Gross motor	9.0 (1.8)	9.8 (1.9)
Adaptive behavior[d]	97.4 (13.3)	101.2 (12.4)

Abbreviations: BSID-III, Bayley Scales of Infant and Toddler Development, Third Edition; DP, deformational plagiocephaly.

[a]Standardized scores for the cognitive, language, motor, and adaptive behavior composite scales have a normative mean (SD) of 100 (15). Scaled scores for the receptive language, expressive language, fine motor, and gross motor subscales have a normative mean (SD) of 10 (3).

[b]Data were excluded for 2 children in the DP group who did not have evidence of DP based on physician ratings of 3-dimensional head photographs and 69 children in the non-DP group who had mild or greater posterior skull flattening or asymmetry. Data were also excluded for 7 children with DP and 2 without DP who were diagnosed as having medical conditions with developmental implications after study enrollment.

[c]Scores rated as invalid by the examiner were excluded from analyses. At time 2, cognitive scores were rated as invalid for 1 child with DP, language scores for 2 children with DP, and motor scores for 2 children with DP.

[d]Adaptive behavior data were missing for 23 children with DP and 13 without DP at time 2. Another 2 children with DP and 2 without DP were not seen for a clinic assessment, and only parent-reported adaptive behavior data were available.

Table 3

Adjusted[a] Group Differences in BSID-III Raw Scores for Children With and Without DP[b]

BSID-III Domain	Adjusted Group Differences in Raw Scores (95% CI)
Time 2 differences	
Cognitive[c]	−2.6 (−3.4 to −1.7)
Language[c]	−3.9 (−5.3 to −2.5)
Receptive language	−2.5 (−3.4 to −1.7)
Expressive language	−1.4 (−2.2 to −0.5)
Motor[c]	−2.3 (−3.2 to −1.5)
Fine motor	−1.0 (−1.5 to −0.6)
Gross motor	−1.3 (−1.9 to −0.7)
Adaptive behavior[d]	−1.6 (−2.7 to −0.4)
Time 2 differences adjusted for time 1 scores	
Cognitive[c]	−2.5 (−3.4 to −1.7)
Language[c]	−3.7 (−5.2 to −2.3)
Receptive language	−2.5 (−3.3 to −1.7)
Expressive language	−1.3 (−2.1 to −0.4)
Motor[c]	−2.3 (−3.2 to −1.4)
Fine motor	−1.1 (−1.6 to −0.6)
Gross motor	−1.2 (−1.8 to −0.6)
Adaptive behavior[d]	−1.7 (−2.8 to −0.6)

Abbreviations: BSID-III, Bayley Scales of Infant and Toddler Development, Third Edition; CI, confidence interval; DP, deformational plagiocephaly.

[a]Adjusted for child age (in months, adjusted for prematurity), sex, socioeconomic status (Hollingshead total, measured continuously), and ethnicity (white, non-Hispanic vs nonwhite or Hispanic).

[b]Data were excluded for 2 children in the DP group who did not have evidence of DP based on physician ratings of 3-dimensional head photographs and 69 children in the non-DP group who had mild or greater posterior skull flattening or asymmetry. Data were also excluded for 7 children with DP and 2 without DP who were diagnosed as having medical conditions with developmental implications after study enrollment.

[c]Scores rated as invalid by the examiner were excluded from analyses. Cognitive scores were rated as invalid for 1 child with DP at time 1 and 1 child with DP at time 2, language scores were rated as invalid for 1 child with DP at time 1 and 2 children with DP at time 2, and motor scores were rated as invalid for 1 child with DP at time 1 and 2 children without DP at time 2.

[d]Parent-reported adaptive behavior data were missing for 19 children with DP and 2 unaffected children at time 1 and for 23 children with DP and 13 unaffected children at time 2. Another 2 children with DP and 2 without DP were not seen for a clinic assessment, and only parent-reported adaptive behavior data were available.

Table 4

Proportion of Infants With and Without DP[a] Scoring in the "Delayed" Range (Standard Score <85) Relative to BSID-III Norms

BSID-III Domain	Delayed (Standard Score <85), %		Adjusted Relative Risk (95% CI)[b]
	Children With DP	Children Without DP	
Time 2 differences			
Cognitive[c]	8.3	0.6	13.8 (1.8–105.5)
Language[c]	18.5	6.1	3.9 (1.6–6.2)
Motor[c]	6.0	1.8	3.2 (1.1–13.1)
Adaptive behavior[d]	11.0	6.1	1.8 (0.9–3.8)

Abbreviations: See Table 3.

[a] Standard scores for the cognitive, language, motor, and adaptive behavior composite scales have a normative mean (SD) of 100 (15). Scaled scores for the receptive language, expressive language, fine motor, and gross motor subscales have a normative mean (SD) of 10 (3).

[b] Data were dropped for 2 children in the DP group who did not have evidence of DP based on physician ratings of 3-dimensional head photographs and 69 children in the non-DP group who had mild or greater posterior skull flattening or asymmetry. Data were also excluded for 7 children with DP and 2 without DP who were diagnosed as having medical conditions with developmental implications after study enrollment.

[c] Scores rated as invalid by the examiner were excluded from analyses. At time 2, cognitive scores were rated as invalid for 1 child with DP, language scores were rated as invalid for 2 children with DP, and motor scores were rated as invalid for 2 children with DP.

[d] Adaptive behavior data were missing for 23 children with DP and 13 without DP at time 2. Another 2 children with DP and 2 without DP were not seen for a clinic assessment, and only parent-reported adaptive behavior data were available.