Cognitive and Language Development in Young Children with Plagiocephaly

Vidhya Krishnamurthy

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Cognitive and Language Development in Young Children with Plagiocephaly

by

Vidhya Krishnamurthy

A dissertation submitted in partial satisfaction of the requirement for the degree of Doctor of Philosophy in Clinical Psychology

September 2008
Each person whose signature appears below certifies that this dissertation in his/her opinion is adequate, in scope and quality, as a dissertation for the degree Doctor of Philosophy.

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DEDICATION

I would like to dedicate this dissertation to my family, who have been a source of inspiration, support, and guidance throughout my life.
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ABSTRACT OF DISSERTATION

Cognitive and Language Development in Young Children with Plagiocephaly

By

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Doctor of Philosophy, Graduate Program in Clinical Psychology
Loma Linda University, September 2008
Dr. Kiti Freier Randall, Chairperson

Deformational plagiocephaly is a craniofacial condition where the occipital region of an infant’s skull becomes flattened as a result of prenatal or external factors. It is considered to be a primarily cosmetic condition that has no significant long term consequences. A few recent studies, however, have begun to suggest that children with deformational plagiocephaly may exhibit developmental delays or deficits. The purpose of this study was to examine the cognitive and language functioning of preschool age children who had been diagnosed with deformational plagiocephaly. Further, the study hoped to understand the relationship between developmental functioning in infancy and cognitive and language functioning during the preschool years in this population as well as the relationship between severity of plagiocephaly and later cognitive development.

The participants of the study were patients of the Loma Linda University Children’s Hospital Craniofacial Team Center, where the children had obtained care for their diagnosis of deformational plagiocephaly. Twelve children (7 males and 5 females) between the ages of 3 and 5 years whose ethnic composition was primarily Caucasian and Latino participated in the study. On the WPPSI-III, the mean cognitive composites of the study participants were all in the Average range. Z-tests also revealed that there were no significant discrepancies between the cognitive composites scores of study participants and the instruments normative sample, however, 58% of the participants had significant
VIQ-PIQ discrepancies. On the TELD-3, the mean language scores for the study sample were in the Average range. Further analyses revealed that early functioning was not associated with performance on verbal and language tasks during the preschool years, but is associated with performance on certain nonverbal tasks. Finally strong, but non-significant, relationships were found only between severity of cranial asymmetry and VIQ.

In conclusion, children with deformational plagiocephaly were found to be on par with same age peers in terms of their cognitive and language functioning during the preschool years. However, some concerns were raised in terms of their long-term development and future academic functioning as significant VIQ-PIQ discrepancies have been associated with academic learning disabilities as well as nonverbal learning disorders in other populations. This suggests that additional research, examining their academic and neuropsychological functioning, is necessary.
Introduction

Children come into this world with a very limited set of skills (Miller, 2002). They have the ability to make their immediate needs known to their caregiver and they can stimulate the caregiver to respond to their needs from birth, but beyond this all others are noted to emerge over time through the interaction between innate ability and external stimulation (Hoff, 2001; Richardson, 1998). How children acquire cognitive competence has been the subject of a great deal of research and has resulted in the development of many theories to explain the course of development.

While the majority of children progress through the normal course of development and acquire cognitive and language competence, there is a significant percentage of children who show deficits or delays in various domains. For example, children with craniofacial anomalies are noted to be at higher risk for exhibiting deficits in both cognitive and language functioning (Neiman & Savage, 1997; Jocelyn, Penko, & Rode, 1996). More specifically, with sharp increases in diagnosis in the past few years, deformational plagiocephaly, a craniofacial condition where an infant’s cranium becomes flattened in the occipital region due to constraints and gravity, has recently gained much attention. A few studies have examined the consequences of this condition on cognitive and language development, and these studies have suggested that children with plagiocephaly are similar to children with other craniofacial conditions in that they are at risk for deficits and delays in these areas (Habal, Leimkuehler, Chambers, Scheuerle, & Guilford, 2003; Miller & Clarren, 2000; Panchal, Amirsheybani, Gurwitch, Cook, Francel, Neas, & Levine, 2010). Outcomes associated with deformational plagiocephaly is quite small and the majority have only used informal assessments methods, it has been
difficult to derive clear conclusions have been drawn regarding the association between deformational plagiocephaly and cognitive and language development. Further, the studies that have used formal objective methods to assess cognitive development in children with deformational plagiocephaly have limited the age range of participants to infancy, and as such there is no information available regarding long-term developmental outcomes in this population (Kordestani, Patel, Bard, Gurwitch, & Panchal, 2005; Panchal et al., 2001). The purpose of the current study is to assess the long-term cognitive and language development of children diagnosed with deformational plagiocephaly.

**Plagiocephaly**

Plagiocephaly, a general term used to indicate cranial deformity, is derived from the Greek word roots “plagios”, meaning oblique, and “kephale”, meaning head (Peitsch, Keefer, LaBrie, & Mulliken, 2002; Teichgraeber, Ault, Baumgartner, Waller, Messersmith, Gateno, et. al., 2002). Traditionally, plagiocephaly had been associated with the cranial asymmetry caused by premature closure of one of the sutures in the cranium, or craniosynostosis, though it was noted that cranial asymmetry could occur without synostosis as well. Health care providers used the terms deformational plagiocephaly, or plagiocephaly without synostosis, and malformational plagiocephaly, or plagiocephaly with synostosis, to distinguish between the two conditions. However, since 1992 with increasing numbers being diagnosed, the general term plagiocephaly has come to refer to the plagiocephaly without synostosis condition almost exclusively. In this study, the term the traditional term “deformational plagiocephaly” will be utilized to
when discussed nonsynstotic plagiocephaly and the term “craniosynostosis” will be used when discussing synstotic plagiocephaly.

An infant is diagnosed with deformational plagiocephaly when he shows evidence of significant flattening in any part of the skull (Argenta, 2004; Peitsch, Keefer, LaBrie, & Mulliken, 2002). While plagiocephaly is primarily associated with flattening of the back cranium in the occipital region, literature indicates that other parts of cranium, including the frontal regions, can become flattened as well. Researchers indicate that there is a classic set of features associated with this condition (Argenta, 2004; Biggs, 2003; Kabbani & Raghuveer, 2004). In addition to flattening on the back of skull (generally on the right side), there is also appears to be bossing on the contralateral occipital region, ear position asymmetry, protrudence of forehead on the ipsilateral side, and facial asymmetry. Further, deformational plagiocephaly tends to be associated with sternocleidomastoid problems, such as torticollis, though it is not clear whether these problems are secondary to plagiocephaly or vice versa (Loveday & de Chalain, 2001; Peitsch, Keefer, LaBrie, & Mulliken, 2002; Persing, 2003). Parents and health care providers reportedly notice the flattening associated with plagiocephaly, if present, by the time the infant is around 2 months old, and a diagnosis of deformational plagiocephaly tends to be made by the time the child is 6 months old.

The severity of deformation plagiocephaly is thought to vary from mild, almost unnoticeable asymmetry, to severe asymmetry (Argenta, 2004; Mitchell & Hutchinson, 2003). In the least severe type of the condition, the deformity is classified as being limited to the back of the cranium. As the condition becomes more severe, other features associated with plagiocephaly, such as the displacement of the ear and frontal bossing,
become visible. In the most severe form of the condition, the brain does not have room to grow, and as a result begins decompressing causing abnormal growth of the posterior cranium. Although the range in severity has been noted in the literature, many health care providers still appear to believe that the condition is primarily cosmetic (American Academy of Pediatrics, 1996; Bridges, Chambers, & Pople, 2002; Wall, 2002).

**Pathogenesis of Plagiocephaly**

Many studies have implicated supine sleeping as a cause of plagiocephaly (Biggs, 2003; Hutchinson, Thompson, & Mitchell, 2003; Peitsch, Keefer, LaBrie, & Mulliken, 2002). In 1992, American Academy Pediatrics (AAP) recommended that all children be placed in a supine position for sleep rather than a prone position to prevent Sudden Infant Death Syndrome (SIDS). Researchers claim that the rates of prone sleeping decreased as a result of this recommendation as did the rates of SIDS (American Academy of Pediatrics, 1996; Peitsch et al., 2002). However, a consequence of the recommendation has been the significant increase in the number of children diagnosed with deformational plagiocephaly. In fact, some health care providers speculate that there has been 3 to 6 fold increase in the number of children diagnosed with plagiocephaly since 1992 (Biggs, 2003; Loveday & de Chalain, 2001). Prior to AAPs recommendation, the prevalence of deformational plagiocephaly was noted to be approximately 1 in 300 live births (Rekate, 1998). Since 1992, however, research indicates that the prevalence rates have ranged from 5 (1 in 20 births) to 48% (almost 1 in 2 live births) of infants (Collett, Breiger, King, Cunningham, & Speltz, 2005; Najarian, 1999; Steinbok, Lam, Singh, Mortenson, & Singhal, 2007). Interestingly, none of these studies have examined the prevalence of
deformational plagiocephaly based on severity. The parents, of children diagnosed with deformational plagiocephaly generally seem to believe that their infant’s skull was round at birth and that the flattening occurred postnatally due to being repeatedly placed in the same position on their back to sleep, supporting the claim that supine sleeping is the cause of plagiocephaly (Peitsch et al, 2002).

Other researchers claim that while supine sleeping probably plays a part, the development of deformational plagiocephaly likely begins prenatally as the result of intrauterine constraint (Bridges, Chambers, & Pople, 2002; Loveday & de Chalain, 2001; Peitsch, Keefer, LaBrie, & Mulliken, 2002). These researchers explain that when a fetus is constrained within the uterus, it does not have much room to move and as result remains in the same position for prolonged periods of time, which has negative consequences. Bridges et al. (2002) claim that when a fetus is in a vertex position within the uterus and constrained, the left side anterior cranium becomes compressed by the maternal pubic bone and the right side posterior cranium by the lumbosacral spine, limiting growth in these areas. Many factors have been noted to cause intrauterine constraint including a large fetus size, small uterus, insufficient amniotic fluid, uterine abnormalities, and multiple gestations (Hutchinson, Thompson, & Mitchell, 2003; Littlefield, Kelly, Pomatto, & Beals, 1999)

This position, that deformational plagiocephaly is the result of intrauterine constraint, has resulted in researchers suggesting that infants who develop plagiocephaly are actually born with signs of cranial flattening that are not detected by the health care providers (Peitsch et al., 2002). They state that supine sleeping merely exacerbates the condition as infants tend to sleep on the flattened sections as it is their “position of
comfort”, further increasing the flatness (p.73). In fact, a study by Peitsch et al (2002) found that a significant portion of infants (13%) who were examined 24 to 72 hours after birth exhibited signs of cranial flattening. In addition, approximately 50% of them also had auricular deformations.

Some researchers have also noted that the bone composition in the cranium of children with plagiocephaly is different from that of children without plagiocephaly. Wall (2002) reported that there is a significantly higher incidence of wormian bones in the cranium of children with plagiocephaly (54%) than in children without the condition (17%). Wormian bones are small irregular plates of bones interposed in the sutures between the large bones of the cranium, making the cranium more malleable to external forces, such as intrauterine constraint or gravity when sleeping in a supine position. Habal, Leimkuehler, Chambers, Scheuerule, and Guilford (2003) reported that cranial bone densities are lower in children with plagiocephaly, which is also noted to cause the cranium to be more malleable to external forces.

Risk Factors

Research suggests that there are several risk factors that predispose an infant to developing deformational plagiocephaly. One risk factor is being born male, as male infants are twice as likely as females to develop deformational plagiocephaly (Bridges, Chambers, & Pople, 2002; Hutchinson, Thompson, & Mitchell, 2003). Bridges et al (2002) claim that that male infants are at greater risk because they tend to be larger and less flexible than females in the uterus. Twins are also at greater risk for deformational plagiocephaly, because they do not have enough room to change positions and are often
pressing against each other (Littlefield, Kelly, Pomatto, & Beals, 2002). Prematurity is noted to be a risk factor for developing plagiocephaly as well (Hutchinson et al, 2003; Najarian, 1999). Najarian states that in general the cranium of newborn tends to be very soft and malleable, the reason it is impacted by gravity and constraint, with the cranium of premature infants being even softer than those of the full term newborn. As such, preterm infants tend to be at highest risk for developing deformational plagiocephaly. Additionally, Hutchinson et al (2003) determined that infants who remained in the supine position the majority of the time and received less than 5 minutes of tummy time per day were at greater risk for developing plagiocephaly. The authors felt that some parents over interpreted the AAPs “back to sleep” suggestion and did not allow their child to spend any time in the prone position, putting their infant at risk for developing deformational plagiocephaly.

Delivery variables, such as the type of birth and whether instruments were used, also tended to differentiate infants diagnosed with deformational plagiocephaly from infants who were not (Persing, 2003; Peitsch, Keefer, LaBrie, & Mulliken, 2002). Breech presentations were more common in infants with deformational plagiocephaly as were deliveries that were forceps or vacuum assisted. Other factors that have associated with increased risk of deformational plagiocephaly are a small or abnormal uterus and insufficient amniotic fluid (Peitsch et. al., 2002).

Treatment of Plagiocephaly

Currently three possible treatment plans exists for deformational plagiocephaly. The first treatment plan consists of active counter positioning and home exercises
(American Academy of Pediatrics, 1996; Loveday & de Chalain, 2001). With active counterpositioning, parents are asked to position the infant so that the rounded portion of the cranium lies against the mattress when laying them down to sleep. In addition, health care providers suggest that the position of the crib be changed so the infant is required to look away from the flattened side to view the objects and people in the room. Supervised tummy time is also recommended when the infant is awake and alert. If torticollis is present, neck motion exercises should be added to the treatment regimen (Biggs, 2003). Studies have shown that the active counterpositioning and exercises are effective in reducing cranial asymmetry in very young infants, younger than 4 months old (Mitchell & Hutchinson, 2003; Moss, 1997). As children become older, they are able to reposition themselves and may not remain in the position the parents placed them, negating the effect of active counterpositioning.

If active counterpositioning is not effective in reducing the asymmetry, the infant may be treated with an orthotic helmet or headband specifically fitted for them (Bruner, David, Gage, Argenta, 2004; Loveday & de Chalain, 2001; Teichgraeber, Ault, Baumgartner, Waller, Messersmith, Gateno, et. al., 2002). This has become the standard of care for treating children with deformational plagiocephaly. Orthotic helmets attempts to alter cranial growth by constraining growth in the areas that are prominent and promoting growth in the areas that are flattened. Infants wear the helmet for 15 to 22 hours everyday, including sleep time. Bridges, Chambers, & Pople (2002) state that there is no evidence that the helmets restrict cranial growth or create other complications, which had been a concern for many health-care providers. Several studies have shown that the helmets are effective in reshaping the cranium and decreasing the abnormalities
(Bruner et al 2004; Teichgraeber, Seymour-Dempsey, Baumgartner, Xia, Waller, & Gareno, 2004). The helmet appears to be maximally effective when the infant is between 4 and 12 months old, as 85% of the cranium growth occurs during that period (Loveday & de Chalain, 2001; Persing, 2003).

Bridges et al (2002) and others argue, however, that orthotic helmets are unnecessary, as normal cranial growth will reduce the asymmetry naturally. They also claim that there is no evidence that the helmets are actually efficacious as the studies assessing their efficacy indicate, since majority of them do not include a control group of children who are not receiving any treatment. Further, Hall (2002) claims that the helmet can affect the psychosocial development and functioning of the infants undergoing treatment, as their interactions with family and non-family members will be affected by the presence of the helmet. Children also appear to find the helmets uncomfortable, particularly in hot weather, and may refuse to wear it or become distressed when wearing it (Hall, 2002; Loveday & de Chalain, 2001).

The third treatment option for plagiocephaly is surgery, though most health care providers consider it unnecessary and even unsuitable for some cases (Bridges, Chambers, & Pople, 2002; Najarian, 1999). Surgery is rarely performed to treat plagiocephaly, but when it is performed, it is generally performed on the infants with the most severe symptoms such that brain growth is being hindered.

Natural Course of Plagiocephaly

Much of the discussion on the natural course of deformational plagiocephaly has centered on the cranial asymmetry. Many researchers believe that there are no long terms
problems associated with deformational plagiocephaly (American Academy of Pediatrics, 1996; Bridges, Chambers, & Pope, 2002; Wall, 2002). These researchers suggest that the cranial asymmetry likely decreases as the infant’s head enlarges and that whatever minor abnormalities remain are probably masked by hair growth. They also claim that any treatments provided for this condition is cosmetic in nature and really not necessary. Other researchers assert that there are long term consequences to the development of deformational plagiocephaly. They claim that deformation may worsen or become permanent if left untreated (Argenta, 2004; Ault, Baumgartner, Waller, Messersmith, Gateno, et. al., 2002). In addition, Miller and Clarren (2000) suggest deformational plagiocephaly may be present in a significant number of adults, but is just not recognized or treated. There has been very little discussion, however, centered on the neurological and neurocognitive development of children diagnosed with plagiocephaly, though there is some suggestion of brain dysfunction and delays in cognitive development in this population.

*Brain Development*

Virtually no studies have examined the course of brain development in children with deformational plagiocephaly, though several researchers have suggested that some brain damage may be present. Balan, Kushnerenko, Sahlin, Huotilainen, Naatanen, and Hukki (2002) indicated that brain functioning, particularly in the auditory pathways, might be compromised in children with deformational plagiocephaly. Habal, Castelano, Hemkes, Scheuerle, and Guilford (2004) stated that the flattening of the posterior regions, in children with deformational plagiocephaly, leads to fluid being displaced to the
anterior regions, resulting in compromised brain functioning. Argenta (2004) suggested that the brain may decompress, as it has no room to grow in severe forms of deformational plagiocephaly. These researchers suggest that some brain dysfunction may be present in children with deformational plagiocephaly and needs to be assessed further.

**Cognitive and Language Development**

Few studies have examined the cognitive and language development of children diagnosed with deformational plagiocephaly. Researchers, in general, appear to believe that the flat spots on the cranium are of cosmetic significance only and cause no long-term effects (American Academy of Pediatrics, 1996; Bridges et al, 2002; Hall, 2002). As such, many researchers in this area do not seem to be interested in examining the cognitive functioning of children with deformational plagiocephaly. The few studies on the cognitive and developmental functioning of children with deformational plagiocephaly, however, shows that this condition is not just of cosmetic concern, that it may have some long-term consequences in terms of cognitive development.

Miller and Clarren (2000), in informally assessing the long-term developmental outcome of children with deformational plagiocephaly, found evidence of impaired cognitive functioning. They determined that a significantly greater percentage of children with deformational plagiocephaly (39.7%) were receiving special help at primary school than their siblings (7.7%). Special help included special education services, physical therapy, occupational therapy, and speech therapy through Individualized Education Plans. Steinbok et al (2007) conducting a similar study in school age children with deformational plagiocephaly found that 14% of the participants were in a special
education class and 34% of the participants were obtaining some form of learning assistance, though no specifications were made regarding the manner of assistance. Both of these studies suggest that children with deformational plagiocephaly exhibit some difficulties with academic demands.

Habal, Leimkuehler, Chambers, Scheuerle, and Guilford (2003) examined the developmental functioning of children between the ages of 3 months and 13 years of age with deformational plagiocephaly using measures such as the Denver Developmental Screening Test and the Boston Naming Test. The initial assessment revealed that over 60% of the participants evidenced below average to significantly impaired cognitive and language scores. A second assessment only examined the functioning of children between 3 and 48 months and found that a significant percentage of the children demonstrated delays in psychosocial (29%), psychomotor (34%), and interactive (40%) functioning.

Panchal, Amirsheybani, Gurwitch, Cook, Francel, Neas, Levine (2001) examined the cognitive and psychomotor functioning of infant with deformational plagiocephaly, using the Bayley Scales of Infant Development - Second Edition (BSID-II), prior to the child receiving any therapeutic interventions. They found that a significantly smaller percentage of infants with plagiocephaly fell in the accelerated and normal levels and a significantly larger percentage fell in the mildly and significantly delayed levels on both the Mental Developmental Index and Psychomotor Developmental Index when compared to children without medical issues. Panchal et al (2001) concluded from these results that children with deformational plagiocephaly demonstrate delays in cognitive development.

Kordestani, Patel, Bard, Gurwitch, & Panchal conducted a follow-up confirmatory study to the Panchal et al (2001) study and again found that fewer
participants obtained scores in the accelerated range on the Mental and Psychomotor Developmental Index of the BSID-II. However, in contrast to the Panchal et al. study, a larger percentage of the participants fell in the mildly and significantly delayed ranges only on the Psychomotor Developmental Index. On the Mental Developmental Index, fewer infants actually performed in the mildly and significantly delayed range than expected from the standardized norms. These studies indicate the infants with deformational plagiocephaly do demonstrate some delays, particularly in terms of motor development, on standardized developmental measures.

Fuentes (2003) found that infants with deformational plagiocephaly were at significant risk for developmental delays when they were assessed with Bayley Infant Neurodevelopmental Screener. In fact, Fuentes found that risk for developmental delay was higher in children with deformational plagiocephaly than in children with craniosynostosis or other craniofacial conditions. Further, the deformational plagiocephaly group tended to remain at high risk ranges even through multiple assessment points, during which various recommendations had been made to ameliorate developmental risk. Additionally, age at time of evaluation (between 3 and 24 months) had no impact on the risk status. In general, Fuentes found that children with deformational plagiocephaly tended to be high risk for developmental delays throughout infancy.

Finally, a study examining auditory event related potentials (ERPs), found that children with plagiocephaly exhibited signs of language impairment (Balan, Kushnerenko, Sahlin, Huotilainen, Naatanen, & Hukki, 2002). The results of the study found that the amplitude of the ERP waveforms were considerably smaller in children
with plagiocephaly than in the matched control group, indicating weaker cortical sound processing and possible auditory processing dysfunction. The authors related the results to disturbed maturation of the auditory pathways, indicating that they were similar to waveforms seen in children with language impairments.

While these studies assessing developmental outcomes in children with deformational plagiocephaly occurred while the child was still an infant or toddler they suggest that there is a potential for serious long-term consequences associated with the condition. Further, the studies that examined the cognitive and developmental functioning suggest that children with deformational plagiocephaly may experience deficits in multiple areas, including cognitive, language, and motor functioning. As such, the overall functioning of the brain may be compromised. However, given the dearth of studies examining cognitive and brain functioning, particularly beyond the infant/toddler period, the lack of consistency in the data, and the limited number of studies using formal objective assessment tools, no clear conclusions regarding developmental outcomes can be drawn. Further, none of the previously mentioned studies assessed functioning at more than one time point, so there is no information available on the progression of cognitive and language development in this population. Additionally, none of these studies took into account severity of the study participant’s cranial asymmetry and assessed their cognitive or language functioning in relation to this variable. This is an important variable to consider as the severity of cranial asymmetry can have significant consequences on brain development and functioning.

As such, this area begs for studies that formally assess the long-term development of children with deformational plagiocephaly using standardized cognitive and language
assessments. Formal assessment of functioning beyond the infancy period and which also address severity of asymmetry can provide data that can confirm or refute hypotheses generated from the previous studies. Further, longitudinal studies which compare children’s functioning in infancy and during the preschool years to determine whether prior functioning has any impact on current functioning would also be beneficial.

Given the concerns raised by the current literature on the cognitive and language development of children diagnosed with deformational plagiocephaly, it is important to briefly consider the process of normal cognitive and language development in human beings. An understanding of these developmental processes, discussed below, may help clarify the deficits that children with deformational plagiocephaly may potentially present with.

**Cognitive Development**

Cognition is the process of organizing, manipulating, and using knowledge (Das Gupta & Richardson, 1995, Mercer, 1998, Spreen, Risser, & Edgell, 1995). It encompasses all mental abilities that lead to knowledge, including thinking, attending, perceiving, learning, remembering, problem solving, relating, and abstracting. Cognitive development refers to the constructive process by which individuals acquire these mental abilities and nurture them to into their mature forms (Mercer, 1998; Spreen, Risser, & Edgell, 1995).

Over the last three decades, information-processing theory has become the dominant theory of cognitive development (Miller, 2002; Richardson, 1998). This theory is derived from cognitive science and uses the metaphor of a computer for the cognitive
system to suggest that humans are information processors. While considered a theory, information processing theory is not actually a theory, but rather a framework that encompasses a large number of diverse theories that share certain assumptions and methodology (McShane, 1991; Miller, 2002). Many of the recent revisions in cognitive measures have been based on research results from the information processing framework (Sattler, 2001; Wechsler, 2002).

The information processing approach defines knowledge as pieces of experience that are combined, transformed, analyzed, or in some other way converted into a more complex form using reasoning, or logical rules (Richardson, 1998). According to this model of cognition, an individual obtains sensory information, or input, at the sensory registers and encodes it in symbolic form, or in the form of mental representations. Theorists claim that information needs to be encoded before they can be manipulated or transformed. This information is then transferred to working memory, where some mental action is performed upon it according to logical rules, which appear to be stored in long-term memory. The result of the mental activity is some behavioral output, which results in the individual obtaining more sensory input and causing this cycle to commence once again. This process continues until the individual reaches a specific state (Miller, 2002; Richardson, 1998).

Components of the Cognitive System

The information processing approach states that the cognitive system is composed of two basic components – the architectural system and the executive system (McShane, 1991; Sattler, 2001). The architectural system is believed to be innate to the individual,
while other the executive systems is thought to be attained through the individual’s interaction with his environment. The functioning of the whole cognitive system is based on the interaction between the architectural and the executive systems.

Architectural component. The architectural system refers to the innate cognitive properties that are essential for information processing, or the system’s hardware (McShane, 1991; Sattler, 2001). These properties include “capacity”, “durability”, and “efficiency” (Sattler, 2001, p. 145). Capacity refers to the space available in working memory for information processing and space available in long-term memory for information storage. Durability is the length of time a stimulus trace remains in the cognitive system to be processed, or the rate at which information is lost. Efficiency is the speed by which information from a stimulus trace is encoded or by which information in long-term memory is decoded. These properties are necessary for basic cognitive processes and are not believed to improve through learning (Sattler, 2001). These properties also tend to be the first to be compromised when the central nervous system becomes compromised.

The sensory registers that encode and represent sensory input are also considered to be part of the architectural system (McShane, 1991; Sattler, 2001). Many information processing psychologists, in fact, perceive the sensory registers as modules, or cognitive sub-systems that are believed to be pre-programmed by genetic instruction to process certain types of input information, such as language information or musical information. The task of the sensory registers is to convert the sensory information into mental representations and transfer them to the central systems, which carry out “higher-level cognitive tasks” (Richardson, 1998, pp. 16).
**Executive component.** The second component of the cognitive system, the executive system, refers to the set of skills and strategies that individuals learn through their interaction with their environment (Miller, 2002; Sattler, 2001). Executive system is composed of four constructs – knowledge base, schemes, control processes, and metacognition - that are essential for problem solving. These constructs allow individuals to go beyond “rote non-strategic” learning and problem solving to more advanced, creative, and adaptive styles. These constructs also direct the activities at each stage of information processing and keeps the whole system working in harmony (Miller, 2002). Further, these constructs are believed to help individuals overcome the structural constraints of how much information can actually be processed at a time. As these skills are learned, they can be improved through experience and learning.

An individual’s knowledge base refers to the information they have stored in long term memory (Miller, 2002; Sattler 2001). This information is stored in long term memory in the form of semantic networks, which reflects the co-occurrence of pieces of information in experience. An individual’s knowledge base affects how he learns and problem solves in several ways. First, the individual’s knowledge base is noted to influence what information the individual attends to and how this information is represented stored. Second, information from the knowledge base can be retrieved and manipulated along with new information to develop new ideas or solve problems. Third, the strategies that an individual uses in solving complex problems are often a part of the individual’s knowledge base. There are but few of the ways in which an individual’s knowledge base impacts how he processes information as well.
Schemas refer to the active construction of the knowledge about events and objects (Richardson, 1998; Sattler, 2001). According to the Information Processing Theory, these are the basis of intelligence. Richardson states that individuals construct schemas through the process of assimilation and accommodation. The aspects of the new information an individual receives that are similar to the information already existing in their knowledge base is assimilated into their knowledge base using processing rules that the individual has already constructed. The knowledge base has to be modified to accommodate the unique aspects of new information and new processing rules have to be developed to deal with these aspects. In this manner, knowledge and the rules of processing information is constructed.

The control processes are strategies that aid individuals in remembering information, solving problems, and other cognitive activities (Miller, 2002; Sattler, 2001). Strategies are defined as “subject-controlled activities” that are utilized to accomplish cognitive goals, such as remembering a name or telephone number (Miller, 2002, p. 231). For example, when trying to remember information, individuals often use rehearsal strategies, such as repeating information to themselves. Researchers believe that children as young as 18 months old begin developing strategies for processing information (Miller, 2002). As children mature, they develop more and more complex strategies and begin to refine these strategies. Children also begin to use strategies spontaneously and automatically as they as mature. Further, researchers claim that as individuals develop “strategic behaviors”, they become more efficient information processors.
The final executive system construct, metacognition, refers to the knowledge that individuals have about their own thought processes and the strategies that they utilize in processing information (Miller, 2002; Sattler, 2001). Sattler indicates that there are two components to metacognition- declarative knowledge, or the knowledge that individuals have about what they know, and procedural knowledge, or the knowledge that the individual has about the procedures that the individual uses in regulating their cognitive functions. Metacognition is involved in recognizing and identifying the nature of the problem, in mentally representing the problem, in choosing an appropriate strategy to solve the problem, in solving the problem and evaluating the solution. Metacognition is an essential component of the executive system that allows individuals to become efficient information processors.

Process of Cognitive Development

According to the information processing approach, developmental change occurs in how individuals encode, represent, store, modify, weigh, and combine information (Miller, 2002; Richardson, 1998). These changes seem to transpire at different points in the system- the sensory store, short-term memory, long-term, and central processes. Information processing psychologists have identified four mechanisms of development- automatization, changes in encoding, generalization, and strategy construction- though there may be more (Miller, 2002).

Automatization is the process by which a mental activity that was initially effortful becomes so highly learned that it becomes automatic to the individual (Miller, 2002). For example, recognizing letters is initially quite effortful for a child, but through
practice it becomes automatic and the child is able to identify the letter as soon as he perceives it. Automatization frees up capacity so that more information can be processed. Changes in the way information is encoded results in the child noticing and utilizing previously unnoticed pieces of the information in solving problems (Miller, 2002). Generalization operates when an individual uses a strategy that was effective with one type of problem to solve a different problem with a similar structure, and strategy construction happens when a child obtains insight into a problem and approaches the problem with a new strategy (Miller, 2002). All of these mechanisms are involved in cognitive development.

In terms of this study, several researchers have demonstrated that brain insults in infancy and early childhood negatively impact the process of cognitive development (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005; Ewing-Cobb, Barnes, & Fletcher, 2003). Early brain injury is noted to impact an individual’s ability to learn new skills, which has consequences for long-term cognitive development. This suggests that early brain injury affects the mechanisms through which cognitive development progresses—automatization, changes in encoding, generalization, and strategy construction—either directly or indirectly by disrupting the architectural or executive components of the cognitive system. Given the concerns about early brain insults in children with deformation plagiocephaly (Argenta, 2004; Habal, Castelano, Hemkes, Scheuerle, & Guilford, 2004), this data suggests that a formal assessment of cognitive development in this population is imperative.
Language Development

Language is one of the primary modes by which individuals communicate with one another (Bancroft, 1995). Linguistic knowledge allows for both verbal and written communications to occur between individuals. Language development refers to the process by which individuals acquire these communicative skills.

Language is composed of arbitrary symbols that are mentally represented (Bancroft, 1995). Objects and events are randomly assigned names and there is no actual relationship between the name and the object or event the name refers to other than the relationship created by human language. The fact that an object or event has different names in different languages further supports this claim that language is composed of symbols. Being able to use words allows individuals to go beyond immediate experience and the concrete object or event. It also allows individuals to use words in new ways and increases the ideas individuals are able to generate.

Theory of Language Development

In the last few decades, the dominant theory of language development has been the connectionist theory. Connectionism is based on the recent research in brain structure and development (Bancroft, 1995; Hoff, 2001; Richardson, 1998). It follows the idea that neurons in the brain are connected with one another to create large networks and that neurons produce electro-chemical that might excite or inhibit other neurons (Bancroft, 1995). Connectionist models state that information that individuals acquire is stored in the form of semantic networks, like schemas, where activation of one concept may activate some concepts that are linked with activated concept and inhibit others. This
pattern of activation and inhibition selectively strengthens the connections between some concept, and development appears to be a dynamic process that is the result of the gradual change in strength of connections between certain concepts (Bancroft, 1995; Hoff, 2001; Marchman, 1997). Linguistic knowledge is represented as the patterns of activity in the semantic network, and the pattern of activation at any time is a function of the current stimuli that the individual is perceiving and the individual’s past history.

The connectionist theory argues that linguistic knowledge is stored as “statistical probabilities” of actual language use, rather than as linguistic rules (Evans, 2001; Hoff, 2001; Marchman, 1997). This means that the links between concepts in a connectionist network are also encoded in terms of statistical probabilities, or how frequently the two concepts co-occur. The statistical probabilities are derived from the individual’s experience with the concepts. Over time, the link between concepts may strengthen or weaken, depending on whether the co-occurrence of the concepts increases or decreases. The statistical probabilities are used effectively by individuals to combine different sources of information in processing language (Marchman, 1997).

Language skills are believed to emerge from the interaction between the biological constraints of the individual and the individual’s environment. According to this connectionist theory, individuals are born with a neural system that will allow them to perceive and process linguistic information and develop connectionist networks, but they obtain the linguistic information through their interactions with their environment (Bancroft, 1995; Evans, 2001; Hoff, 2001; Marchman, 1997). So the individual’s biological system perceives and processes linguistic information present in the
environment and either adds that information to an existing network or develops a new network based on this information.

Language development is depicted as being non-linear, where small gradual changes can accumulate to create dramatic stagelike changes (Evans, 2001; Marchman, 1997). As language development is noted to be the result of an individual’s interactions with his environment, changes in the environment can cause the individuals to move into and out of states known as attractors (Marchman, 1997). Generally, linguistic information in strong attractor states tends to be older, more stable, and more immune to external perturbations. Considerable energy is required to modify this knowledge, though dissolution of linguistic knowledge does occur. Linguistic information in weaker attractor states tends to be newer, less stable, and sensitive to environmental changes.

Considerable energy needs to be expended in maintaining the attractor states in these situations. Development, according to perspective, is the result of the appearance of new attractor states and disappearance of old ones in response to changes in the environment (Marchman, 1997). As a result, at any point, individuals have both strong and weak attractor states and their language abilities appear to be highly variable, suggesting that the individual’s linguistic abilities are continuously evolving.

When children acquire a language, they acquire the sounds and sound patterns of the language (phonology), the words of the language (lexicon), the grammar of the language (grammar), and the ability to communicate using the language (communication) (Hoff, 2001). Hoff provides an overview of the course of language development in these four domains from birth to 4 years. During the first year, Hoff claims that children are primarily involved in phonological development – they learn sounds, learn to
discriminate between sounds, and learn to produce sounds – they develop a phonological representational system. During the second year, children are primarily believed to be involved in lexical development- they say their first word, they are developing a vocabulary, and begin to produce word combinations. During the third year, children are primarily learning the grammar of the language- they begin to combine words to form sentences and begin asking questions. By the fourth year, children have already acquired language skills and are in the process of refining and developing them further.

Communication development occurs throughout the lifespan.

Researchers have demonstrated that the process of language development can become disrupted as a result of early brain insults (Chilosi, Cipriani, Bertuccelli, Pfanner, & Cioni, 2001; Lidzba and Kräkeloh-Mann, 2005; Vicari, Albertoni, Chilosi, Cipriani, Cioni, & Bates, 2000). Children who have experienced early brain insults have noted to have delays in their language development, particularly in terms of their expressive language functioning. Researchers explain that this is likely due to the children having to reacquire language skills that they had lost during the insult when they should be acquiring new skills (Lidzba and Kräkeloh-Mann, 2005). Further, delayed maturation of auditory pathways in the brain is noted to result in delays in cognitive and language abilities (Talero-Gutiérrez, Carvajalino-Monje, Samper de Samper, & Ibáñez-Pinilla, 2008). Therefore, given the concerns raised regarding the brain development and auditory pathway maturation of children with deformational plagiocephaly by previous researchers (Argenta, 2004; Balan, Kushnerenko, Sahlin, Huotilainen, Naatanen, & Hukki, 2002; Habal, Castelano, Hemkes, Scheuerle, & Guilford, 2004), it appears
important that a formal assessment of the cognitive and language development of children with deformational plagiocephaly be conducted.

Statement of the Problem & Hypotheses

Several studies have indicated that the neurological and neurocognitive functioning of children with deformational plagiocephaly may be compromised (Balan, Kushnerenko, Sahlin, Huotilainen, Naatanen, & Hukki, 2002; Habal, Leimkuehler, Chambers, Scheuerle, & Guilford, 2003; Miller & Clarren, 2000; Panchal, Amirsheybani, Gurwitch, Cook, Francel, Neas, & Levine, 2001; Steinbok, Lam, Singh, Mortenson, & Singhal, 2007). Panchal et al (2001), in examining their developmental functioning, concluded that infants with plagiocephaly might be at risk for long-term cognitive and motor impairments. Miller and Clarren (2000) and Steinbok et al (2007) found that a significant percentage of children with deformational plagiocephaly were receiving special education services or other cognitive remediation services, indicating these children might have cognitive impairments. Balan et al (2002) found that children with deformational plagiocephaly evidence weaker cortical sound processing, which may result in language impairments. Habal et al (2003), in examining the cognitive and language functioning in children, ages 3 months to 13 years, with deformational plagiocephaly, determined that a significant percentage of children in their study had below average to impaired language functioning. These studies suggest that the children may exhibit delays and deficits in multiple developmental areas including cognitive and language development.
The purpose of this exploratory study is: 1) to examine the cognitive functioning of children with plagiocephaly and compare it to the normative sample, 2) to examine the language functioning of children with plagiocephaly and compare it to the normative sample, 3) to determine whether children with plagiocephaly who evidenced developmental delays in past continue to exhibit delays, 4) to determine what effect the severity of the condition has on cognitive and language development.

Hypotheses

1) On average, children with plagiocephaly will obtain significantly lower scores than the normative sample on the cognitive measure.

2) On average, children with plagiocephaly will obtain significantly lower scores than the normative sample on the language measure.

3) Children with plagiocephaly who evidenced delays early on will obtain lower scores on the cognitive measure than children who did not exhibit delays previously.

4) Children with plagiocephaly who evidenced delays early on will obtain lower scores on the language measure than children who did not exhibit delays previously.

5) Children with more severe cranial flattening will obtain lower scores on the cognitive measure than children with less severe cranial flattening.

6) Children with more severe cranial flattening will obtain lower scores on the language measure than children with less severe cranial flattening.
Methods

Participants

The participants of this study were obtained from the Loma Linda University Children's Hospital Craniofacial Team Center. Children who are currently between the age of 3 and 5 years and who had obtained medical care at the CFT Center for the diagnosis of deformational plagiocephaly in infancy were included. Children with other craniofacial and/or medical diagnoses were excluded from the study. The participants all had been diagnosed with deformational plagiocephaly by the Craniofacial Team Center Pediatrician. The pediatrician also provided a rating for the degree of cranial asymmetry, or severity of cranial flattening, from a visual assessment of the child's skull. The rating was on a 3-5 point likert scale ranging from mild to severe. Further, all of the eligible participants had been evaluated by Pediatric Psychology during their visit to the craniofacial team clinic with the Bayley Infant Neurodevelopmental Screener and were assessed to have been at high risk, moderately risk, or low risk for developmental delays.

Parents of children eligible to participate in this study were contacted via telephone about whether they would be interested in participating in the study. Since the principal investigator is a service provider and a member of the Loma Linda University Children's Hospital, Craniofacial Team Clinic, she made contact with the caregivers of eligible children to ask whether they would be interested in participating (Appendix A) in the study. Those parents who volunteered to participate were invited to come to Kids FARE, the LLU Pediatric Psychology laboratory headed by the primary investigator, to have their children assessed. Parents who verbally consented to participate were asked to sign written consent (Appendix B) at the time of their appointment at Kids FARE.
Materials

Consent Form

The parents of all study participants were asked to read and sign the informed consent form (Appendix B).

General Demographic Form

The parents were also asked to complete a brief demographic questionnaire (Appendix C). This questionnaire included questions regarding the child’s age, gender, ethnicity, gestational age, the age at which the child was diagnosed with deformational plagiocephaly, what treatment strategies (counterpositioning, molding helmet, surgery, none) were used to ameliorate the cranial flattening, other medical issues including other craniofacial anomalies, prenatal history, birth history, developmental history, current family environment, current academic or pre-academic functioning, and current social functioning.

Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III)

The children participating in this study were all administered the WPPSI-III as a measure of their cognitive functioning. The WPSSI-III is a measure of verbal, nonverbal, and overall cognitive functioning in children between the ages of 2 years, 6 months and 7 years, 3 months. For children between the ages of 2 years, 6 months and 3 years, 11 months, the 4 core and 1 supplementary subtest were administered to obtain their verbal intelligence quotient (VIQ), performance intelligence quotient (PIQ), and their full scale intelligence quotient (FSIQ) scores. For children between the ages of 4 years, 0 months
and 7 years, 3 months, the 7 core and 1 supplementary subtest were administered to obtain their VIQ, PIQ, Processing Speed Index (PSI), and FSIQ scores.

The WPPSI-III scales have demonstrated good psychometric properties. The alpha reliability coefficient based on the normative sample for the FSIQ scale was 0.95, for the verbal domain was 0.95, and for the performance domain was 0.93 (Wechsler, 2002). Several different validity studies have been conducted with the WPPSI-III and the results of these studies are described in the manual (Wechsler, 2002). These studies have demonstrated strong links between the WPPSI-III and other measures of cognitive functioning, such the Wechsler Intelligence Scale for Children- Third Edition (WISC-III), the Wechsler Individual Achievement Test-Second Edition (WIAT-II), and the Differential Ability Scales (DAS).

*Test of Early Language Development – Third Edition (TELD-3)*

The children who participated in this study were also administered the TELD-3. The TELD-3 is a measure of receptive and expressive language in children between 2 and 7 years of age. The TELD-3 provided three language scores – a Spoken Language composite score, a Receptive Language score, and an Expressive Language score. The TELD-3 scales have demonstrated good psychometric properties. The alpha reliability coefficient based on the normative sample for all composites exceeded 0.90 (Hresko, Reid, & Hammill, 1999). Several different validity studies have been conducted with the TELD-3 and the results of these studies are described in the manual (Hresko et al., 2002). These studies have demonstrated strong links between the TELD-3 and other measures of
language functioning, such as the Clinical Evaluation of Language Functioning – Preschool and Test of Language Development – Primary Third Edition.

**Design and Procedure**

The parents of children who had been diagnosed as an infant with deformational plagiocephaly at the Loma Linda University Craniofacial Team Clinic were contacted by telephone by the primary investigator, who is a member of the craniofacial team, and asked if they and their child would be interested in participating in this study. They were informed that the study is examining the long-term cognitive development of children who have been evaluated for deformational plagiocephaly. Those parents who verbally consented to have their children participate were then invited to come to Kids FARE to have their child assessed.

When the parents brought their child to the laboratory, they were given a brief synopsis of the study and asked to sign the informed consent form. The parents were also asked to sign the Protected Health Information form, so the investigators could obtain information regarding the severity of the child’s condition from their medical chart. The parents were then asked to complete the demographic questionnaire while their child was being administered the WPPSI-III and TELD 3. Following the assessment, the parents were informed that they would receive a report containing the results of this evaluation and that they may contact the investigators if they have any questions.
Results

Participants

Forty two children and their parents were eligible to participate in this study. The children met all of the inclusion criteria for the study including 1) being between 3 and 5 years of age, 2) having a diagnosis of deformational plagiocephaly as an infant, and 3) having no other craniofacial or medical diagnosis with the exception of torticollis or sternocleidomastoid imbalance. All of the children had been previously evaluated using the Bayley Infant Neurodevelopmental Screener. Of the forty two children, twenty were unreachable due to disconnected or incorrect phone numbers. Another 6 were unreachable after multiple attempts (at least 12) had been made to contact them over a 6 month period. Of the remaining 16 participants, two refused to participate in the study and two expressed interest in the study but were unreachable when attempts were made to schedule the evaluations. As such, 12 children and their parents completed the study (n = 12). The demographic information is presented for the study participants in Table 1.

Table 1:
Summary of Patient Demographic Statistics

<table>
<thead>
<tr>
<th>Demographic Variables</th>
<th>58% Male (n = 7)</th>
<th>42 % Female (n = 5)</th>
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</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<tr>
<td>Ethnicity</td>
<td>42 % Caucasian (n = 5)</td>
<td>33% Latino (n = 4)</td>
</tr>
<tr>
<td>Age</td>
<td>Mean Age = 4.6 years (SD = 8.7 month)</td>
<td>Range 3.2 to 5.9 years</td>
</tr>
</tbody>
</table>
All participants had a diagnosis of deformational plagiocephaly, with 6 of the participants additionally having the diagnosis of torticollis. Fifty eight percent of participants were male, while forty two percent were female. The average age of the participants at the time of the evaluation was 4.6 years (8.7 SD). The ethnic composition of the participants was 42% Caucasian, 33% Latino, 8% African American, and 17% Nonspecified. The participants were all assessed between October 2007 and April 2008. The profile of each participant is provided in Appendix D.

Clinical Variables

Participant’s medical and clinical information was obtained from the participant’s medical chart. This information included the severity of the participants’ plagiocephaly, or cranial flattening, their developmental risk status, and what treatments were utilized by the participants and their families to ameliorate the plagiocephaly. Table 2 displays the study participant’s clinical data.

Severity of cranial flattening was assessed by the Pediatrician/Medical Director of the Craniofacial Team Clinic, who encoded it as being mild, moderate, or severe, during the participants’ routine visits to the clinic. This information was available for 11 of the 12 participant’s in the study. Among the 11 participants with severity rating scores, 4 (36%) were noted to have mild flattening, 6 (55%) were noted to have moderate flattening, and 1 (9%) to have severe flattening of the occipital region. The cranial asymmetry of the study participants were compared to those who could not be contacted or refused to participate in this study and no significant differences were found.
Table 2:

Summary of Patient Clinical Variables

<table>
<thead>
<tr>
<th>Clinical Variables</th>
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</thead>
<tbody>
<tr>
<td>Mean Age at time of Diagnosis</td>
<td>6.8 months (SD = 3.6 months)</td>
</tr>
<tr>
<td>Severity of Plagiocephaly</td>
<td></td>
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<tr>
<td>- 36% Mild (n = 4)</td>
<td></td>
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<tr>
<td>- 55% Moderate (n = 6)</td>
<td></td>
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<tr>
<td>- 9% Severe (n = 1)</td>
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<tr>
<td>BINS Risk Status</td>
<td></td>
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<tr>
<td>- 17% Low Risk (n = 2)</td>
<td></td>
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<tr>
<td>- 50% Moderate Risk (n = 6)</td>
<td></td>
</tr>
<tr>
<td>- 33% High Risk (n = 4)</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
</tr>
<tr>
<td>- 25% Active Counterpositioning, Exercises (n = 3)</td>
<td></td>
</tr>
<tr>
<td>- 25% Molding Helmet (n = 3)</td>
<td></td>
</tr>
<tr>
<td>- 17% Active Counterpositioning, Helmet (n = 2)</td>
<td></td>
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<tr>
<td>- 33% No treatment (n = 4)</td>
<td></td>
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<tr>
<td>Maternal Health</td>
<td></td>
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<tr>
<td>- 66% had health issues during pregnancy (n = 8)</td>
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<tr>
<td>Teratogens</td>
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<tr>
<td>- 0% of the parents reported using drugs or alcohol during pregnancy</td>
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<tr>
<td>Gestational Age</td>
<td></td>
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<tr>
<td>- 75% of Participants were full term (n = 9)</td>
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<tr>
<td>- 25% were born premature (n = 3)</td>
<td></td>
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<tr>
<td>Delivery</td>
<td></td>
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<tr>
<td>- 58% Normal Vaginal (n = 7)</td>
<td></td>
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<tr>
<td>- 42% Caesarean Section (n = 5)</td>
<td></td>
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<tr>
<td>Twins</td>
<td></td>
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<tr>
<td>- 25% were one of a set of twins (n = 3)</td>
<td></td>
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<tr>
<td>- 75% were single children (n = 9)</td>
<td></td>
</tr>
<tr>
<td>Sleep</td>
<td></td>
</tr>
<tr>
<td>- 92% were placed in a supine position to sleep (n = 11)</td>
<td></td>
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<tr>
<td>- 8% were placed in a prone position (n = 1)</td>
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<tr>
<td>Tummy time</td>
<td></td>
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<tr>
<td>- 58% obtained tummy time on a daily basis (n = 7)</td>
<td></td>
</tr>
<tr>
<td>- 42% received very little tummy time</td>
<td></td>
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<tr>
<td>Developmental Milestones</td>
<td></td>
</tr>
<tr>
<td>- Mean Age Roll Over = 5.1 months (SD = 2.6 months)</td>
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<tr>
<td>- Mean Age Sat Up = 7.6 months (SD = 3.7 months)</td>
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<tr>
<td>- Mean Age Crawling = 8.6 months (SD = 3.4 months)</td>
<td></td>
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<tr>
<td>- Mean Age Walking = 15.2 months (SD = 7.1 months)</td>
<td></td>
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<tr>
<td>- Mean Age Babbling = 7.8 months (SD = 3.3 months)</td>
<td></td>
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<tr>
<td>- Mean Age 1st Word = 12.5 months (SD = 4.2 months)</td>
<td></td>
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<tr>
<td>- Mean Age Sentences = 17.7 months (SD = 2.3 months)</td>
<td></td>
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<tr>
<td>School</td>
<td></td>
</tr>
<tr>
<td>- 25% Kindergarten (n = 3)</td>
<td></td>
</tr>
<tr>
<td>- 67% Preschool (n = 8)</td>
<td></td>
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<tr>
<td>- 8% No School (n = 1)</td>
<td></td>
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<tr>
<td>School Performance</td>
<td></td>
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<tr>
<td>- 83% were noted to be Average or Above Average</td>
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<tr>
<td>- 17% did not respond to the item</td>
<td></td>
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<tr>
<td>Therapy</td>
<td></td>
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<tr>
<td>- 33% had obtained or are currently getting services</td>
<td></td>
</tr>
<tr>
<td>- 17% Speech and Language Therapy (n = 2)</td>
<td></td>
</tr>
<tr>
<td>- 8% Occupational Therapy (n = 1)</td>
<td></td>
</tr>
<tr>
<td>- 33% Physical Therapy (n = 4)</td>
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</tbody>
</table>

The participant’s developmental risk status had been evaluated in their infancy by the pediatric psychologist in the craniofacial clinic using the Bayley Infant
Neurodevelopmental Screener (BINS). All participants had been evaluated using the BINS during their initial visit to the clinic. From their performance on the BINS, 2 (17%) participants were noted to be at Low risk for developmental delays, 6 (50%) participants were at Moderate Risk for delays, and 4 (33%) participants were at High Risk for delays. The developmental risk status of the study participants was also compared to that of children with deformational plagiocephaly who did not participate in the study, and no significant differences were found.

In terms of interventions used to treat the cranial flattening, 3 (25%) of the participants received active counterpositioning and home exercises, 3 (25%) were noted to have worn molding helmet, and an additional 2 (17%) participants were noted to have obtained both active positioning and molding helmet therapy. Four (33%) of the participants had not received any specific treatments for this condition. Treatment that was used to ameliorate the cranial flattening did depend on the severity of the flattening. The participants with mild flattening were more likely to not receive any treatment than participants with moderate and severe flattening. Only one of the four participants with mild flattening received any treatment, whereas all 7 of the participants with moderate to severe flattening received treatment. The treatment strategies, however, was not found to be related to developmental risk status as assessed on the BINS. Some participants classified to be at low risk for delays obtained counterpositioning and molding helmet treatment, while some participants at moderate and high risk obtained no treatment for the cranial flattening. Further, there was no consistent pattern with the type of intervention received and developmental risk status. Additionally, no differences in
developmental risk status were noted based on the interaction between severity of cranial flattening and type of intervention the participant obtained.

The parents of all participants also completed a demographic data form at the time of the evaluation. The information collected on these forms included information regarding the participants’ prenatal, perinatal, developmental, familial, academic, and social history. Table 2 also displays summary data for these demographic variables. Of note, 67% of the participants’ parents reported that there were maternal health problems during the pregnancy. These health problems included hypertension, gestational diabetes, placental abruption, and preeclampsia. Further, forty two percent of the children were reportedly born via cesarean section and 25% reportedly had significant health complications following delivery. Three of the children were born as one of a set of twins and all three were born considerably prematurely (at approximately 29 weeks gestational age). The other children were all born at full term. Other information of note include the report from parents that 92% of the participants were placed on their backs to sleep following the American Academy of Pediatrics Guideline, with only 58% of the participants obtaining tummy time on a daily basis. Finally, about one third of the participants had previously obtained or are currently obtaining intervention services (speech/language, physical therapy, and occupational therapy).

Results of Psychological Measures

Cognitive

All twelve participants were administered the WPPSI-III (3 were administered the 2.6-3.11 forms and nine were administered the 4.0-7:11 form). Table 3a provides the
means, medians, standard deviations, and ranges for all cognitive composites. The Mean FSIQ, VIQ, PIQ, and PSI were all in the Average range. With respect to individual cognitive composite scores, 58% of the participants obtained Average FSIQ scores and 33% obtained Above Average to Superior FSIQ scores, while only 1 participant obtained a FSIQ score that was below average (Borderline). In terms of VIQ and PSI, none of the participants obtained below average scores, while 44% (PSI) to 75% (VIQ) of the participants obtained Average scores and 25% (VIQ) and 66% (PSI) of the participants obtained Above Average scores. With respect to PIQ, 25% of the participants obtained below Average scores (Borderline to Low Average), while 50% performed in the Average range and 25% performed in the Above Average to Superior range.

Table 3a:

Summary Statistics for Cognitive Composites

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale IQ</td>
<td>12</td>
<td>103.0 (13.1)</td>
<td>103</td>
<td>75-125</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>12</td>
<td>103.8 (9.1)</td>
<td>103.5</td>
<td>88-115</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>12</td>
<td>100.5 (17.3)</td>
<td>101.5</td>
<td>70-129</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>9</td>
<td>107.9 (7.9)</td>
<td>110</td>
<td>97-119</td>
</tr>
</tbody>
</table>

When looking at the data in more detail, 58% of the participants were noted to have significant discrepancies (greater than or equal to 11 points) between their Verbal IQ and Performance IQ. According the normative data in the WPPSI-III technical manual, this discrepancy is present in less than 5% of the standardization sample. Among the individuals with the significant discrepancy between their Verbal and
Nonverbal IQs, 57% evidenced higher Verbal than Performance IQs and 43% evidenced higher Performance than Verbal IQs.

In terms of individual subtests, the Mean scores were all in the Average range. Table 3b presents the means, medians, and standard deviations of the individual WPPSI-III subtests. One result of note is that there was much more variability among the participant’s scores on the Block Design and Picture Concepts subtests than on the other subtests, with a significant larger percentage falling in below average on these subtests (42% on Block Design, 22% on Matrix Reasoning, 8-11% on the other subtests).

Table 3b:

Summary Statistics for Cognitive Subtests

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information</td>
<td>12</td>
<td>10.7 (2.2)</td>
<td>10.5</td>
<td>7-14</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>9</td>
<td>12.2 (2.7)</td>
<td>12</td>
<td>7-16</td>
</tr>
<tr>
<td>Word Reasoning</td>
<td>9</td>
<td>10.4 (2.8)</td>
<td>11</td>
<td>7-16</td>
</tr>
<tr>
<td>Receptive Language</td>
<td>9</td>
<td>10.4 (2.8)</td>
<td>11</td>
<td>7-16</td>
</tr>
<tr>
<td>Block Design</td>
<td>12</td>
<td>9.0 (3.8)</td>
<td>8</td>
<td>4-15</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>9</td>
<td>11.1 (2.4)</td>
<td>11</td>
<td>6-14</td>
</tr>
<tr>
<td>Picture Concepts</td>
<td>9</td>
<td>10.6 (4.2)</td>
<td>9</td>
<td>5-16</td>
</tr>
<tr>
<td>Object Assembly</td>
<td>3</td>
<td>11.7 (1.5)</td>
<td>12</td>
<td>10-13</td>
</tr>
<tr>
<td>Coding</td>
<td>9</td>
<td>11.5 (12)</td>
<td>12</td>
<td>9-13</td>
</tr>
<tr>
<td>Symbol Search</td>
<td>9</td>
<td>11.6 (2.4)</td>
<td>12.5</td>
<td>7-14</td>
</tr>
</tbody>
</table>

Language

All twelve of the participants were administered the TELD as a measure of their language functioning. The mean, median, standard deviations, and ranges for all relevant language composites are displayed in Table 4. In general, the majority (92%) of the participants performed in the Average to Above Average range on both the receptive and
expressive language composites, obtaining overall language composites that were within
the Average range. A considerable percentage of the participants (50%), however, also
evidenced large discrepancies (11 points or greater) between their receptive and
expressive language functioning scores.

Table 4:

*Summary Statistic of the Language Composites*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean (SD)</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoken Language Composite</td>
<td>12</td>
<td>106.9 (16.6)</td>
<td>103.5</td>
<td>74-137</td>
</tr>
<tr>
<td>Receptive Language Composite</td>
<td>12</td>
<td>107.3 (16.4)</td>
<td>109.5</td>
<td>72-131</td>
</tr>
<tr>
<td>Expressive Language Composite</td>
<td>12</td>
<td>104.5 (14.8)</td>
<td>100.5</td>
<td>84-131</td>
</tr>
</tbody>
</table>

*Tests of Hypotheses*

*Hypothesis 1*

It was hypothesized that there would be statistically significant differences
between the cognitive scores of the study participants and the age matched nonclinical
normative sample. To test this hypothesis, z-tests were conducted between the cognitive
scores of the study sample and the published norms in the WPPSI-III manual. Table 5
displays the z-statistics and p-values for all cognitive variables.

The cognitive composite scores and the majority of the subtest scores of the study
participants were not statistically different from the published norms thus not supporting
this hypothesis. There did prove to be a statistically significant difference between the
scores of the participating sample and the published norms on one subtest – Vocabulary.
The participating group’s scores on this subtest were significantly higher than the published norms. Thus these findings did not support the study hypothesis.

Table 5:

*Comparison of Cognitive Assessment Results with the Normative Sample*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>z-value</th>
<th>p-value</th>
<th>95% CI for the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale IQ</td>
<td>12</td>
<td>0.69</td>
<td>0.49</td>
<td>94.5 – 111.5</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>12</td>
<td>0.88</td>
<td>0.38</td>
<td>95.3 – 112.3</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>12</td>
<td>0.11</td>
<td>0.91</td>
<td>92.0 – 109.0</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>9</td>
<td>1.40</td>
<td>0.16</td>
<td>97.5 – 118.3</td>
</tr>
<tr>
<td>Information</td>
<td>12</td>
<td>0.77</td>
<td>0.44</td>
<td>9.0 – 12.4</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>9</td>
<td>2.22</td>
<td>0.03</td>
<td>10.3 – 14.2</td>
</tr>
<tr>
<td>Word Reasoning</td>
<td>9</td>
<td>0.44</td>
<td>0.66</td>
<td>8.5 – 12.4</td>
</tr>
<tr>
<td>Receptive Language</td>
<td>3</td>
<td>-0.19</td>
<td>0.85</td>
<td>6.3 – 13.1</td>
</tr>
<tr>
<td>Block Design</td>
<td>12</td>
<td>-1.15</td>
<td>0.25</td>
<td>7.3 – 10.7</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>9</td>
<td>1.11</td>
<td>0.27</td>
<td>9.2 – 13.1</td>
</tr>
<tr>
<td>Picture Concepts</td>
<td>9</td>
<td>0.56</td>
<td>0.58</td>
<td>8.6 – 12.5</td>
</tr>
<tr>
<td>Object Assembly</td>
<td>3</td>
<td>0.96</td>
<td>0.34</td>
<td>8.3 – 15.1</td>
</tr>
<tr>
<td>Coding</td>
<td>9</td>
<td>1.41</td>
<td>0.16</td>
<td>9.5 – 13.7</td>
</tr>
<tr>
<td>Symbol Search</td>
<td>9</td>
<td>1.53</td>
<td>0.13</td>
<td>9.4 – 13.6</td>
</tr>
</tbody>
</table>

*Hypothesis 2*

It was hypothesized that the language scores of the plagiocephaly group would be statistically different from that of the published norms. Z-tests were conducted to test this hypothesis and determine whether the language scores of the plagiocephaly group were significantly different from the mean language scores of the standardization sample. Table 6 displays the z-statistics and p-values for all language variables. Again, the language scores of the study sample were not significantly different from the normative data thus not supporting this hypothesis.
Table 6:

*Comparison of Language Assessment Results with Normative Sample*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>z-value</th>
<th>p-value</th>
<th>95% CI for the Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoken Language Composite</td>
<td>12</td>
<td>1.60</td>
<td>0.11</td>
<td>98.4 – 115.4</td>
</tr>
<tr>
<td>Receptive Language Composite</td>
<td>12</td>
<td>1.69</td>
<td>0.09</td>
<td>98.8 – 115.8</td>
</tr>
<tr>
<td>Expressive Language Composite</td>
<td>12</td>
<td>1.03</td>
<td>0.30</td>
<td>96.0 – 113.0</td>
</tr>
</tbody>
</table>

*Hypothesis 3*

It was hypothesized that prior risk status for developmental delays, assessed in infancy during the participant’s first visit to the craniofacial clinic using the Bayley Infant Neurodevelopmental Screener, would be predictive of the participant’s current cognitive functioning. It was believed that participants who were at high risk for delays would evidence lower cognitive functioning than participants found to be at moderate or low risk for delays. One way ANOVAs were conducted to test this hypothesis. Table 7 presents the summary ANOVA statistics for all relevant cognitive measures. The results indicate that prior risk status for developmental delays was not a significant predictor of Verbal IQ or Processing Speed. The relationship between risk status and Performance IQ and Full Scale IQ, however, approached significance. Post-Hoc tests (Bonferroni), however, do not indicate any significant differences in the Performance IQ or Full Scale IQ scores of participants in different risk categorization groups.
Table 7:

Association between Prior Developmental Risk Status and Cognitive Functioning

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale IQ</td>
<td>2.9</td>
<td>3.36</td>
<td>0.081</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>2.9</td>
<td>1.40</td>
<td>0.297</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>2.9</td>
<td>4.08</td>
<td>0.055</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>2.6</td>
<td>2.87</td>
<td>0.148</td>
</tr>
<tr>
<td>Information</td>
<td>2.9</td>
<td>0.10</td>
<td>0.911</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>2.6</td>
<td>2.36</td>
<td>0.175</td>
</tr>
<tr>
<td>Word Reasoning</td>
<td>2.6</td>
<td>0.66</td>
<td>0.551</td>
</tr>
<tr>
<td>Receptive Language</td>
<td>1.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Block Design</td>
<td>2.9</td>
<td>2.54</td>
<td>0.134</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>2.6</td>
<td>8.53</td>
<td>0.018</td>
</tr>
<tr>
<td>Picture Concepts</td>
<td>2.6</td>
<td>3.53</td>
<td>0.097</td>
</tr>
<tr>
<td>Object Assembly</td>
<td>2.6</td>
<td>0.04</td>
<td>0.879</td>
</tr>
<tr>
<td>Coding</td>
<td>2.6</td>
<td>1.99</td>
<td>0.231</td>
</tr>
<tr>
<td>Symbol Search</td>
<td>2.6</td>
<td>6.43</td>
<td>0.041</td>
</tr>
</tbody>
</table>

When subtest scores were used in analyses to determine whether prior risk status was a predictor of performance on specific cognitive tasks, the results support the hypothesis on several subtests. Prior risk status was not a significant predictor of performance on verbal tasks, but was a significant predictor of performance on certain nonverbal and processing speed tasks. In particular, previous risk status was found to be significant predictor of performance on the Matrix Reasoning and Symbol Search subtests. Further, the relationship between risk status and performance on the Picture Concepts subtest approached significance. Post hoc analyses (Bonferroni) indicate that the significant difference in scores on these subtests appear between those individuals in the Moderate Risk group and those in the High Risk group. Further, the data indicates that children in the Moderate Risk group had the highest scores on these subtests, with those in the Low Risk group having the next highest group and those in the High Risk
group having the lowest scores. In general, participants in Moderate Risk group had the highest scores on the Performance and Processing Speed subtests, while participants in the Low Risk group had the highest scores on the Verbal subtests. Overall, statistical analyses revealed that developmental risk status during infancy was not predictive of verbal functioning, but did impact nonverbal functioning and processing speed.

*Hypothesis 4*

It was hypothesized that previous risk status for developmental delays would also be predictive of the participant’s current language functioning. It was believed that participants categorized as being at High risk for delays would obtain the lowest scores on the language measure, followed by participants determined to be at Moderate risk, and then finally those at Low risk for delays. To test this hypothesis, one way ANOVAs were again conducted with the language variables as the outcome variable and previous risk status as the predictor. Table 8 presents the summary ANOVA statistics for the relevant language variables. Previous risk status was not found to be predictive of current language development as there were no differences in the scores of participants who were previously categorized as being at High, Moderate, or Low risk for delays.

Table 8:

*Association between Prior Risk Status and Language Functioning*

<table>
<thead>
<tr>
<th></th>
<th>df</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoken Language Composite</td>
<td>2, 9</td>
<td>0.307</td>
<td>0.743</td>
</tr>
<tr>
<td>Receptive Language Composite</td>
<td>2, 9</td>
<td>1.026</td>
<td>0.397</td>
</tr>
<tr>
<td>Expressive Language Composite</td>
<td>2, 9</td>
<td>0.050</td>
<td>0.952</td>
</tr>
</tbody>
</table>
Hypothesis 5

It was hypothesized that severity of the plagiocephaly, or cranial flattening, would be related to cognitive functioning. It was believed that participants characterized as having more severe cranial flattening would obtain lower cognitive scores than participants with less severe flattening. Data regarding cranial asymmetry in infancy was not available for one of the participants', as such this participant was excluded from the analyses. Further, only one of the participants’ was rated to have had severe cranial asymmetry, and this participant was also excluded from the analyses. As a result, only the 10 participants with the severity rating of mild asymmetry or moderate asymmetry were included in this analysis. Pearson product-moment correlations were conducted to assess the relationship between cranial asymmetry and cognitive functioning.

Table 9 displays the correlation statistics for all relevant cognitive variables. There were no statistically significant correlations noted between cranial asymmetry and cognitive composite scores. However, strong correlations were noted between severity and several variables. In particular, moderate negative correlations were noted between severity of plagiocephaly and Verbal IQ ($r = -0.61$). This suggests that children with mild cranial asymmetry had higher Verbal IQs than children with moderate cranial asymmetry. In contrast, moderate positive correlations were noted severity of plagiocephaly and Processing Speed Index ($r = 0.46$), indicating that children with moderate cranial asymmetry obtained higher scores on the Processing Speed tasks than children with mild asymmetry. This correlation data does suggest that the degree of cranial asymmetry is related to certain cognitive composite scores in children with deformational plagiocephaly.
When the relationship between cranial asymmetry and performance on individual subtests was examined, again no statistically significant correlations were noted. Strong relationships between asymmetry and scores on several of the subtests were, however, again found. Moderate negative correlations was found between asymmetry and performance on Word Reasoning \((r = -0.64)\), a verbal subtest. Further, the other verbal subtests, Information and Vocabulary, were also negatively correlated with cranial asymmetry, though those correlations were fairly low. As such, in general, children with mild cranial asymmetry appear to obtain higher scores on verbal tasks than children with moderate asymmetry. Moderate positive correlations were noted on two of the subtests as well – Symbol Search \((r = 0.45)\) and Block Design \((r = 0.36)\). Additionally, correlations between degree of asymmetry and nonverbal tasks (Performance and Processing Speed) were generally positive, indicating that children with moderate asymmetry performed better on these tasks than children with mild asymmetry.

Table 9:  
Association between Cranial Asymmetry and Cognitive Functioning

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>r</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Scale IQ</td>
<td>10</td>
<td>-0.12</td>
<td>0.744</td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>10</td>
<td>-0.61</td>
<td>0.061</td>
</tr>
<tr>
<td>Performance IQ</td>
<td>10</td>
<td>0.25</td>
<td>0.491</td>
</tr>
<tr>
<td>Processing Speed Index</td>
<td>8</td>
<td>0.46</td>
<td>0.252</td>
</tr>
<tr>
<td>Information</td>
<td>10</td>
<td>-0.33</td>
<td>0.354</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>8</td>
<td>-0.29</td>
<td>0.479</td>
</tr>
<tr>
<td>Word Reasoning</td>
<td>8</td>
<td>-0.64</td>
<td>0.086</td>
</tr>
<tr>
<td>Receptive Language</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Block Design</td>
<td>10</td>
<td>0.36</td>
<td>0.309</td>
</tr>
<tr>
<td>Matrix Reasoning</td>
<td>8</td>
<td>0.27</td>
<td>0.518</td>
</tr>
<tr>
<td>Picture Concepts</td>
<td>8</td>
<td>0.31</td>
<td>0.463</td>
</tr>
<tr>
<td>Object Assembly</td>
<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coding</td>
<td>8</td>
<td>0.45</td>
<td>0.311</td>
</tr>
<tr>
<td>Symbol Search</td>
<td>8</td>
<td>0.32</td>
<td>0.491</td>
</tr>
</tbody>
</table>
Hypothesis 6

Additionally, it was hypothesized that the severity of the cranial flattening would have an impact on the participant’s language scores. Again it was hypothesized that participants noted to have more severe flattening would have lower language scores in comparison to participants with less severe cranial flattening. Pearson Correlations were conducted to determine whether there is an association between the participants’ cranial asymmetry and language scores. Table 10 presents the correlation statistics for all relevant language variables. The data suggests that severity of cranial flattening was not significantly associated with language development. The relationship between cranial asymmetry and language functioning was negative, indicating that children with milder asymmetries had obtained higher scores, but it was very weak. Therefore, the participant’s cranial asymmetry does not appear to be related to their language development.

Table 10:

*Association between Cranial Asymmetry and Language Functioning*

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>r</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spoken Language Composite</td>
<td>10</td>
<td>-0.19</td>
<td>0.591</td>
</tr>
<tr>
<td>Receptive Language Composite</td>
<td>10</td>
<td>-0.31</td>
<td>0.391</td>
</tr>
<tr>
<td>Expressive Language Composite</td>
<td>10</td>
<td>-0.01</td>
<td>0.988</td>
</tr>
</tbody>
</table>

Additional Exploratory Analyses

Beyond the hypotheses of the study, additional analyses were conducted to determine whether the clinical variables, obtained through parent report and chart review,
were associated with the participants’ cognitive and language functioning. One way ANOVAs were conducted with the cognitive and language composite scores as the dependent variable and the clinical variables, such as maternal health complications during pregnancy and gestational age at time of birth, as the independent variables to determine whether there were any associations. The majority of the clinical variables were not noted to be associated with the participants’ cognitive and language composite scores. In particular, none of the prenatal and delivery variables were found to be associated with the participants’ cognitive and language scores. The treatment that the participants received to ameliorate the cranial flattening was also not found to be related to the participants’ cognitive and language scores.

One clinical variable that was found to be associated with the participants’ cognitive and language scores was whether the participant had received any intervention services (speech and language therapy (Speech), physical therapy (PT), occupational therapy (OT)) in the past. Significant differences were noted between participants who had and had not obtained intervention services on Verbal IQ (F = 9.216, \( p = 0.013 \)) and the Spoken Language composite (F = 5.194, \( p = 0.046 \)). The children who had received therapy services obtained significantly lower scores (Mean = 95.3) on these composites than children who had not received therapy services (Mean = 108.1). Further, participants who obtained multiple types of intervention services (Speech and PT, OT and PT, or all three) had much lower scores on all of the cognitive and language composites than participants who had only obtained only one type of therapy service (primarily PT) and participants who had not received any services.
Table 11:

*Cognitive and Language Results of Participants who have and have not received therapeutic service.*

<table>
<thead>
<tr>
<th></th>
<th>Mean FSIQ (n)</th>
<th>Mean VIQ (n)</th>
<th>Mean PIQ (n)</th>
<th>Mean Spoken Language (n)</th>
<th>Mean Receptive Language (n)</th>
<th>Mean Expressive Language (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Therapy Services</td>
<td>82 (2)</td>
<td>91 (2)</td>
<td>80 (2)</td>
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</tr>
<tr>
<td>One Therapy Service</td>
<td>112.5 (2)</td>
<td>101.5 (2)</td>
<td>120 (2)</td>
<td>102.5 (2)</td>
<td>109 (2)</td>
<td>95.5 (2)</td>
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<tr>
<td>No Therapy Services</td>
<td>105.9 (8)</td>
<td>108.1 (8)</td>
<td>100.8 (8)</td>
<td>113.5 (8)</td>
<td>113.3 (8)</td>
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Deformational plagiocephaly, a craniofacial condition where an infant’s cranium becomes flattened in the occipital region due to intrauterine constraints and gravity, has recently gained much attention in the medical literature and community. In 1992, American Academy of Pediatrics recommended that all children be placed in a supine rather than prone position for sleep. Since that time there reportedly has been a 3 to 6 fold increase in the number of children seen in craniofacial clinics across the country with this diagnosis (Biggs, 2003; Loveday & de Chalain, 2001). Given the increasing number of children diagnosed with this condition, it is imperative that the potential long-term consequences of this condition be studied.

A few studies have examined the consequences of this condition on cognitive and language development, and these studies have suggested that children with deformational plagiocephaly are at risk for deficits and delays in these areas (Balan Kushnerenko, Sahlin, Huotilainen, Naatanen, & Hukki, 2002; Miller & Clarren, 2000; Panchal, Amirshyebani, Gurwitch, Cook, Francel, Neas, & Levine, 2001). However, as the number of studies on this topic is quite limited and these studies have mostly used informal assessments methods, it is difficult to derive strong conclusions based on these studies. In addition, these studies have only assessed the children’s functioning at a single time point rather than multiple time points, which does not allow for any conclusions to be drawn about whether cognitive functioning improves over time, as it has been proposed (American Academy of Pediatrics, 1996; Bridges, Chambers, & Pope, 2002; Wall, 2002). Nor do these studies assess the effect the severity of the condition has
on cognitive and language functioning. The present study was conducted with the intent to address some of these concerns.

The current study evaluated the cognitive and language functioning of preschool age children who were diagnosed with deformational plagiocephaly in infancy. All of the participants had undergone developmental screenings during infancy to determine their developmental risk status, so assessment of functioning over time was possible. Further, the severity of the participants' cranial asymmetry was also assessed in infancy and used in the analyses to determine its potential effect on participants' cognitive and language functioning.

Hypothesis 1

The first study hypothesis was not supported in that the cognitive functioning of the participants was on average noted to be on par with that of same-aged peers when their performance on the cognitive measures was compared to the normative sample. The mean cognitive composite scores were all in the Average range, and majority of the participants obtained composite scores that were in the Low Average to Superior range. Only one participant obtained cognitive scores in the Borderline range, and even that participant's VIQ and PSI were in the Average range. Further, z-tests comparing the participant's scores to normative sample indicated that there were no statistical differences between them. When subtest scores are examined, the Mean scores were again noted to be in the Average range and z-tests indicated that there are no statistical differences between the participants' performance and that of the normative sample on majority of the subtests. One subtest on which there were statistical difference between
the study participants and the normative sample was Vocabulary. However, contrary to the hypothesis that the study participants will not perform as well as normative sample on the subtest, the study participants actually performed significantly better than the normative sample on the subtest.

One intriguing aspect of the study data is the large Verbal IQ (VIQ) and Performance IQ (PIQ) discrepancy evidenced by a significant percentage of the study participants. Fifty eight percent of the participants evidenced significantly large discrepancies between their VIQ and PIQ. Thus, on a clinical note, the FSIQs of these participants would not be considered to be an accurate reflection of their overall cognitive functioning and would not be reported. However, for the purposes of this study, it was felt that the scores should be reported to demonstrate how skewed the picture becomes when there is a large discrepancy between Verbal and Performance scores. Importantly, there was no consistency on which IQ score was higher as almost an equivalent number of participants obtained VIQs greater than PIQs and PIQs greater than VIQs.

There are no evident reasons why such a large number of participants exhibited these discrepancies. The PIQ > VIQ discrepancies evidenced by some of participants may be explained as being related to linguistic issues. Two of the three participants who evidenced larger PIQs than VIQs were from bilingual homes where both English and Spanish were broken. Children from bilingual homes often exhibit delays early on and this could be a reason for the PIQ-VIQ discrepancy they exhibit. For the participants with higher VIQs, one possible explanation for this result may be that a subgroup of the participants has visual impairments that have not been identified. In fact, a recent study has noted that children with deformational plagiocephaly may have visual field defect,
which prevents them from perceiving their environment accurately (Siatkowski, Fortney, Nazir, Cannon, Panchal, Francel, et al., 2005). As such, it may be that the participants with the lower PIQ just have visual field abnormalities that are impacting their performance on nonverbal tasks. However, without additional research, no clear explanation for these deficits can be posited.

Importantly, however, given that a significant number of the participants evidence significant VIQ-PIQ splits, concerns regarding the impact these discrepancies may have on future development are raised. Some studies have examined the effect of VIQ-PIQ discrepancies on neuropsychological and academic functioning in older child and adolescent psychiatric populations, and have found that PIQ > VIQ discrepancies were associated with learning disabilities in reading, spelling, and math (Gilger & Greary, 1985; Leuger, Albott, & Hilgendorf, 1985). VIQ > PIQ discrepancies, in contrast, are noted to indicate deficits in visuospatial processing, visual motor integration, and the ability to solve novel problems (Sattler, 2001). Further, large VIQ > PIQ discrepancies are noted to be a classic sign of the presence of nonverbal learning disability (NLD) in children above the age of 7 years (Drummond, Ahmad, & Rourke, 2005; Pelletier, Ahmad, & Rourke, 2001). There has been no studies examining the presence of NLDs in children below the age of 7, but it may be that the study participants who are evidencing the large VIQ > PIQ splits are evidencing symptoms that are a precursors to a diagnosis of NLD. Additionally, in anecdotal conversations, several of the parents of study participants evidenced concerns about their child’s socioemotional development, which is another area of deficit in children with NLDs.
As the majority of the study participants were too young for academic achievement and more comprehensive neuropsychological evaluations at this time, this will need to be addressed in the studies with older children to understand the long-term consequences of VIQ-PIQ discrepancy in this population. Further, examining the potential consequences of these discrepancies raises concern regarding how the participants with VIQ > PIQ will perform on verbal cognitive tasks as these tasks become abstract and dependent on problem solving, rather on just acquired knowledge. However, initially it is important to try to understand the cause behind the discrepancies, as many of the possible long-term consequences may be negated if the significantly lower PIQs evidenced by a percentage of the participants were the result of visual field deficits rather than deficits in visual-spatial processing or nonverbal problem solving.

In sum, however, the study data suggests that the children diagnosed with deformational plagiocephaly did not evidence deficits in overall cognitive functioning. This data is not consistent with some of the existing literature on cognitive development in children with deformational plagiocephaly (Miller & Clarren, 2000; Panchal, Amirshybani, Gurwitch, Cook, Francel, Neas, & Levine, 2001; Steinbok, Lam, Singh, Mortenson, & Singhal, 2007). Miller and Clarren (2000) and Steinbok et al (2007) found that a larger percentage of children diagnosed with deformational plagiocephaly received special education services (learning assistance, special education classroom, physical therapy, etc) in school than the regular population. Panchal et al (2001) found that when the development of infants diagnosed with deformational plagiocephaly was evaluated using the Bayley Scales of Infant Development, Second Edition (BSID-II), a significant percentage of the infants were found to evidence significant delays on the both Mental
and Psychomotor Developmental Index. These three studies suggest that children diagnosed with developmental plagiocephaly exhibit some deficits in their development and/or cognitive functioning.

The current study, while not indicating that children with deformational plagiocephaly exhibit delays in cognitive functioning, does not necessarily contradict the conclusions of previous studies either. With respect to the Panchal et al (2001) study, the significant disparity in the ages between participants in that study and the participants in the current study result in the data not being directly comparable. Panchal et al assessed the developmental functioning of children with deformational plagiocephaly in infancy, while the current study evaluates the cognitive and language functioning of children during the preschool years. It may be that children diagnosed with deformational plagiocephaly do evidence some delays in development early on, but the delays are not evident by their preschool years. In fact, even in this study, the early developmental screening data, obtained through the administration of the Bayley Infant Neurodevelopmental Screener (BINS), available for the current study participants, does suggest the presence of developmental delays. The majority of the study participants were noted to be at Moderate to High risk for delays. This data is roughly consistent with that of Panchal et al in noting that developmental delays are present in a significant percentage of children diagnosed with deformational plagiocephaly during infancy. However, the delays may not be evidenced in the preschool years. This may be due to interventions (formal or informal) that the child has received over those first few years of life and/or it may be that, as noted above, the preschool age child is not yet at the age to exhibit the deficits that were foreshadowed in infancy and toddlerhood.
In terms of Miller and Clarren (2000) and Steinbok et al (2007) studies, the current study did not examine academic achievement or learning disabilities as outcome variables or conduct physical therapy, occupational therapy, or speech and language therapy evaluation; and as such results cannot not be readily compared. The caregivers were asked in the demographic questionnaire whether the children had received physical therapy, occupational therapy, or speech and language therapy in the past, or are currently receiving special education services under an individual education plan. The results indicated that 33% of participants had received some form of therapy in the past, with the majority obtaining physical therapy, but only one participant is currently in a special education program. Further, even among therapies obtained in the past, the participants who had received services had obtained very few sessions (the maximum being 6 visits). While these results do not seem to be consistent with that Miller and Clarren or Steinbok et al, even this data is not readily comparable as the current study participants were not similar in age to the participants in those studies and did not have similar academic demands. The majority of the participants in the current study were not old enough to have many academic demands placed on them or be assessed for learning disabilities. As such, it may be that children diagnosed with deformational plagiocephaly may require additional support with the academic demands as they grow older.

During the preschool years, children diagnosed with deformational plagiocephaly appear to be on target with their cognitive development. However, the minor deficits that they demonstrate at this time, such as verbal – nonverbal ability discrepancies, can develop into more significant concerns in the future as the children become older and have more cognitive and academic demands placed on them. Experiencing more
difficulty in a particular area leads to frustration and stress when dealing with tasks within that area, often causing the child to avoid those tasks. This can result in the child developing significant deficits in certain skill areas as he fails to grow in those areas along with his peers. Further, given that fluid reasoning, or the ability to solve novel problems, appears to be an area of relative weakness for children with deformational plagiocephaly, it is likely that they will express delays when having to learn new tasks, particularly those related to abstract reasoning. Additionally, in an academic environment where they have to acquire new skills in multiple areas, the children may struggle and need additional services and support. Therefore, children with deformational plagiocephaly may perform similarly to their peers on cognitive tasks during the preschool years, but the presence of certain deficits suggest that they may develop significant cognitive and academic difficulties as they grow if they are not regularly monitored and supported.

Based on the current study data, children with deformational plagiocephaly appear to be on par with their peers, in terms of cognitive functioning, by the preschool years. This conclusion is fairly consistent with the most popular theory on the long-term outcome of children with deformational plagiocephaly, which states that the condition is primarily cosmetic and has no significant long-term consequences in terms of cognitive development (American Academy of Pediatrics, 1996; Bridges, Chambers, & Pope, 2002; Wall, 2002). Importantly, this belief that there are no long-term consequences to deformational plagiocephaly in infancy is similar to the belief that many researchers previously had regarding the effects of traumatic brain injury (TBI) during early childhood on long-term cognitive development. Early TBI researchers believed that brain
is quite plastic in early childhood and that any insults occurring during this period results in less structural damage and functional deficits and better long-term outcomes (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005; Aram & Enkleman, 1986; Donders & Warschausky, 2007; Stiles, 2000). In contrast, more recent research has been demonstrating that children with TBIs that occurred in early childhood demonstrate deficits in multiple skill areas including intellectual functioning, information processing, attention, memory, and social development (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005; Donders & Warschausky, 2007; Ewing-Cobbs L, Fletcher JM, Levin HS, et al; 1997; Taylor & Alden, 1997). While the level of deficits appears to be mediated by the severity of the TBI, many children with mild TBIs evidence deficits as well (Parker, 1994). Many of the earlier studies suggesting brain plasticity had only examined functioning within a short period after the injury, as such during the preschool years, and did not find any deficits (Stiles, 2000). It was not until research began examining the consequences of the condition beyond the preschool years, that children with TBIs were noted to have deficits in higher order functioning. These deficits are noted to impact the developmental process, limiting the children’s ability to learn new skills and creating a gap between the functioning of children with TBIs and their non-clinical peers (Anderson, Catroppa, Morse, Haritou, & Rosenfeld, 2005). It is possible that, similar to children with TBIs, children diagnosed with deformational plagiocephaly may not begin to evidence deficits in cognitive until they have reached abstract higher order tasks. Further, this is may be seen as an even more plausible hypothesis given the significant discrepancies in the IQ profiles of the children in this sample. Therefore, it is
imperative that future studies examine the cognitive development of children with deformational plagiocephaly beyond the preschool years.

In sum, the study results seem to indicate that at least by the preschool years, children with deformational plagiocephaly are very similar to their peers in terms of their cognitive functioning. However, there are some gray areas in the data that suggest that outcomes might be more variable. In particular, the large VIQ and PIQ discrepancies and relative difficulties the majority of the participants experienced with nonverbal tasks indicate that they may evidence more deficits and delays in the future when tasks are focused on problem solving and abstract reasoning. Further, the children do not have much cognitive or academic demand at this time, and given their probable difficulty with learning novel skills, it is imperative that additional more comprehensive evaluations are conducted in future to determine whether children with deformational plagiocephaly are really similar to their peers in terms of their cognitive functioning.

*Hypothesis 2*

The majority of the study participants obtained language scores that were in the Average to Above Average range as well. The mean Spoken Language, Receptive Language, and Expressive Language composites were all in the Average range. Further, z-tests comparing the participants' language composite scores to that of normative sample indicated no significant differences. These results contradict the study hypothesis that children with deformational plagiocephaly will obtain lower scores than the normative samples on all measures of language.
The results are not consistent with a previous study that examined language functioning in this population and reported language delays (Habal, Leimkuehler, Chambers, Scheuerle, & Guilford, 2003). Habal et al found that over 60% of the study participants obtained below average scores on language assessments. In contrast, in the current study, only one participant (8% of the sample) was found to have below average language scores. This discrepancy, as with hypothesis one may also be due to differences in the ages of the study participants. Habal et al examined the language functioning of children from 3 months to 13 years, and majority of the participants who exhibited speech and language delays were much younger than the participants of the current study. The participants in Habal et al study who evidenced delays were generally between 5 months and 2 years, with only one individual over 3 years being diagnosed with a speech and language disorder. This is more consistent with the results of the current study, and again suggests that children with deformational plagiocephaly may exhibit more delays in infancy but do not really seem to evidence any delays by their preschool years, and perhaps beyond.

Additionally, these results do not support the conclusions that Balan et al (2002) derived based on their research on auditory event related potentials (ERPs) in children with deformational plagiocephaly. Balan et al found that children with plagiocephaly evidenced smaller ERP waveforms than the non-medical and very similar to those seen in children with language impairments. They concluded from this that children with deformational plagiocephaly have weaker cortical sound processing abilities and possible auditory processing deficits, which might result in deficits or delays in language development. The majority of participants of the current study demonstrated Average to
Superior receptive and expressive language abilities, with only one participant exhibiting mild language delays. This data is consistent with the percentage of language impairments seen in the general population. Overall, these results suggest that children with deformational plagiocephaly do not demonstrate language delays or deficits by their preschool years. It may be that children with deformational plagiocephaly evidence non-typical auditory ERPs, but these differences do not seem to be reflected in their language functioning, at least during the preschool years.

**Hypothesis 3 & 4**

A third premise of this study was to examine whether there were any associations between early development and later cognitive and language functioning in children with deformational plagiocephaly. The study was intended to examine whether there were any differences in cognitive and language functioning at the preschool years between children who were diagnosed to be at low, moderate, and high risk for developmental delays in infancy. Research, in general, suggests that early development is not predictive of later functioning, and low correlations are noted between performance on early development assessment tools, such as the Bayley Scales of Infant and Toddler Development or the BINS, and performance on later cognitive assessment tools, such as the Wechsler scales (Crowe, Deitz, & Bennett, 1987; Seigel, 1979). As such, strong relationships between the participants’ performance on the BINS and performance on the WPPSI-III or the TELD was not expected, but some difference in performance on the WPPSI-III and TELD was expected based on prior development risk status.
Limited relationships between prior developmental risk status and current cognitive and language functioning was found in the current study. In terms of cognitive functioning, no significant differences were found on Verbal IQ or Processing Speed Index based on developmental risk status. However, with respect to Full Scale IQ and Performance IQ, the relationship with prior developmental risk status revealed a trend in the direction of the study hypothesis. This suggests that prior developmental risk status may have an impact on the development of nonverbal skills. Post hoc evaluations, however, did not indicate the presence of any differences between the FSIQ and PIQ scores of the three risk groups (low, moderate, and high). As current outcomes may be due to small sample size of the study this area requires further investigation.

Significant differences were noted between the three developmental risk groups (low, moderate, and high) on several of the cognitive subtests. In particular, prior developmental risk status appeared to be a statistically significant predictor of performance on the Matrix Reasoning and Symbol Search subtests, and the relationship between risk status and performance on the Picture Concepts subtest approached significance. No statistically significant differences were noted between the three developmental risk groups on the verbal subtests. As such, prior risk status appears to be strong predictor of the development of nonverbal skills, but not on verbal skills.

It is not clear at this time why developmental risk status is associated with nonverbal abilities and not with verbal abilities and information processing. One possible explanation for this relationship is that children with deformational plagiocephaly often have sternocleidomastoid muscle problems in addition to the cranial flattening, which result in tight neck muscles, limited range of neck movement, and head tilt.
Sternocleidomastoid muscle problems are also associated with gross and fine motor delays in infancy, which could be reflected in their developmental risk status potentially even as a preschooler. These neuromuscular problems might also impact the ability of children with deformational plagiocephaly to develop visual-perceptual and visual-spatial-motor skills, as they would have difficulty tasks associated with these skills. The head tilt and limited range of neck motion might prevent them from seeing their environment accurately and completing visual-perceptual tasks. The tight neck muscles and head tilt plus the gross motor delays would cause them difficulty on visual-spatial-motor tasks. As such, the developmental risk status, marked by the delays in gross and fine motor functioning, and nonverbal functioning during the preschool years could be related. Additionally research examining the connection between motor functioning in infancy and later cognitive development in this population is needed.

Additionally, post hoc evaluations indicated that the difference in scores on the nonverbal subtests were occurring between individuals in Moderate and High risk groups, rather than between Low and Moderate or Low and High groups. Even more interestingly, the children in Moderate risk group evidenced the highest mean scores of all three groups on all of the nonverbal tasks. However, the mean scores of the moderate risk group were not much higher (i.e. not clinically significant) than the scores of the low risk group on these subtests. Scores on verbal tasks were more mixed with children in low risk group obtaining majority of the highest mean scores. This phenomenon of the moderate risk group having higher mean scores in likely due to more study participants having been noted to be at moderate risk for delays (6) than at low risk for delays (2). However, another intriguing explanation that may need to be given some thought is
whether parents of children noted to be at moderate risk experienced more concern regarding their child’s development and followed the recommendations of the pediatric psychology and team recommendations more stringently than the parents of children noted to be at low risk for delays. The distribution of individuals among the different risk groups, however, is more likely the explanation for this phenomenon. This uneven distribution of individuals is also one of the limits of the study as this weakens conclusions that can be drawn from this data.

Finally, in terms of language functioning, no significant differences were noted between the three developmental risk groups on the participants’ language composite scores. The children in the high risk groups performed as well on the language tasks as children in the low and moderate risk groups.

In general, prior risk status does not appear to have any impact on the development of verbal skills, but does appear to impact the development of nonverbal skills. One implication that was previously raised that can be restated again is that children with deformational plagiocephaly may demonstrate some developmental delays in their infancy, but seem to be on par with their non-clinical peers by their preschool years. The majority of the study participants were assessed to be at moderate to high risk for delays in their infancy, but performed in the Average to Above Average range on the cognitive and language measures during the preschool years. However, nonverbal functioning does appear to be an area of relative weakness for a significant percentage of the study participants and it is noted to be impacted by their prior functioning, suggesting it is an area of concern that needs to be assessed further. One possible explanation for this relationship is that the prior risk status may be reflecting the participants’ gross and fine
motor development which may be secondary to their sternocleidomastoid problems, and which could result in deficits in visual-perceptual and visual-spatial-motor skill development. Additional research is necessary to confirm or refute this hypothesis.

_Hypothesis 5 & 6_

Hypothesis 5 and 6 addressed the relationship between the cognitive and language variables and the severity of cranial flattening evidenced by the study participants. The current study hypothesized that individuals with more severe forms of deformational plagiocephaly will evidence lower scores on the cognitive and language measures than individuals with less severe forms of the condition, given the sequelae associated with the more severe forms of the conditions. The study results indicated that the correlations between severity of the plagiocephaly and the cognitive and language variables were not statistically significant. However, strong relationships were noted between cranial asymmetry and several of the cognitive variables. Moderate negative correlations were noted between severity of cranial flattening and Verbal IQ and one verbal subtest, Word Reasoning. These correlations indicate that the participants with moderate cranial asymmetry had lower Verbal IQs and lower scores on the Word Reasoning subtest than participants with mild asymmetry. Moderate positive correlations, however, were noted between cranial asymmetry and Processing Speed Index and several nonverbal subtests, including Symbol Search and Block Design, which suggests that the participants with moderate asymmetry had higher scores on these subtests as well as on the Processing Speed Index.
These results appear to suggest that the degree of cranial asymmetry has some impact on the development of verbal skills. Negative correlations were noted between cranial asymmetry and all of the verbal and language scores, though outside of Verbal IQ and the Word Reasoning subtest, the correlations were all quite weak. This indicates that the participants with the milder cranial asymmetry, on average, obtained higher scores on verbal and language tasks than participants with moderate asymmetry. One possible explanation for the strong negative correlation between cranial asymmetry and Verbal IQ may be that as the condition becomes more severe, it may be affecting the pathways involved in acquiring, storing, and retrieving verbal knowledge. Insult to this pathway would limit a person’s ability to respond to verbal problems. Alternatively, due to the small sample size, the strong relationship between Verbal IQ and cranial asymmetry could be a random artifact of this data.

In contrast, the correlations between cranial asymmetry and nonverbal tasks (Performance IQ and Processing Speed tasks) were all positive, indicating the participants with the moderate asymmetry, on average, had higher scores than participants with milder asymmetry. This data appears to suggest that severity of cranial asymmetry has no impact on the development of nonverbal skills. As such, it may be that there is no relationship between severity of cranial asymmetry and nonverbal skill development. Similarly, research examining visual development in children with deformational plagiocephaly have noted increased incidence of visual field constrictions in this population; however, the degree of constriction does not appear to be impacted by degree of cranial asymmetry (Siatkowski, Fortney, Nazir, Cannon, Panchal, Francel, et al., 2005). Thus both the literature and the current study suggest that children with
deformational plagiocephaly may be at risk for visual and visual spatial deficits, but that these deficits do not correspond linearly to the severity of plagiocephaly.

An alternate explanation for the lack of relationship between cranial asymmetry and nonverbal performance may be that it is limited by the subjectivity of the physician’s ratings regarding severity of asymmetry. As the severity of asymmetry ratings are derived through the pediatrician’s subjective visual inspection of the participant’s cranium, it is possible that one provider could have rated a child’s skull as being moderately asymmetric while another provider classifies the same child’s skull as being mildly asymmetric. Thus, the ratings of cranial asymmetry for the study participants may be have been different if they had been assessed by a different pediatrician. In this manner, the relationship between cranial asymmetry and nonverbal performance could be limited by the subjectivity in assessing cranial asymmetry.

Finally, the small number of participants in this study limits any conclusions that can be drawn from this data regarding the relationship between cranial asymmetry and cognitive and language development. It is quite possible that the relationships noted with this data may disappear if additional participants were included in this study. As such, it is not clear at this time whether a strong relationship between severity of plagiocephaly and cognitive and language development exists. However, based on this data, there appears to be a relationship between asymmetry and verbal skill development, but not between asymmetry and nonverbal skill development.
Clinical Variables and Additional Exploratory Analyses

Additional clinical data was obtained through parent questionnaire and medical chart review so as to have a better understanding of the participants’ developmental profiles. Information of note from the clinical data was that a large percentage of the participants’ parents reported that there were significant maternal health complications during the pregnancy. As some hypotheses regarding the pathogenesis of plagiocephaly implicate the flattening to have begun prenatally, this raises some concerns whether there are any associations between these factors. While, this is out of the scope of this current study, it does bear examining in future studies. Another interesting point is that not all participants had received treatment to ameliorate the cranial flattening and whether the participant had obtained treatment appeared to be dependent on the severity of the flattening. The majority of the participants with mild flattening did not obtain any intervention, while all the participants with the moderate to severe flattening obtained some treatment. This suggests that participants’ with mild flattening did not need intervention to resolve that flattening, but that individuals with more severe flattening did need some treatment. Based on this, it appears that moderate to severe cranial flattening does not resolve without some clinical intervention, contradicting some researchers who indicate that the condition resolves on its own (Bridges, Chambers, & Pople, 2002; Wall, 2002).

Further, additional exploratory analyses were conducted to determine whether any of the clinical variables were associated with the participants’ cognitive and language functioning. It was interesting here to note that none of the prenatal or delivery variables were associated with the participants’ cognitive and language functioning. It was also
interesting that the type of treatment the participants obtained for the cranial flattening was not associated with their cognitive and language development. Participants who had worn molding helmets performed just as well on cognitive tasks as participants who had received the exercises and counterpositioning and participants who had not received any services.

Finally, receiving therapeutic services (speech, PT, OT) did appear to have some relationship to the participants’ cognitive and language functioning, especially on the verbal domains. Participants’ who had received therapeutic services were noted to have lower scores than participants who had not, with participants receiving multiple therapeutic services obtaining the lowest scores. One hypothesis for this is that participants obtaining the services were the more impacted than participants who had not and needed therapeutic services to address their deficits. In examining this further, the developmental risk status in infancy of the participants who had obtained therapeutic services were found to be in the moderate to high risk range, suggesting they had experienced some delays in their development early on. Further, the two participants who had received multiple therapeutic services were both at high risk for delays. This supports the hypothesis that these participants may have been more impacted and needed therapeutic services to enhance their functioning. This data also supports the need for early detection of developmental delays in the population and hence the benefit of early developmental screening as was done in this population.
Implications

The primary conclusion that can be drawn from this study is that children with deformational plagiocephaly in general exhibit Average to Above Average cognitive and language during the preschool years. They may be at risk for delays or exhibit delays in infancy, but appear to be on par with same-aged peers by about 3-5 years of age. However, this does not necessarily mean that there are no long term consequences to the condition. One piece of evidence that has already appeared that suggests that there might be some long term consequences are the large VIQ-PIQ discrepancies evidenced by a significant number of the study participants. These discrepancies have been associated with learning disabilities in reading, math, and spelling; visuospatial processing difficulties; deficits in problem solving; and nonverbal learning disorders. As the children grow older and face more cognitive and academic demands, it may be that they develop one or more of these learning difficulties. Therefore, it is imperative that these children’s functioning be monitored regularly through comprehensive assessments to rule out any of these difficulties and optimize their functioning.

Additionally, the results of the study indicated that prior risk status is not associated with language and verbal skills development in the children with deformational plagiocephaly, but is associated with the development of nonverbal skills, such as visuospatial processing and the ability to solve novel problems. In this study, children at low and high risk for developmental delays in their infancy obtained lower nonverbal scores than children at moderate risk, though all three groups were generally in the Average range in terms of cognitive and language functioning. This suggests that developmental screenings and assessments in infancy are necessary and can be a benefit
for children with deformational plagiocephaly as it can identify those at risk for delays and provide recommendations for reducing the risk and improving their nonverbal skills.

Finally, the study data seemed to indicate that there is a strong, but non-significant, relationship between severity of cranial asymmetry and verbal skill development. The participants with moderate cranial asymmetry had lower scores on the verbal cognitive and language measures than the participants with mild cranial asymmetry. In contrast, no relationship was found between cranial asymmetry and nonverbal skills development. Though no formal conclusions can made given the dearth of children with severe cranial flattening in the study and the subjectivity of the rating system, this data does seem to suggest that severity of cranial asymmetry only impacts verbal development.

Limitations

There are several limitations to this study that preclude its results from being generalized. The primary limitation of this study is its small sample size. The initial list of children eligible to participate in this study was much smaller than expected, which eliminated the ability to obtain as many study participants as hoped. The main reason for the less than optimal eligibility list was the inclusion criteria that participants of this study had to have been previously evaluated using the BINS. This criteria prevented children who had not obtained developmental screenings from participating in this study, thus significantly reducing the size of the initial eligibility pool. Further, the high number of incorrect and disconnected participant phone numbers and low response rate also impacted the recruitment of participants for this study.
An associated limitation of the study was the lack of equal distribution among the risk category groups and cranial asymmetry groups. Among the risk category groups, there were much fewer individuals in the low risk group than in the moderate or high risk groups. This likely has impacted the data and weakens any conclusions that can be drawn from this data regarding the relationship between prior developmental risk status and later cognitive and language development. Similarly, there were significantly more study participants in the mild and moderate cranial asymmetry groups than in the severe asymmetry group, which likely impacts the data and weakens any conclusions that can be drawn.

A second limitation of the study is the subjectiveness of the rating scale for severity of cranial flattening. As previously mentioned, the pediatrician makes this rating based on visual inspection of the child following certain guidelines. The subjectiveness of this rating system means that two pediatricians can each provide a different rating for the same child’s cranial asymmetry. Many studies using a subjective rating tool often have multiple raters to minimize the subjectiveness of the instrument. Multiple raters, however, were not possible in this study thus eliminating the possibility of interrater reliability as a method of minimizing the subjectiveness. As such, the subjectiveness of the rating system and lack of interrater reliability weakens any conclusions that can be drawn regarding the relationship between severity of cranial asymmetry and cognitive and language functioning.

Another limitation of the study is the lack of comparison, or control, group of age-matched children. All of the study participants were recruited from the same geographic region, which limits the generalizability of these results to children with deformational
plagiocephaly in other regions. Further, the data from study participants was not compared to that of age-matched children with no medical issues in the same geographic region, but to normative data. As such, it is not clear whether study participants have lower cognitive scores that age-matched peers but this difference is not noted because of increased cognitive functioning of the entire region, or whether there are simply no differences in overall cognitive functioning between study participants and children with no medical issues. By comparing the study participants to the normative data, any conclusions being drawn regarding whether there are differences in cognitive functioning between children with deformational plagiocephaly and children with no medical difficulties are weakened.

Self-selection bias is also a weakness of this study. The parents of the study participants all self-selected to participate in this study. This raises questions regarding whether there were differences between the children with deformational plagiocephaly that participated in the study and those that did not. It also raises the question of whether the study data is skewed in the positive direction because of this self-selection bias. The parents of the children who participated in this study may be the ones who are very active in their child’s development and seek out all possible resources to optimize their child’s functioning. As such, other children with deformational plagiocephaly, ones whose parents may not be as active in their development, may not perform quite as well on these assessment as the study participants,

A final limitation to the study is that no information was obtained regarding parent demographic factors. Parent demographic factors, such family income and parent education levels, are noted to impact child functioning, both positively and negatively.
Not obtaining this information again reduced the conclusions that can be drawn from this study.

**Future Directions**

Since the current study is the first of its kind to examine the long-term cognitive and language development of children with deformational plagiocephaly, additional studies are needed. The extremely small size of this study also suggests a need for additional research in examining the cognitive and language development in preschool age children with deformational plagiocephaly. Future research on this topic should have a larger sample size and more equivalent distribution in the developmental risk groups and cranial asymmetry. It should also be well controlled by using an age-matched comparison groups. Further, it would be beneficial to use a comprehensive developmental assessment tool rather than a screener. This would provide more detailed information regarding the participant’s cognitive, language, and motor functioning in infancy. It would also strengthen any conclusions drawn regarding the relationship between developmental functioning in infancy and later cognitive and language functioning.

The results of this study contained several intriguing facets that suggest that assessing the neurodevelopment of children with deformational plagiocephaly as they grow older is imperative. A significant percentage of the study participants evidenced large VIQ-PIQ discrepancies, which could be a precursor to developing learning disabilities in reading, math, and spelling or nonverbal learning disabilities. Further, these discrepancies suggest that learning new tasks and skills may be relatively difficult for children with deformational plagiocephaly. As such, it is important that future studies
conduct comprehensive neuropsychological evaluations on school age children with deformational plagiocephaly to rule out these concerns. Anecdotal data, conversations with parents and observations of the children, indicates the need for future research examining the socioemotional development of children with deformational plagiocephaly as well.
References


Telephone Script

Dear sir or madam

This is Dr. Kiti Freier, Pediatric Psychologist with the Craniofacial Team at Loma Linda University Children’s Hospital and Director of the Kids FARE laboratory. I am contacting you as your child, __________, underwent a developmental screening during a routine visit to the craniofacial clinic. Our lab is currently conducting a study examining the long term development of children who were screened in infancy, and we would like to invite you and your child to participate in the study. Participation in this study will involve a visit to Kids FARE, a pediatric psychology clinic. During this visit, you will be asked to fill out a questionnaire about your child, and your child will then be administered tests that would measure his (her) cognitive and language abilities by a doctoral level psychology student and supervised by a licensed pediatric psychologist. The entire visit should take approximately 3 hours of your time. As a benefit to participating in this study, you will receive a written report of the test results, which will contain information regarding your child’s developmental functioning. You may find this report to be helpful in obtaining educational or other developmental services for your child, if needed. Would you be interested in participating in the study?

- If potential client is interested: Vidhya Krishnamurthy, a doctoral psychology student from Kids FARE, will contact you to schedule an appointment. If you have any questions, please feel free to contact me at (909) 379-1507. Thank you.

- If potential client is not interested: Thank you for your time.
Informed Consent

Cognitive and Language Development of Children with Plagiocephaly

INFORMED CONSENT

Purpose and Procedure:
We would like to invite you and your child to participate in a research study for children who had plagiocephaly as an infant. The purpose of the study is to examine the development of children who have been diagnosed with plagiocephaly.

If you decide to participate, you will be asked to complete questionnaires about your child’s developmental history, behavior, and adaptive skills. A doctoral level psychology student supervised by a pediatric psychologist will assess, using standardized measures, your child’s cognitive and language functioning. You will receive a written report of the test results several weeks after the testing session. Participation in this study should take approximately 3 hours of your and your child’s time.

Risks:
While it is not expected, your child may become mildly upset or frustrated during the presentation of tasks. If this happens, breaks will be provided to help him/her calm down. However, in the event that s/he is unable to be focused back on the task you will have the following options: 1) reschedule testing for a subsequent time, 2) or discontinue your participation in this study. The committee at Loma Linda University that reviews human studies (Institutional Review Board) determined that participating in this study exposes you and your child to minimal risk.

Benefits:
You will be provided with a written report about how your child’s cognitive and language development compares with that of other children in the same age range. In the event that additional assessment and/or services are warranted, you will be provided with the appropriate referrals (e.g. school district) in your area. You will also be provided with the option of having the results of this assessment sent you your child’s physician.

Additionally, the results of this study will be shared with health care providers who work with children with plagiocephaly to improve their ability to identify those children who might be at risk for cognitive and language delays.
Participants’ Rights:
Participation in this study is voluntary. Your decision whether or not to participate or terminate at any time will not affect your child’s present or future medical care.

Confidentiality:
All results are strictly confidential. All data is kept in a locked filing cabinet and can be accessed only by authorized research personnel. You are provided with the option of including the results of this evaluation in your child’s confidential medical records. Any published document resulting from the study will not disclose your identity without your permission.

Additional Cost:
There is no cost to you for your child’s participation in this study.

Reimbursement:
There will be no monetary reimbursement for those participating in this research study.

Impartial Third Party Contact:
If you wish to contact an impartial third party not associated with this study regarding any complaint you may have about the study, you may contact the Office of Patient Relations, Loma Linda University Medical Center, Loma Linda, CA 92354, (909) 379-1507, for information and assistance.

Informed Consent:
I have read the contents of this consent form and have listened to the verbal explanation given by the investigator. My questions concerning the study have been answered to my satisfaction. I hereby give voluntary consent to participate in this study and more my child to participate in this study. Signing this consent document does not waive my rights nor does it release the investigators, institution, or sponsors from their responsibilities. I may call Kiti Freier, Ph.D. during routine office hours at 909-558-8577 should I have additional questions or concerns.

Consent Copy:
I have been given a copy of this consent form.

California Experimental Subject’s Bill of Rights:
I have received a copy of the California Experimental Subject’s Bill of Rights and have had these rights explained to me.
Signatures

This protocol has been explained to my child at a level that he/she can comprehend and I give my consent for my child to participate in the study.

<table>
<thead>
<tr>
<th>Signature of Parent of Guardian</th>
<th>Date</th>
</tr>
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</table>

I have reviewed the contents of the California Experimental Subject’s Bill of Rights and this consent form with the person signing above. I have explained potential risks and benefits of the study.

<table>
<thead>
<tr>
<th>Signature of the Investigator</th>
<th>Phone Number</th>
<th>Date</th>
</tr>
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</table>
General Demographic Questionnaire

Name of Child

Name of Parent (Informant)

Child’s Age  Child’s Gender  Ethnicity

Address

Telephone Number

1) Age at which your child was diagnosed with plagiocephaly?

2) How was the condition treated?
   a) active counterpositioning & exercise
   b) helmet therapy
   c) surgery
   d) none

3) Has your child been diagnosed with other medical problems?
   a) Torticollis or other Sternocleidomastoid problems
   b) Craniosynostosis
   c) Other craniofacial diagnoses _______________________
   d) Other medical condition _______________________

Prenatal History:

4) How was your health during pregnancy?
   a) Good
   b) Fair
   c) Poor
   d) DK

5) Did you have accidents or falls during pregnancy?
   a) No
   b) Yes
6) Were you ever told you had a small uterus?
   a) No
   b) Yes

7) Were you ever told during pregnancy that there was insufficient amniotic fluid?
   a) No
   b) Yes

8) Did you use any substances or medications during pregnancy?
   a) Beer or wine
   b) Hard liquor
   c) Caffeine
   d) Cigarettes
   e) Drugs
   f) Medications__________________________________

9) Did you have any other medical complications during the pregnancy or the delivery?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Birth History:

10) Was your child born full term?
    a) Yes
    b) No, how many weeks premature____________________

11) Were there any complications during labor or delivery?
    a) No
    b) Yes

12) Was the delivery
    a) Normal
    b) Cesarean
    c) Breech
    d) Forceps assisted
    e) Vacuum assisted

13) What was the child’s birth weight?_______________________________________
14) Were there any health complications following birth?
   a) No
   b) Yes

15) Is your child a twin—does he have a twin brother or sister?
   a) No
   b) Yes

**Developmental History:**

16) Did your child experience any health problems during infancy?
   a) No
   b) Yes

17) Was your child placed on his back when laid down to sleep during infancy?
   a) No
   b) Yes

18) Did your child prefer to sleep on one side during infancy?
   a) No
   b) Yes

19) How much tummy time did your child receive during infancy? __________

20) At what age did your child:

   Turn over ________________ Sit up ________________
   Crawl ________________ Walk ________________
   Babble ________________ Say 1st Word ________________
   String two or more words together ________________
   Become Toilet Trained: Bladder __________ Bowel __________

**Current Family Environment:**

21) Who currently lives at home?

22) How does the child get along with his parents?
   a) Better than average
23) Does the child have any siblings?
   a. No
   b. Yes, how many

24) How does he get along with his siblings?
   a. Better than average
   b. Average
   c. Worse than average

**Academic History:**

25) Does your child currently go to school or preschool?
   a. No
   b. Yes, what type and how often

26) Is your child currently receiving any of the following early intervention services or did they receive any of the following in the past?
   a. Speech and Language Therapy. How often?
   b. Occupational Therapy. How often?
   c. Physical Therapy. How often?
   d. Other How often?

27) How long has your child been receiving these Early Intervention Services?

28) If your child goes to school, what grade is he (she) currently in?

29) How does your child perform in school?
   a. Better than average
   b. Average
   c. Worse than average

30) Is your child receiving any special education services at school?
   a. No
   b. Yes, what types

**Social History:**
31) Does your child have friends—other children his/her age to play with?
   a. No
   b. Yes

32) How easily does your child make friends?
   a. Easier than average
   b. Average
   c. Worse than average

33) How does your child get along with other children in general?
   a. Better than average
   b. Average
   c. Worse than average