SPECIAL ARTICLE: Slow Learners (Borderline Intellectual Functioning)
J Korean Acad Child Adolesc Psychiatry 2024;35(3):188-191
https://doi.org/10.5765/jkacap.240013

eISSN 2233-9183

Etiology of Borderline Intellectual Functioning

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Borderline intellectual functioning (BIF), characterized by intelligence quotient scores between 71 and 84, can lead to challenges in daily life. This review explored the multifaceted nature of BIF by examining the interplay between genetic predisposition, prenatal/perinatal factors, environmental influences, and underlying medical conditions.

Keywords: Borderline intellectual functioning; Etiology; Genetics.

Received: April 10, 2024 / **Revised:** May 31, 2024 / **Accepted:** June 7, 2024

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INTRODUCTION

Individuals with borderline intellectual functioning (BIF) have cognitive abilities that range between average intellectual functioning and intellectual disability (ID) and correspond to an intelligence quotient (IQ) between 71 and 84 [1]. BIF can be differentiated from ID by examining the deficits in cognitive and adaptive functions rather than relying solely on IQ scores. The prevalence of BIF ranges from 7% to 14% [2,3].

Children with BIF often display limitations in the cognitive, motor, social, and adaptive domains of development, which can result in learning difficulties and an increased risk of developing psychiatric disorders later in life. Limitations in social and academic areas, along with learning difficulties, imply underlying cognitive impairments, particularly in attention, executive functions, gross and fine motor skills, and the development of compensatory strategies [4]. However, individuals with BIF can present with diverse clinical and cognitive profiles.

BIF is a constellation of symptoms caused by diverse etiologies rather than a single neurodevelopmental syndrome [5]. A recent study found a primary etiological cause of BIF in 245/651 cases (37.6%) [6]. The etiological causes identified in the 245 cases were pre- or perinatal causes (40.4%), genetic syndromes/chromosomal abnormalities (31.0%), neurologic condition (9.0%), maternal substance use (7.8%), cerebral dysgenesis (5.7%), brain injury (4.1%), psychosocial deprivation (1.6%), and central nervous system infection (0.4%). The number of cases in which a cause could be identified was similar in BIF and ID, which was similar to other cases of developmental delay [7-9].

The diversity in clinical and cognitive profiles indicates that a multitude of factors contribute to the condition, such as genetic predispositions, prenatal/perinatal events, and environmental factors [10].

GENETIC PREDISPOSITION

Although the development of intelligence and various cognitive functions is influenced by genetic and environmental factors, intelligence is highly heritable and is heavily influenced by genetic factors [11]. The heritability of intelligence is caused by several genes with small effects [12]. A recent large-scale genetic association study including 269867 participants identified 205 associated genomic loci and 1016 genes that were involved in the development of the nervous system and synaptic structure [13]. The heritability of intelligence increases throughout the lifespan and the same genes can affect diverse cognitive abilities [14].

Individuals with BIF often have a positive family history of BIF, ID, or other neurodevelopmental disorders, genetic syndromes, or chromosomal abnormalities [6]. Neurological conditions are more frequent among first- or second-degree relatives than in the general population. Although the association may not be as strong as in ID cases, there may be a familial trend wherein BIF can be observed across generations.

Several case reports of clinical syndromes associated with rare variants of genetic mutations have suggested that several genes may be related to intelligence or BIF. *SNAP-25* polymorphism has been linked to intelligence through the mediating role of brain morphological features among children

with BIF [15]. Additionally, case reports of BIF have observed genetic mutations in loci, including 7q11.23 [16] and 15q21.2 [17], and genes such as *CACNA1I* [18], *USP7* [19], *LRFN2* [20], and *MAGEL2* [21]. However, whether these genetic variants are specifically related to BIF or overall brain development is unclear and requires further research.

PRENATAL/PERINATAL FACTORS

Intellectual development can be affected by prenatal factors, such as advanced maternal age, exposure to alcohol or drugs during pregnancy, and maternal infection during pregnancy, and perinatal factors, such as preterm birth, low birth weight (LBW), and complications during birth. Furthermore, they are significantly associated with an increased risk of ID and can contribute to BIF.

LBW increases the risk of BIF. Studies on hospital birth cohorts have shown a higher prevalence of LBW among the adult population with BIF than among the population with average intelligence [22]. Additionally, the prevalence of BIF among individuals with LBW ranges from 13% to 24% [23].

Preterm birth, defined as birth before 37 weeks of gestation, is also associated with cognitive difficulties. In general, intelligence tends to be directly proportional to the gestational age. Preterm children are more likely to experience developmental delays, have low academic performance, and low mean IQ scores than their full-term counterparts [24]. Recent meta-analyses shows that preterm children (<32 weeks of gestational age) score an average of 11.5 to 12.9 points lower on IQ tests than full-term children [25].

Prenatal exposure to drugs, alcohol, infections, or malnutrition can influence neural development and potentially lead to BIF. The negative effects of alcohol exposure during pregnancy on the child's cognitive development have been well documented [26]. Children exposed to alcohol during pregnancy typically score in the low-average-to-borderline range on IQ tests and display impairments in visual-spatial reasoning, memory, learning, and executive functioning [27]. Maternal infections during pregnancy can have a latent effect on cognitive development and decrease the child's IQ [28].

Children's brain development can be affected by various prenatal and perinatal risk factors, which can further impact their cognitive development and contribute to the development of BIF. Therefore, it is crucial to monitor the cognitive development of children born with perinatal risk factors closely and provide early educational interventions.

ENVIRONMENTAL FACTORS

Research has shown that children with intellectual impairment are at a greater risk of exposure to early life adversities, including low socioeconomic status (SES), maltreatment, neglect, and high levels of parental/family stress. Additionally, several neuroimaging studies investigating the impact of early life adversity have shown a link between low SES, maltreatment, and neglect experienced during childhood and abnormal brain functioning and development [29-31].

Children from low-income families may be at a higher risk of developing BIF because of factors such as malnutrition, lack of early stimulation, or exposure to environmental toxins. A very large cohort study of 14000 children showed that children from low-SES families scored an average of 6 IQ points lower at age 2 than children from high-SES families. Furthermore, this difference became more pronounced with age [32]. Low SES has also been reported to affect both learning abilities and development of brain regions critical for memory and emotion regulation, such as the hippocampus and amygdala [30].

A higher number of adults with BIF had mothers with low education level than the population with average intelligence [22]. Furthermore, Farhadifar et al. [33] reported an association between maternal illiteracy and BIF in their children, suggesting that low parental education may contribute to the development of BIF.

Family structures characterized by a lack of support, enrichment, or frequent disruptions can increase the risk of developing BIF [34]. Living with a single parent is also associated with a higher incidence of BIF [35]. Early childhood experiences of family disruption, such as maltreatment or neglect, can have a lasting impact on brain development [31,36,37]. Maltreatment reportedly reduces the volume in the hippocampus, anterior cingulate, and ventromedial and dorsomedial cortices, affects the development of key white matter tracts and appears to alter cognitive development processes [38].

A crucial aspect of environmental risk factors is that they are modifiable and amenable to interventions. Moreover, social support, including supportive parents, role models for achievement, and warm relationships, is considered to be a preventive factor against BIF [34]. Thus, interventions are required to create a supportive social infrastructure where parents can raise their children well and provide parents with comprehensive parenting education programs.

CONCLUSION

BIF is a complex condition with diverse causes and presentations. Although it is not classified as an ID, individuals with BIF can experience challenges in various aspects of life. This review highlights the interplay between genetic predisposition, prenatal/perinatal factors, and environmental fac-

tors in the development of BIF.

Enhancing our understanding of factors that contribute to BIF is crucial for early identification and intervention. Early intervention strategies combined with access to supportive environments and educational resources can significantly improve the outcomes for individuals with BIF. Future research should identify the modifiable risk factors and develop effective preventive measures to reduce the impact of BIF.

Availability of Data and Material

Data sharing not applicable to this article as no datasets were generated or analyzed during the study.

Conflicts of Interest

The author has no potential conflicts of interest to disclose.

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Funding Statement

None

Acknowledgments

None

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