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BODY MASS INDEX AND HEAD CIRCUMFERENCE AS PREDICTORS OF DEVELOPMENTAL QUOTIENT IN CHILDREN WITH DOWN SYNDROME: A STUDY ON EASTERN UTTAR PRADESH, INDIA

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ABSTRACT

Background: Children with Down syndrome exhibit significant variation in their developmental results. Although anthropometric measures like head circumference and body mass index (BMI) are commonly regarded as indications of neurodevelopment and physical growth, it is yet unknown how these measures affect the developmental functioning of children with Down syndrome.

Objective: The present study aimed to examine whether body mass index and head circumference predict developmental quotient (DQ) in children with Down syndrome.

Method: We used a cross-sectional correlational design. The study included 55 children with Down syndrome were used to measure developmental quotient. Standard clinical techniques were used to record anthropometric factors such as head circumference and body mass index. The predictive role of head circumference and BMI to developmental quotient was examined using hierarchical regression analysis with age and gender held constant.

Results: The study comprised 55 children from a semi-rural population with Down syndrome, aged 5 to 10 years. Age and developmental quotient (DQ) were shown to be significantly positively correlated ($r = 0.369$, $p = 0.003$). A significant negative association was found between gender and DQ ($r = -0.299$, $p = 0.013$). Additionally, age and gender ($r = -0.337$, $p = 0.006$) and age and BMI ($r = 0.369$, $p = 0.003$) showed significant correlations. Hierarchical regression analysis revealed that age, gender, BMI, and head circumference did not significantly predict developmental quotient. Model 1 explained 0.5% of variance in DQ ($R^2 = 0.005$, $p = 0.888$), while 5.7% of the variance ($R^2 = 0.057$, $p = 0.259$) was explained by Model 2.

Conclusion: The results imply that the predictors demonstrated limited independent contribution toward developmental outcomes in the study population. Anthropometric measures by themselves may not be very useful in predicting how well children with Down syndrome would develop. More general neurobiological, environmental, psychological, and intervention-related factors probably have an impact on developmental outcomes in Down syndrome.

KEYWORDS: Down syndrome; developmental quotient; body mass index; head circumference; hierarchical regression

1.INTRODUCTION

One of the most prevalent genetic conditions linked to neurodevelopmental delay and intellectual disabilities is Down syndrome[1]. It is caused by trisomy of chromosome 21 and is typified by a number of medical comorbidities, delayed developmental milestones, cognitive impairment, and difficulty with adaptive functioning[2,3]. There is significant variation in the developmental outcomes of children with Down syndrome, indicating that a variety of biological and environmental factors may have an impact on developmental functioning.

Arnold Gesell, a developmental psychologist, developed the first systematic schedules to differentiate between normal and abnormal newborn development. According to Gesell, a child's observable milestones can be mapped onto standard developmental milestones to determine their Developmental Age (DA) because early human development proceeds smoothly enough with age. A numerical ratio called the Developmental Quotient (DQ) is used to show how a child is developing in relation to their age[14]. The DQ is a more comprehensive measure used in early life (infancy through preschool) to evaluate how well a child is fulfilling physical, social, and functional milestones, whereas the Intelligence Quotient (IQ) focuses solely on cognitive and intellectual ability[15]. The formula for Developmental Quotient (DQ):

$$DQ = \frac{\text{Developmental Age (DA)}}{\text{Chronological Age (CA)}} \times 100$$

Body mass index (BMI) and head circumference (HC) are examples of anthropometric measures that have often been studied in connection to infant development. While head circumference is frequently thought of as an indirect measure of early childhood brain growth and neurodevelopment, BMI is thought to be an indicator of nutritional and physical health status[5]. Lower head circumference trajectories are highly correlated with more severe cognitive impairments, speech delays, and impaired motor functioning when tracking structural growth[9]. HC is a crucial, natural predictor of a child's cognitive capacity and overall Developmental Quotient (DQ) because children with DS exhibit persistent departures from regular development when looking at longitudinal growth patterns[7,8].

Previous studies have shown connections between growth metrics, cognitive outcomes, and nutritional status in typically developing populations. However, there is still conflicting evidence about neurodevelopmental disorders like Down syndrome.

We contend that a child's developmental result is an active, unfolding process rather than a fixed artifact of Trisomy 21, echoing Karmiloff-Smith's central claim that "development itself is the key to developmental disorders." We may systematically study the dynamic processes of physical change as they occur by incorporating proximal, biological growth predictors, namely head circumference as a proxy for brain development and BMI as an indicator of systemic metabolic health. By evaluating the predictive power of physical growth markers on developmental outcomes—the proclivity to see the behavioural phenotype linked to Down syndrome as a static, genetically predetermined development pattern—this study directly addresses a major gap in the literature. Simple, non-invasive, and clinically accessible anthropometric factors like head circumference and BMI are frequently employed in paediatric evaluation. Their prognostic association with developmental quotient in children with Down syndrome, especially in Indian populations, is not well-established. To best of our knowledge, there are scarcity of published literature in India that have particularly looked at whether BMI and head circumference significantly predict developmental quotient, despite the growing body of knowledge on developmental outcomes in Down syndrome. The present study therefore aimed to investigate the predictive role of body mass index and head circumference on developmental quotient in children with Down syndrome. Hence the objective of the present study is to evaluate the association between developmental quotient (DQ) and selected demographic and anthropometric variables in children with Down syndrome from a semi-urban population who are between the ages of 5 to 10 years. Based on this rationale, hypotheses formulated were

Null Hypothesis (H0)

There is no significant association between age, gender, head circumference, body mass index and developmental quotient among children with Down syndrome.

Alternative Hypothesis (H1)

There is a significant association between age, gender, head circumference, body mass index and developmental quotient among children with Down syndrome.

2METHODOLOGY

2.1 Design of the Study

The research design used in this study was cross-sectional design which was observational in nature.

2.2 Sample

There were 55 children in the sample aged between 5- 10 years who had been diagnosed with Down syndrome belonging to semi urban areas of eastern Uttar Pradesh, India. Purposive sampling from Genetic and Metabolic clinic, Department of Paediatrics, Institute of Medical Sciences was used to choose participants. A relatively small age range (5–10 years) enhanced the study sample's homogeneity and decreased age-related variability, enabling more precise comparisons of participants' anthropometric and developmental characteristics through enough cooperation and responsiveness to allow for accurate assessment of behavioural deficits and anthropometric measures[21,22]. The sample size of N = 55 was justified via an a priori power analysis using G*Power statistical software. For a hierarchical multiple regression testing the addition of predictors, this sample size provides sufficient statistical power ($1-\beta = 0.80$) to capture a medium effect size ($f^2 = 0.15$) at a significance level of alpha = 0.05.

2.3 Inclusion Criteria

- Children diagnosed with Down syndrome (based on confirmed karyotyping report)
- Children belonging to semi urban area as categorised through Kuppuswamy Socioeconomic scale)
- Availability of caregiver consent**.**

2.4 Exclusion Criteria

- Severe neurological or medical conditions interfering with assessment.
- Comorbidities of other neurodevelopmental disorders (Attention Deficit/Hyperactivity Disorder, Autism Spectrum Disorder, etc)
- Uncooperative behaviour preventing completion of developmental evaluation.

2.5 Study Variables

Dependent Variable-	Developmental Quotient (DQ)
Independent Variables-	Body Mass Index (BMI)
	Head Circumference (HC)
Covariates-	Age
	Gender

2.6 Tools Used

2.6.1 Developmental Assessment Measure

The Developmental Screening Test (DST) by Bharat Raj, (1983) was used to assess the kids' developmental condition. The 88 items in the tool measure social-personal, linguistic, and motor milestones from infancy to age 15. Each participant's Developmental Quotient DQ was calculated using Chronological Age (CA) and a Developmental Age (DA) determined from successfully completed milestones, formulated as

DQ = DA/CA X100

Following computation, the Developmental Quotients (DQ) of the subjects were categorized into clinical tiers using the predefined norms found in the Developmental Screening Test manual (Bharat Raj, 1983). According to worldwide neurodevelopmental diagnostic criteria (World Health Organization, 1992), scores between 90 to 109 were considered to be within the average developmental range, while a DQ threshold of less than 70 was used to indicate developmental delay. After classification all 55 were categorised under mild intellectual disability ranging from 50-69 as per ICD-10 classification.

2.6.2 Body Mass Index

Standard anthropometric procedures were used to measure participants' height and weight in order to evaluate their nutritional and metabolic health. A calibrated digital weighing scale (Omron, HN -289) was used to record participants' weight to the closest 0.1 kg while they wore light clothing and no shoes. With the participant's head positioned in the Frankfurt horizontal plane, height was measured to the closest 0.1 cm using a wall-mounted stadiometer (IS IndoSurgicals®, 20015). The conventional formula for calculating body mass index (BMI) was then used: weight in kilograms divided by height in meters squared (kg/m^2. In order to ensure accurate classification of underweight, normal weight, overweight, and obesity, raw BMI values were transformed into age- and sex-specific BMI-for-age Z-scores and percentiles using the “WHO Growth Reference / specialized growth charts for Down syndrome”. The BMI was found to be underweight for all 55 children under investigation and their raw scores were used for regression analysis.

BMI was calculated using the standard formula:

BMI = Weight (kg) / Height (m^2)

2.6.3. Head Circumference Measurement

Head circumference was measured using a non-stretchable measuring tape following standard anthropometric procedures. A flexible, non-stretchable plastic anthropometric measuring tape [Zitcomed] of 60 inch in length was used to physically measure the occipitofrontal circumference (OFC). The tape was placed anteriorly over the forehead, somewhat above the supraorbital ridges, and posteriorly over the external occipital protuberance and around the skull's maximum circumference. Measurements were made three times to the nearest 0.1 cm in order to reduce measurement error and take hair density into account. The greatest value obtained was then recorded as the final continuous head circumference metric for regression analysis.

2.7 Procedure

Before any data was collected, institutional approval and informed consent were acquired. Using defined methods, anthropometric measures were recorded. A distraction-free setting room was used for the individual developmental assessment. Before each child was enrolled in the study, the parent or guardian gave their informed written consent and along with child assent was taken wherever appropriate. For every child, information on linked co-morbidities was also gathered from their clinical health records.

The study was approved by "Institute Ethics Committee" of Institute of Medical Sciences, Banaras Hindu University, Varanasi, India .

2.8 Statistical Analysis

IBM SPSS Statistics version 25 was used to examine the data. For every study variable, descriptive statistics were calculated. Pearson r was used to find any associations between the variables. To find out if head circumference and BMI significantly predicted developmental quotient, hierarchical regression analysis was used. The framework to carry out the analysis was conceptualised as:

Model 1: Control Variable

{Age and Gender}

Model 2: Neuro-structural variable and Systemic physical health

{Head circumference (H.C)} (body mass index)

Outcome variable

{Developmental Quotient (DQ)}

Conceptual explanation

Model 1: Examining the demographic influences on Developmental quotient
Model 2: Determining how much more variance can be attributed to anthropometric measures beyond demographic factors on Developmental quotient

3.Results

Table 1: Descriptive analysis for the total sample(N=55) based on the study variables

Variables	Mean ±Standard Deviation
Age	6.945 ± 1.48
Head Circumference	46.52 ± 3.27
Body Mass Index	17.711 ± 3.59
Developmental Quotient	54.36 ± 6.82

Table 2: Gender Distribution for the total sample, N= 55

Variable	Frequency (n)	Percentage (%)
Male	35	63.3
Female	20	36.4

Table 3: Correlation Matrix Among Study Variables (N = 55)

Variables	D.Q	Age	Gender	H.C	BMI
D.Q	1.000	-0.058	0.052	-0.094	0.165
Age	-0.058	1.000	-0.337**	0.187	0.369**
Gender	0.052	-0.337**	1.000	-0.015	-0.299*
H.C	-0.094	0.187	-0.015	1.000	0.054
BMI	0.165	0.369**	-0.299*	0.054	1.000

Note: Above table shows strong negative correlation between age and gender was found to be statistically significant ($r = -0.337$, $p < 0.01$). There was a strong positive association ($r = 0.369$, $p < 0.01$) between age and body mass index. Furthermore, gender and body mass index showed a strong negative connection ($r = -0.299$, $p < 0.05$). Further, associations that met statistical significance were not observed.

Table 4: Model summary for Hierarchical Regression Analysis Predicting D.Q (N = 55)

	Predictors	R	R^2	Adjusted R^2	F change	Sig. F Change
Model 1	Age Gender	0.068	0.005	-0.034	0.120	0.888
Model 2	Age Gender Head circumference BMI	0.239	0.057	-0.019	1.387	0.259

Note: No meaningful prediction of Developmental Quotient was made by the regression models. Just 0.5% of the variance was explained by Model 1 ($p = 0.888$), whereas 5.7% of the variance was explained by Model 2 ($p = 0.259$). The predictors did not significantly affect the dependent variable because the significance values were higher than 0.05.

Table 5: Coefficients of Variables predicting the Dependent Variable (N=55)

Predictor variables	B	SE B	β	t	p
Model 1					
Constant	55.514	5.366	-	32.098	<0.001
Age	-0.212	0.676	-0.046	-0.314	.755
Gender	0.510	2.065	0.036	0.247	0.806

Model 2					
Constant	57.358	14.229	-	4.031	<0.001
Age	-0.454	0.716	-0.099	-0.634	0.529
Gender	1.221	2.095	0.087	0.583	0.563
Head Circumference	-0.181	0.292	-0.087	-0.621	0.538
Body Mass Index	0.441	0.286	0.232	1.542	0.129

Note: Dependent variable = Developmental Quotient (DQ); Model 1 consisted control variables (age and gender); Model 2 additionally included head circumference and BMI.
None of the predictor variables emerged as statistically significant predictors of DQ ($p > .05$).

After adjusting for age and gender, a hierarchical multiple regression analysis was performed to see if head circumference and BMI substantially predicted Developmental Quotient (DQ). Only 0.5% of the variation in DQ was explained by age and gender in Model 1 ($R^2 = .005$, $p = .888$). The explained variance rose to 5.7% ($R^2 = .057$) after head circumference and BMI were added to Model 2, although the difference in variance explained was not statistically significant ($\Delta R^2 = .052$, $p = .259$). These results show that in the current sample, the predictor variables had no discernible impact on the prediction of DQ. No multicollinearity was observed among the predictors (VIF < 2).

4. DISCUSSION

The present study assessed the association between Developmental Quotient (DQ) and selected demographic variables (age and gender) and anthropometric variables including Head circumference (H.C) and Body Mass Index (BMI), among children with Down syndrome from a semi-rural population. The study also investigated whether head circumference and body mass index were important predictors of developmental quotient in children with Down syndrome.
A positive significant association was observed between age and BMI, indicating that BMI increased with advancing age among participants. Similar findings have been reported in children with Down syndrome, where growth parameters and BMI tend to increase progressively with age due to altered growth patterns and reduced physical activity[17,18] .
There was a substantial negative connection between gender and BMI, indicating that male and female participants had different anthropometric traits. Previous research in populations with Down syndrome has also shown gender-based variations in growth trajectories, body composition, and fat distribution[19]. Additionally, a strong correlation between age and gender was found, suggesting that the current sample's age distribution is uneven among gender groups. Cross-sectional studies including children with Down syndrome frequently report such demographic heterogeneity[20].
In the current study, head circumference and developmental quotient did not significantly correlate. However, because of abnormal brain growth and neurodevelopmental delay, children with Down syndrome are known to frequently display microcephaly and a smaller head size. Studies conducted in India on people with Down syndrome have shown that affected children have much smaller head circumferences, with microcephaly present in over half of the cases[7]. The current research indicates that head size may not adequately reflect cognitive-developmental functioning in Down syndrome, despite the fact that head circumference has historically been thought of as an indirect indicator of brain growth during early life.
Also, The Developmental Quotient (DQ) and BMI in this study had a positive but non-significant connection. This suggests that although there was a modest and statistically insignificant correlation, children with higher BMI tended to have somewhat better developmental scores which has been reported by several studies[4,5,17]. This study implies that while increased physical and nutritional health may theoretically lead to higher developmental functioning, the complexity of neurodevelopmental outcomes in children with Down syndrome may not be sufficiently captured by BMI alone.

4.1 Strength of the study

These results provide credence to the expanding theory that Down syndrome developmental outcomes are diverse and complicated. The results also support earlier research highlighting the diversity of developmental paths in Down syndrome. Children with Down syndrome may exhibit complex interactions between environmental factors and genetic susceptibility in terms of cognitive and developmental diversity[9,10,11,25]. Although theoretical frameworks indicate a close relationship between functional outcomes, metabolic growth markers (BMI), and neuroanatomical proxies (head circumference), our results indicate that these physical measures do not directly determine developmental competence in children with Down syndrome. This demonstrates how functional development is distinct from gross physical phenotypes, indicating that tailored therapy and contextual enrichment interventions may be significantly more important in determining DQ than biological growth markers alone[12]
Therefore, the current research emphasizes the necessity of going beyond discrete physical growth indicators in favour of more comprehensive biopsychosocial and ecological models of developmental functioning in Down syndrome.

4.2 Limitations

It is important to recognize that this study is subjected to few limitations. First, the results might not be extensively generalizable because of small sample size. It is may be possible that the semi-urban setting made participants'

environmental and lifestyle traits more uniform, which decreased sample variability and prevented statistically meaningful associations from emerging.

5 CONCLUSION

The present study looked at how developmental quotient in children with Down syndrome is predicted by head circumference and body mass index. The results showed that head circumference and BMI did not significantly predict developmental quotient. According to the study, anthropometric measures by themselves might not be very useful in explaining the developmental heterogeneity of children with Down syndrome. A complex interplay of neurodevelopmental, environmental, psychological, therapeutic, and adaptive factors is probably responsible for developmental outcomes in children with Down syndrome. Children with Down syndrome frequently experience altered growth patterns, hypotonia, endocrine abnormalities, congenital cardiac issues, and varying rates of neurological advancement. Therefore, factors including as neurological maturation, early intervention exposure, adaptive functioning, family environment, and therapy support may have a greater impact on developmental outcomes than only physical growth indicators.

5.1 Implications

The findings of this study offer valuable insight for both clinical practice and future academic inquiry. The results are however relevant since they add to the scant literature on children with Down syndrome from semi-urban populations, even though no statistically significant associations were found. From a clinical perspective, it is evident that developmental assessments for individuals with Down syndrome should move beyond a narrow reliance on anthropometric indicators in favour of a more multidimensional evaluation approach. Furthermore, the implementation of longitudinal designs and larger multicentric studies is recommended to more accurately map developmental trajectories and enhance the generalizability of the results across diverse populations.

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