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INTELLIGENCE QUOTIENT DEVELOPMENT IN RELATION TO PHYSICAL GROWTH, DEVELOPMENT AND NUTRITIONAL STATE IN EARLY CHILDHOOD: A SYSTEMATIC REVIEW

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ABSTRACT

High prevalence of suboptimal physical growth and development and nutrition in young children and current limited knowledge of the effect on Intelligence Quotient (IQ) development, a systematic review of the subsequent association between physical growth-development and IQ development in early childhood is needed. Present study addresses the important knowledge gaps by systematically reviewing the current available literature on the relationship between physical growth and development with IQ development in early childhood (6 months to 12 years). We observed that birth weight, catch-up growth for undernourished, Height-for-age z score (HAZ), Weight-for-age z score (WAZ) and nutrition in early life (including breastfeeding and diet pattern) manifested a significant association with cognitive performance especially IQ score (grade, mathematical score, vocabulary test).

KEYWORDS: IQ, physical growth, development, maturity and nutrition.

INTRODUCTION

Growth and development is one of the human body's most complex processes. Each body part has its own unique growth patterns.[1] Monitoring health status, detection of growth achievements or failure, and determining the efficacy of interventions for a population can be performed by assessing the physical growth.[2] Thus, monitoring physical growth and development is an important component of primary health care in pediatrics.[3] Children's development is affected by psychosocial and biological factors.[4] and by genetic inheritance. Thus, early years of life are a period of considerable opportunity for growth as well as vulnerability of harm. The cumulative experience of buffers or burdens is a more powerful determinant of children's developmental well-being than single risk or protective factors.[5] Early developmental opportunities can establish a critical foundation for children's academic success, health, and general well-being.[6]

Neuro-developmental sequences can be described broadly in terms of the traditional developmental mile-stones which provide a systematic approach to observe the progress of the children over time. Children younger than 5 years in developing countries are exposed to multiple risks[7] like poverty, malnutrition, poor health, and non-stimulating home environments, which detrimentally affect their cognitive, motor, and social-emotional development. Poverty and its attendant problems are major risk factors.[8-12] Two factors with available worldwide evidence—the prevalence of early childhood stunting and the number of people living in absolute poverty is used as indicators of poor development. Studies showed that both indicators are closely associated with poor cognitive and educational performance in children and use them to estimate that over 200 million children under 5 years are not fulfilling their developmental potential.[7]

Growth potential in pre-school children is similar across countries,[13,14] and stunting in early childhood is caused by poor nutrition and infection rather than by genetic differences. Patterns of growth retardation are also found to be similar across countries.[15] But, there are few national statistics on the development of young children in developing countries to identify and review whether childhood growth and developmental process affects intelligence and/or behavior development. Both the interaction of biology and the social environment endeavour a powerful influence on a child's swiftness to learn and on success in school, both antecedents to health outcomes in later life.[16,11]

Children's development consists of several inter-dependent domains, including sensory-motor, cognitive, and social-emotional, all of which are likely to be

affected. Further, besides nutrition, it is likely that environmental factors, i.e., socio-economic status, learning environment, stimulation at home, family size, recurrent infection etc. also play important role in mental development. The discrepancy between their current developmental levels and what they would have achieved in a good nurturing environment with adequate stimulation and nutrition indicates the degree of loss of potential. In later childhood these children will subsequently have poor levels of cognition and education, both of which are linked to later earnings. Furthermore, improved parental education, particularly of mothers, is related to reduced fertility,[17,18] and improved child survival, health, nutrition, cognition, and education.[18-22] Thus, the failure of children to fulfill their developmental potential and achieve satisfactory educational levels plays an important part in the intergenerational transmission of poverty. In countries with a large proportion of such children, national development is likely to be affected.

Recent advances in brain research have proven that an infant's environment has a dramatic affect on brain-building and healthy development. It is this early stage of brain development that results in how and how well one thinks and learns—both as children and as adults. The early years are the "prime time" for a developing brain. This intense period of brain growth and network building capacity happens only once in a lifetime so as caregivers and parents, people have this brief but unique opportunity to encourage the formation of brain circuitry in our infants.

The first few years of life are particularly important because vital development occurs in all domains.[5] The brain develops rapidly through neurogenesis, axonal and dendritic growth, synaptogenesis, cell death, synaptic pruning, myelination, and gliogenesis. These morphological events happen at different times[23] and build on each other, such that small deviation in these processes can have long-term effects on the brain's structural and functional capacity. Brain development is modified by the quality of the living environment. Research showed that early under-nutrition, iron-deficiency, environmental toxins, stress, and poor stimulation and social interaction can affect brain structure as well as functions, and have long-lasting cognitive and emotional effects.[24-28] Early cognitive and social-emotional developments are strong determinants of school progress in developed countries.[29-31] Longitudinal studies in developing countries that linked early child development and later educational progress identified two studies; In Guatemala, preschool cognitive ability predicted children's enrolment in secondary school[32] and achievement scores in adolescence.[33] In South Africa, cognitive ability and achievement at the end of grade one predicted later school progress in school children.[34]

Poor children are more vulnerable to inadequate development outcomes[7] and significant developmental delay i.e. cognitive, language, physical and socio-emotional by socio-economic gradient was evident in several countries.[35,36] In Colombia, the socio-economic gap in children's receptive and expressive language skills widened between 14 to 42 months.[37] Children with lower birth weight have lower school performance attainments & earning.[38,39]

Failure to complete primary education[40] (Millennium Development Goal 2) gives some indication of the extent of problem of poor cognitive development, although school and family characteristics also play a part. In developing countries, an estimated 99 million children of primary-school age are not enrolled, and of those enrolled, only 78% complete primary school.[35] Most children who fail to complete are from sub-Saharan Africa and south Asia. Only around half of the children enroll in secondary schools. Furthermore, children in some developing countries have much lower achievement levels than children in developed countries in the same grade.[41]

Thus, given the high prevalence of suboptimal physical growth and development and nutrition in young children and current limited knowledge of the effect on IQ development, a systematic review of the subsequent association between physical growth-development and nutrition state with IQ development in early childhood is needed. Present study addresses the important knowledge gaps by systematically reviewing the current available literature in last 5 years on the relationship between physical growth and development and different nutrition state with optimum IQ development in early childhood (6 months to 12 years).

Search Strategy
In accordance with the preferred reporting items for systematic reviews and meta-analysis (PRISMA) statement,[42] present systematic review conducted on young children's physical growth & development and different nutrition state in relation to their intelligence quotient. To identify relevant studies, PubMed, PubMed Central, Google Scholar were searched using key words "intelligence", "intelligence quotient", "children's growth", "childhood development", "studies on IQ test", "randomized controlled trails", "cross-sectional studies", "nutrition status", "child nutrition".

Inclusion and Exclusion Criteria
Participants: Studies of comparatively healthy children at their early childhood of either sex were included. Studies were excluded if adults, elderly, patients or special children examined (Figure 1 and 2).
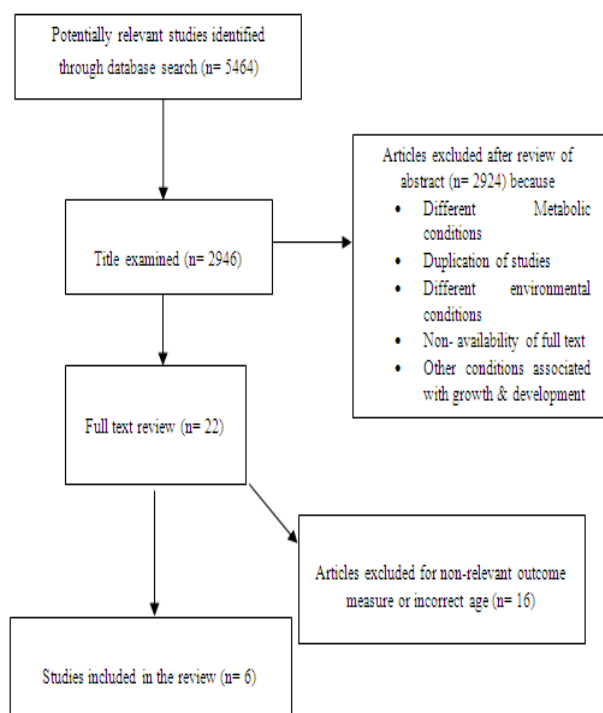
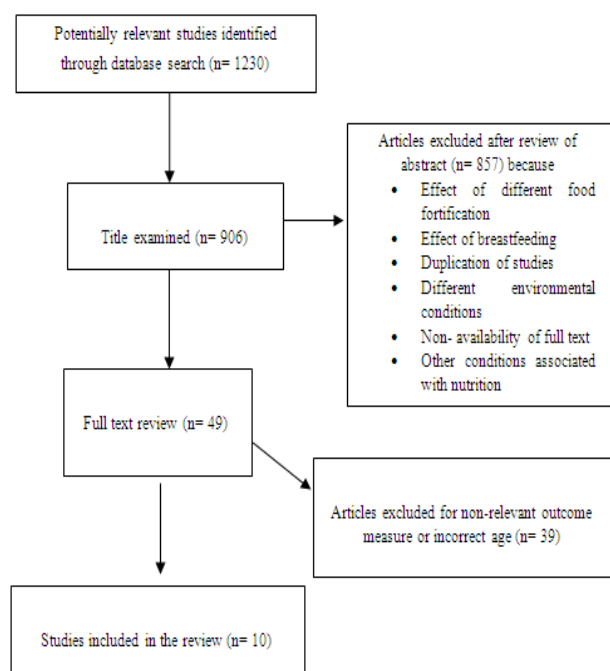**Figure 1: Search strategy for Physical growth and development.**

Figure 2: Search strategy for different nutritional state.

Outcome measures: Studies including any standardized outcome measures of cognitive performance with IQ were included. Studies solely examining fatigue or employing only qualitative measures of cognitive performance were excluded. Studies individually containing physical growth & development or intelligence quotient were excluded. Studies explaining

IQ outcome measures by using available standardized method are included, so nuro-imeging is not the part of current review.

Manipulations: Any types of genetically modified health or mental condition, different environmental exposures were excluded. Studies were not excluded on the basis of nutritional status for example studies that include poverty state, malnutrition & diet was included. Studies like single case reports, dissertations, meeting abstracts were excluded.

DISCUSSION

The goal of the study was to review the literature from last 5 years that how physical growth & development and different nutrition state are associated with IQ development in children from 6 months to 12 years. Evidence suggests that human physical growth & developmental quotient and different nutrition state have strong association with cognitive development, especially IQ development in children at their early ages. Early childhood years are critical for both life-style disease prevention and overall school performance in later life. The inadequacy of literature in this area needs more intense research with strong methodology. In addition, studying this, interventionists and/or child care programmers may emphasize on early deficits in linear growth and cumulative prenatal and postnatal malnutrition to develop early child care settings.

With regard to physical growth & development (Table.1), many cross-sectional studies of high-risk children have stated associations between concurrent stunting, poverty and poor school progress. Stunted children, compared with non-stunted children, more likely to enroll late e.g. Nepal[43] and Ghana and Tanzania[44] and have poorer cognitive ability or achievement scores studied in Kenya[45] Guatemala,[46] Indonesia,[47] Ethiopia, Peru, India, and Vietnam, and Chile[13] respectively. Weight-for-age, which indicates a combination of weight-for-height and height-for-age, has often been used instead of stunting to measure nutrition in young children. Weight-for-age was associated with child development in India[14] Ethiopia,[48] and Bangladesh,[49,15] Studies demonstrated that children who are stunted at 8 years matched catch-up growth have smaller deficits in learning/ school performance than who did not match catch-up growth.[50]

Table 1: Studies on IQ development in relation to physical growth & development.

Authors	Year	Study Characteristics	IQ test	Study Design	Main outcomes
Li et al.[66]	2016	n= 1744 Age: 8 Years	Wechsler intelligence scale for children-IV	Longitudinal	Result suggests the important influences of birth weight on intellectual functioning in early school-aged children.
Ranabhat et al.[67]	2016	n= 173 Age: up to 12 Years	The universal nonverbal intelligence test (UNIT)	Cross sectional	BMI and IQ scores were significantly lower in the ultra-poor group
Fink & Rockers[50]	2014	n= 3327 Age: 8-15 Years	Standardized Math Test developed by Yong Lives investigators	Follow-up study of Young Lives Study	Children who are stunted matched catch-up growth have smaller deficits in learning than who did not match catch-up growth.
Crookston et al.[68]	2013	n= 8062 Age: 8 Years	Mathematics test, The Early Grade Reading Assessment (EGRA) from the World Bank Living Standards Measurement Study and The Peabody Picture Vocabulary Test (PPVT)	Follow-up study of Young Lives Study	The HAZ was inversely associated with overage for grade and positively associated with mathematics achievement, reading comprehension, and receptive vocabulary.
Huang et al.[69]	2013	n= 8389 Age: 4-7 Years	Chinese Wechsler intelligence scale for young children	Longitudinal	Among pre-term children post-natal weight gain was positively associated with IQ. Among term children both birth wt. & postnatal growth were associated with IQ.
Smithers et al.[70]	2013	n= 25831 Age: 6.5 Years	Wechsler Abbreviated Scales of Intelligence and the Strengths and Difficulties Questionnaire (SDQ)	Cross sectional	Faster gains in weight or head circumference in the 4 weeks after birth may contribute to children's IQ in the future.

Four published longitudinal studies showed that early stunting predicted later cognition, school progress, or both. Stunting at 24 months was related to cognition at 9 years in Peru[51] and, in the Philippines to intelligent quotient (IQ) at 8 and 11 years, age at enrolment in school, grade repetition, and dropout from school.[52,53] In Jamaica, stunting before 24 months was related to cognition and school achievement at 17–18 years and dropout from school.[54] In Guatemala, height at 36 months was related to cognition, literacy, numeracy, and general knowledge in late adolescence,[55] and stunting at 72 months was related to cognition between 25–42 years. Two other longitudinal studies from Brazil[56] and South Africa[57] stunting between 12 and 36 months were related to later measures of cognition or grade attainment.

Smithers et al., the only study of our knowledge has analyzed dietary pattern trajectories from 6 to 24months of age and cognitive abilities at age 8 and 15 years. They observed long-term effect of dietary pattern at early years of life and later cognitive development including school performance that better nutrition at early life exerts better cognition.[58] Some evidence suggested that effects may be more apparent in undernourished children who improved their nutritional status from at risk to adequate following a School Breakfast Programme.[59] Search for literature (Table 2) also suggests that Preterm infants are vulnerable to suboptimal early nutrition in terms of their cognitive performance—marked influence on language based skills—at 7.6 - 8 years, when cognitive scores are highly predictive of adult ones.[60] Nyaradi et al. showed in a study recruited from the West Australian Pregnancy Cohort (Raine) Study Higher diet scores at 1 year representing better diet quality are significantly associated with faster reaction times in cognitive performance at 17 years i.e. Nutrition in early childhood may have a long-term association with fundamental cognitive processing speed.[61] This review also suggests that a healthy diet consists of all food groups starting from early ages of life (< 5 years) may have positive and strong association with childhood IQ development though there is need of additional investigations. There is much attention has been given on the role of breast milk and development of brain function,[62,63] which is not the current area of interest of present review where globally children are deprived of healthy diet i.e. high in fruits, vegetables, good amount of energy & protein where else they are more prone to outside junk foods and more likely developing picky

eating behavior. Future research can support the association, improvement in the area of child eating behavior and healthy diet practice would be possible.

Table 2: Studies on IQ development in relation to nutritional state.

Authors	Year	Study Characteristics	IQ test	Study Design	Main outcomes
Li et al.[66]	2016	n= 1744 Age: 8 Years	Wechsler intelligence scale for children-IV	Longitudinal	Result suggests the important influences of postnatal malnutrition on intellectual functioning in early school-aged children.
Ghosh et al.[71]	2015	n= 566 Age: 5-12 Years	Raven's colored progressive matrices (RCPM)	Cross-sectional	Cognitive development of school children is influenced by the grade of under nutrition and SES
Tabriz et al.[72]	2015	n= 1151 Age: 6-7 Years	Wechsler Intelligence Scale for Children Fourth Edition	Cross - sectional	A lower IQ score is associated with abnormal BMI, especially higher BMI
Adolphus et al.[73]	2013	-	-	Review article	Increased frequency and quality of habitual breakfast was consistently positively associated with academic performance
Bogale et al.[74]	2013	n= 100 Age: 5 Years	Raven's colored progressive matrices (RCPM)	Cross-sectional	Performance on memory and visual processing tasks was significantly lower in children with growth deficits
Liu et al.[75]	2013	n= 1269 Age: 6 Years	Chinese version of Wechsler Preschool and Primary Scale of Intelligence	Cross-sectional	Children who regularly have breakfast on a near-daily basis had significantly higher full scale, verbal, and performance IQ test scores
Sandjaja et al.[76]	2013	n= 6746 Age: 6-12 Years	Test of Non-verbal Intelligence test (TONI-3)	Cross – sectional	Undernourishment and non-verbal IQ are significantly associated in 6-12-year-old children
Warsito et al.[77]	2012	n= 58 Age: 3-5 Years	Home Observation for Measurement of the Environment Inventory for children ages 3-6 years and developed by Caldwel and Bradley	Cross – sectional	Participation in early childhood education and nutritional status based on the height index for age had a positive and significant effect on cognitive development of the preschool children
Taki et al.[78]	2010	n= 290 Age: 5.6 Years	Japanese version of the Wechsler intelligence scale for children (WISC version 3)	Cross sectional	Breakfast staple type affects brain gray and white matter volumes and cognitive function in healthy children.
Gale et al.[79]	2009	n= 241 Age: 4 Years	Wechsler Pre-School and Primary Scale of Intelligence (version 3)	Cross - sectional	Dietary patterns in early life may have some effect on cognitive development

CONCLUSION

We observed that birth weight, catch-up growth for undernourished, Height-for-age z score (HAZ), Weight-for-age z score (WAZ) and nutrition in early life (including breastfeeding and diet pattern) manifested a significant association with cognitive performance especially IQ score (grade, mathematical score, vocabulary test). Since there are racial/ethnic disparities in early life risk factors for such as childhood obesity, feeding practices, and many of the same children are at higher risk for poor cognitive and academic achievement, the relationships examined in this study also have implications for socioeconomic disparities.[64,65] As present review was focused solely on growth & development and different nutritional state, studies including nuro-imeging for better understanding of IQ development in growing children are not taken into consideration. Therefore, studies concluded with advance nuro-imeging should be one of the areas of future research. Further research is needed in this important area e.g. use of neuro-imaging to evaluate the neurological mechanisms linking physical growth &

development and nutrition to IQ development. Physical growth & development, different nutritional influence and preschooler's academic performance with overall future outcomes need to be emphasized more so that it could provide additional motivations for policy makers to promote healthier childhood.

Limitations

This review is limited to last 5 years of studies which are published in English; other informative studies in other languages could be missed. Many studies are left behind due to the non-availability of full text to support the review. Study design and measurement tools varied widely which immediately affect our ability to make direct comparison between studies. Cognitive outcome measures are not uniform like some measure academic scores, or others focus into mathematical test scores. Also, many factors like genetic or environmental may influence the outcome. Unfortunately with small sample size, many studies may not been able to present the potentially confounding variables. IQ measurements were done by standardized test methods available in present time, so to establish any fact by nuro-imeging is not part of these studies which may reflect as a strong limitation of current review.

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