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REVIEW ARTICLE

Determining factors of child linear growth from the viewpoint of Bronfenbrenner's Bioecological Theory

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KEYWORDS
Child;
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Protection factors;
Bioecological theory

Abstract
Objective: To analyze the factors associated with children's linear growth, according to the different subsystems of the 6Cs model and Bronfenbrenner's Bioecological Theory.
Data sources: Narrative review, carried out in the Scielo, Lilacs, Pubmed, and Science Direct databases, based on research using the terms Bioecological Theory, child growth, and risk factors, combined with the use of Boolean operators.
Summary of findings: According to the 6Cs model, proposed based on Bronfenbrenner's Bioecological Theory, the determining factors of children's linear growth are in six interrelated subsystems - cell, child, clan, community, country/state and culture. The empirical studies included in this review made it possible to analyze protection and risk factors within the subsystems. Among the protective factors: are adequate birth weight and satisfactory weight gain, breastfeeding for six months or more; proper hygienic habit of hand washing, proper elimination of feces, and access to clean water. As risk factors: low, birth weight and size, prematurity, multiple deliveries, short interval between deliveries, non-exclusive breastfeeding until the 3rd month, frequency and severity of infectious processes and anemia, little parental education, short maternal statur, inadequate maternal nutritional status, domestic violence, family poverty, food, and nutritional insecurity, living in rural areas or at high altitudes.
Conclusion: Children's linear growth is determined by interrelated factors that encompass aspects prior to the child's birth, as well as socioeconomic, political, family and community issues.

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Introduction

The inseparability of growth and development processes is a widely recognized fact. Both are complex phenomena, which depend on the interaction between genetic potential and environmental factors. Regarding linear growth, there is a consensus that environmental factors are the main factors responsible for height variations between individuals from different populations.[1,2] Different theoretical-conceptual approaches encbetween nature and environment. Among these, Urie Bronfenbrenner's Bioecological Theory stands out, which integrates genetic, biological, and environmental factors.[3]

Based on this theory, Harrison et al.[4] proposed the 6Cs Model, composed of factors distributed in six interrelated subsystems: cell, child, clan, community, country/state (country) and culture. This model was initially proposed for the investigation of factors that contribute to childhood, obesity; considering its scope, however, it has been adapted to other complex problems that require a systemic approach.

Although a number of studies in the literature have sought to investigate factors associated with children's linear growth, it is important to analyze this phenomenon, including environmental factors, which expands the understanding of the interaction between the components involved. Thus, based on Bronfenbrenner's Bioecological Theory and guided by the 6C Model, it is necessary to consider that children's linear growth reflects the socioeconomic and cultural conditions of a community. Therefore, the evaluation of the systemic and interrelational character of the factors that are related to it is important for the definition of strategies that aim to minimize inequalities between people. The proposed study of child stature from the construction of a bioecological model, whose outcome is the linear growth of children and influenced by the Harrison Model[4], may open a promising field to understand central issues in the prevention and treatment of growth retardation in children. There is no doubt that the task is challenging, mainly because it implies applying systemic and contextual thinking in research practice and intervention.[5]

This review, then, was based on a brief conceptual summary of the Bioecological Theory and the 6Cs Model, and reports of empirical studies that analyzed determining factors in the linear growth of children from the perspective of the 6Cs Model.

Methods

Data source

This is a literature review carried out from April/2022 to June/2022. The search strategy comprised the use of these descriptors, in Portuguese and English: Bioecological Theory, child growth, and risk factors, combined with the use of Boolean operators AND / OR, to expand the search in the Scielo, Latin American Literature in Health Sciences (Lilacs), Pubmed and Science Direct databases.

The inclusion criteria were empirical studies that aimed to explain children's linear growth, evaluated by the height-for-age anthropometric index, from an ecological point of view, with analyses of possible factors that could interfere with this outcome.

Data synthesis

Data referring to author/year, objective, methods and main results were extracted. For the description and interpretation of the results, the information was grouped under the perspective of the 6Cs Model. Finally, an explanatory model was elaborated, making a synthesis of the current state of knowledge.

Bioecological theory of human development and the development of the 6C model

Bronfenbrenner proposed a theory and a model that avoided the fragmented approaches to the study of human development, each level of which focused on a level of analysis: only the child, only the family, only the society.[5] The first theoretical model, outlined in 1979, called "ecological", highlighted the environment as the fundamental factor for understanding how the individual develops. In 1992, the approach became a little more detailed, contemplating aspects of development linked to the person, and was named "Theory of Ecological Systems".[6] Later, the theory envolved and the understanding of human development began to contemplate a more complex model, broader, considering four interrelated aspects: the process, the person, the context and the time (PPCT Model). In this more advanced perspective, the focus shifted to the individual, considering the dimension of time and the interaction between the person and the context in which he/she is inserted. These adjustments led to new denominations: the "Bioecological Theory of Human Development" and the "Bioecological Model of Human Development", which defined the subsystems where the developing being is inserted.[3,5,7]

This PPCT process is highlighted as the main influencer of development and has to do with the reciprocal interactions that happen gradually, in terms of complexity, between the individual and others, and between objects and symbols present in their immediate environment. Regarding the person, Bronfenbrenner recognized the relevance of biological and genetic factors in development and paid special attention to personal characteristics that could contribute to the socialization of the individual.[6]

The context is characterized by any event or condition outside the organism that can influence or be influenced by the developing person, and is classified into four subsystems: microsystem, mesosystem, exosystem and macrosystem, socially organized, which help to support and guide the being in growth. These subsystems are arranged to describe and analyze the life contexts, proximal and distal, of human development.[6,7]

The microsystem, considered as the gravitational center of the biopsychosocial being, is the environment where face-to-face interactions take place. This level is extremely important, as it is where neighborhood relationships and family relationships occur, especially mother/child, which are crucial in child development.[7]

The contributions of Urie Bronfenbrenner and his PPCT model to the understanding of human development are based

on the fact that his assumptions were able to reformulate the study of the development, where the developing individual is seen in a dynamic interaction with the multiple contexts in which he/she is inserted, that can directly affect their biopsychosocial well-being, as represented by Figure. 1.

Taking into account the breadth and complexity of the model presented, the need to consider the influence of each subsystem on the development of the individual becomes evident; clearly, this thinking is limited linear and unicausal. For the factors that determine a child's healthy development, in addition to innate biological conditions, it is necessary to think about the influence of family, community, and broader aspects of the socioeconomic and political situation, without losing sight of the temporal and historical transformations of each of these contexts.[8,9]

The 6Cs model proposed by Harrison et al.,[4] based on Bronfenbrenner's systemic theory, explains the interaction of different factors; this model is composed of six subsystems, which in the description of the graphic model are called spheres: cell, child, clan, community, country/state and culture. In the cellular sphere, genetic and biological factors are included. The child sphere includes personal and behavioral characteristics. The clan sphere, in turn, includes family characteristics, such as parental dynamics and domestic rituals. Peers, schools, and other institutional factors and community factors are combined into a single sphere called community, which represents factors relating to the child's social world outside the home. In the country sphere, state and national institutions are included that influence citizens' priorities and restrict their opportunities. Finally, in the sphere of culture, culture-specific norms, myths and prejudices that guide the fundamental assumptions of citizens and policymakers about food, exercise, health and the body are considered.[4]

This model does not focus just on individual factors in the understanding of growth and development processes; it recognizes the importance of environmental factors and context for the explanation of phenomena. From the revised articles (Table 1), a model was constructed having the linear growth of the child as outcome, based on the Harisson et al.[4] Model (Figure. 2).

Determining factors of children's linear growth

Although there are several studies in the literature that explore factors associated with children's linear growth, the systemic approach, by allowing the visualization of possible interactions between the various factors that make up the subsystems, facilitates understanding of the phenomenon and, thus, makes it possible to determine where interventions at different levels - cell, child, clan, community, country/state and culture - can be effective in promoting adequate child linear growth.[4]

Figure. 2 illustrates an explanatory model for the determining factors of children's linear growth, according to the six subsystems defined by Harrison et al.[4] It is possible to visualize, then, protection and risk factors that are

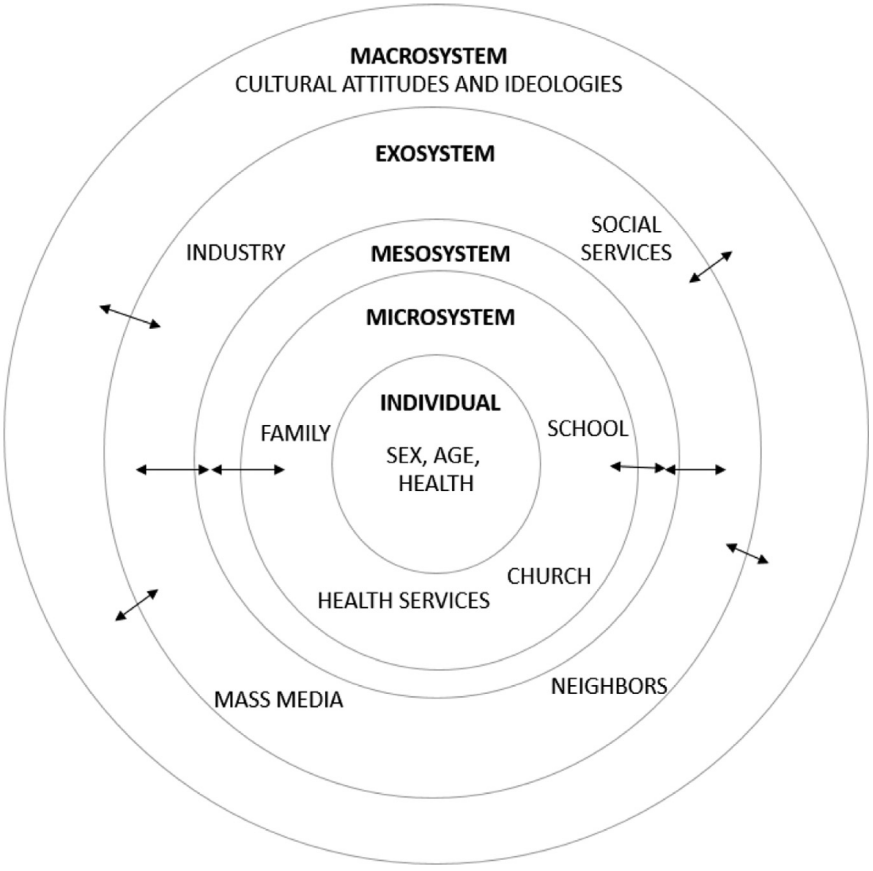

Figure. 1 Second revision of ecological theory (Bronfenbrenner, 1977).

Table 1 Studies on determining factors of children's linear growth.

Author;Year	Place	Title	Objective	Population (Type/N)	Study design	Results
Immink & Payongayong, 1999	Guatemala	Risk analysis of poor health and growth failure of children in the central highlands of Guatemala	To identify high risk factors in children under five and of school age.	515 children under 5 years old	Cross-sectional study	The low availability of food per capita, and particularly the absence of staple foods from own production at home, was the most significant risk factor for stunting in children under five years of age. Non-food risk factors were the most important for failure to thrive in school-age children. These factors included: basic sanitation, housing conditions, literacy level, and adult women's body mass index.
Assis et al., 2005	Brazil	Growth faltering in childhood related to diarrhea: a longitudinal community based study	To assess the association of diarrhea and acute lower respiratory tract infections (ALRI) with the growth of preschoolers	487 children between 6 and 48 months	Longitudinal study	Mean height-for-age Z-scores decreased in children with 7 or more days of diarrhea but not with 1 or more days of ALRI
Casapía et al., 2007	Peru	Parasite and maternal risk factors for malnutrition in preschool-age children in Belen, Peru using the new WHO Child Growth Standards	To determine the prevalence of chronic malnutrition (short stature) and associate risk factors	252 children under 5 years old	Cross-sectional study	The risk factors for stunting were: decreasing maternal age and height
Semba et al., 2008	Indonésia e Bangladesh	Effect of parental formal education on risk of child stunting in Indonesia and Bangladesh: a cross-sectional study	To determine the effect of duration of maternal and paternal education on short stature in children under 5 years of age.	590, 570 families in Indonesia and 395,122 families in Bangladesh	Cross-sectional study	In Indonesia, greater formal maternal education led to a decrease of between 4.4% and 5% in the chances of childhood stunting; higher formal paternal education led to a 3% decrease in the odds of childhood stunting. In Bangladesh, more formal maternal education led to a 4.6% decrease in the odds of stunting, while greater formal paternal education led to a decrease of between 2.9% and 5.4% in the odds of stunting.
Rehman et al., 2009	Vellore, South India	Chronic growth faltering amongst a birth cohort of Indian children begins prior to weaning and is highly prevalent at three years of age	To describe the growth over the first three years of life and the factors related to the low growth of this population	452 chilfren under 3 years old	Cohort study	Factors associated with stunting at three years were birth weight less than 2.5 kg, 'manufacturing cigarettes' (manual production of cigarettes for a daily wage) at home, maternal height less than 150 cm, being stunted, thin or underweight at six months of age and having at least one older sibling
Avan & Kirkwood, 2010	Paquistão	Role of neighbourhoods in child growth and development: Does 'place' matter?	To assess the relative contributions of socioeconomic status and rural-urban neighborhoods to psychomotor growth and development	1,244 chilfren under 3 years old	Cross-sectional study	Lower socioeconomic status and living in a rural rather than an urban neighborhood were strongly associated with lower psychomotor scores and short stature.
Shang et al., 2010	Guangxi Autonomous Regional and Hainan Province	Stunting and soil-transmitted-helminth infections among school-age pupils in rural areas of southern China	To determine risk factors for stunting and provide guidance on the prevention and control of stunting and helminth infections for future studies in this field	1,031 children between 9 and 12 years old	Cross-sectional study	Risk factors for stunting based on logistic regression analyses were: (1) moderate to severe helminth infections; (2) anemia; (3) mother's low education
Lee et al., 2010	Guatemala	Disentangling nutritional factors and household characteristics related to child stunting and maternal overweight in Guatemala	To identify nutritional factors and household characteristics associated with child stunting, maternal overweight and family coexistence of both types of malnutrition.	2,261 households with at least one child aged 12 to 60 months and their mother.	Cross-sectional study	Factors associated with short stature in children, such as poverty, short maternal stature and indigenism, were predictors of the binomial of overweight mothers and short stature children. These findings support the notion that SCOM is an extension of the spectrum of malnutrition in the most disadvantaged population groups.
Menezes et al., 2011	Brasil	Determinants of stunting in children under five years of age in the State of Pernambuco	To describe the stunting of children under five and identify associated factors	935 children between 0 and 59 months	Cross-sectional study	Socioeconomic variables (low per capita family income, low maternal schooling, high number of people in the household and reduced access to consumer goods), low maternal height and low birth weight remained among the risk factors associated with the structural deficit of children.

Table 1 (*Continued*)

Author;Year	Place	Title	Objective	Population (Type/N)	Study design	Results
Nasreen et al., 2013	Bangladesh	Impact of maternal depressive symptoms and infant temperament on early infant growth and motor development: Results from a population based study in Bangladesh	To investigate the independent effect of maternal perinatal depressive symptoms on infant growth and motor development in rural Bangladesh	720 pregnant women and 652 babies aged 2—3 months and 6—8 months were evaluated	Mothers with children aged 6 weeks to 12 months	Prepartum depressive symptoms predicted delay in baby growth
Chagas et al., 2013	Brasil	Prevalence and factors associated to malnutrition and excess weight among under five year-olds in the six largest cities of Maranhão	To research the prevalence of malnutrition and overweight in children under five and their association with socioeconomic, health and demographic factors	1,214 children under 5 years old	Cross-sectional study	Children from families headed by women had lower prevalence of stunting. In the hierarchical logistic regression analysis, no factor was associated with height-for-age deficit.
Schott et al., 2013	Etiópia, Índia, Peru e Vietnã	Periods of Child Growth up to age 8 Years in Ethiopia, India, Peru and Vietnam: Key Distal Household and Community Factors	To characterize infant growth up to age 1 year and from ages 1 to 5 and 5 to 8 years, controlling for the initial height-for-age z-score, and to identify the main distal family and community factors associated with these measures of growth	7,266 children between 01 and 8 years	Cross-sectional study	Low parental education, inadequate food consumption and low height of mothers are the main correlates of height at around 1 year of age.
Reurings et al., 2013	Guatemala	Stunting rates in infants and toddlers born in metropolitan Quetzaltenango, Guatemala	To describe the prevalence of stunting and the association with early feeding practices, morbidity patterns and socioeconomic status	299 children between 6 and 23 months	Cross-sectional study	Being male, aged between 13 and 18 months, born at home, having a mother with low schooling and stature, being of Mayan ethnicity (indigenous), and having already received iron supplementation were associated with stunting.
Corsi et al., 2015	Índia	Risk factors for chronic undernutrition among children in India: Estimating relative importance, population attributable risk and fractions	To assess the simultaneous contribution of 15 known risk factors to childhood stunting in India	54,325 children between 6 and 59 months	Cross-sectional study	In the adjusted models, the five most important predictors of stunting/low weight were low maternal stature, uneducated mother, households in the lowest wealth quintile, low dietary diversity, and low maternal weight.
Krasevec et al., 2016	Estados Unidos	Diet quality and risk of stunting among infants and young children in low— and middle—income countries	To examine the association between two indicators of diet quality - food diversity and consumption of foods of animal origin and stunting.	74,548 children between 6 and 23 months	Cross-sectional study	Low food diversity and consumption of different types of food of animal origin were associated with short stature.
Neves et al., 2016	Brasil	Growth and development and their environmental and biological determinants	To investigate children's cognitive/language growth and development and their environmental and biological determinants	92 children between 24-36 months	Cross-sectional study	Biological variables showed a greater association with growth, after the multivariate analysis, only low birth weight and the small number of prenatal consultations were risk factors for stunting.
Rachmi et al., 2016	Indonésia	Stunting, Underweight and Overweight in Children Aged 2.0—4.9 Years in Indonesia: Prevalence Trends and Associated Risk Factors	To determine temporal trends in the prevalence of underweight, short stature and risk of overweight or obesity in Indonesian children aged 2.0 to 4.9 years; and examine associated risk factors.	4,101 children between 2 a 4,9 years old	Cross-sectional study	Short stature and low weight were related to lower birth weight, being breastfed for 6 months or more, having low weight or low stature fathers, and mothers who had never attended formal education. The stunting was also greater in rural áreas.
Musaad et al., 2016	Estados Unidos	The Independent and Cumulative Effect of Early Life Risk Factors on Child Growth: A Preliminary Report	To examine growth patterns (birth to 12 months) and their association with risk factors in early life.	351 mothers with children aged 6 weeks to 12 months	Cohort study	Adherence to the low-growth versus medium-stable group doubled with non-exclusive breastfeeding at month 3, but increased among children who had three risk factors compared with none
Chai et al., 2016	29 países	Association between intimate partner violence and poor child growth: results from 42 demographic and health surveys	To determine the impact of intimate partner violence against women on the growth of children in low- and middle-income countries.	204,159 women aged 15 to 49 years	Cross-sectional study	Height deficit in children was positively associated with lifetime maternal exposure to physical violence and/or sexual violence by a partner.

Table 1 (*Continued*)

Author;Year	Place	Title	Objective	Population (Type/N)	Study design	Results
Magalhães et al., 2016	Brasil	Stunting and associated factors in children aged 6 to 24 months attended in the Southwest of Bahia Health Units	To assess the prevalence and factors associated with stunting in children aged 6 to 24 months.	360 children between 12 and 24 months	Cross-sectional study	The factors that were associated with the outcome were: absence of paternal work and low birth weight
Valente et al., 2016	Portugal	Acute and chronic malnutrition and their predictors in children aged 0e5 years in Sao Tome: a cross-sectional, population-based study	To evaluate the nutritional status and its predictors in children aged 0 to 5 years old in São Tomé	1,285 children between 0 and 5 years old	Cross-sectional study	Adequate birth weight, adequate maternal nutritional status, the mother's good education and good weight gain, especially in the first year of life, were important protective factors against short stature in childhood.
Kim et al., 2017	Banglades, India, Nepal, Pakistan, Afghanistan	Relative importance of 13 correlates of child stunting in South Asia: Insights from nationally representative data from Afghanistan, Bangladesh, India, Nepal, and Pakistan	To investigate the relative and joint importance of a set of 13 correlations of stunting and severe dwarfism in infants and young children aged 6 to 23 months	3,159 babies 6 to 8 months 18,586 children aged 6 to 23 months	Cross-sectional study	The strongest correlates of childhood stunting were: low maternal height, low family wealth, high maternal BMI, minimal dietary diversity, low maternal education, and age at marriage.
Cruz et al., 2017	Moçambique	Factors Associated with Stunting among Children Aged 0 to 59months from the Central Region of Mozambique	To identify key sociodemographic, health and environmental determinants of stunting in children aged 0-59 months and provide useful information for future health strategies and interventions	282 children under 5 years	Case control	Low birth weight, low maternal schooling, maternal occupation, living in rural areas, large family, large number of children under five at home, cooking with charcoal, living in a wooden or straw house or without adequate flooring, short total breastfeeding time as well as the duration of exclusive breastfeeding and the time of initiation of complementary feeding were significantly related to stunting.
Fentahun et al., 2018	Etiópia	Seasonality and determinants of child growth velocity and growth deficit in rural southwest Ethiopia	To assess child growth velocity, stunting and their determinants in rural southwest Ethiopia.	2,607 children under 5 years olds	Longitudinal household survey	Children's linear growth had similar determinants in the post and pre-harvest seasons. Children with low food diversity and born in the lean season showed lower linear growth in both seasons. Child age was positively associated with children's linear growth in both seasons. On the other hand, not having had any illness during the last 2 weeks and the household's severe food insecurity were positively associated with the linear growth of the child in the post-harvest period..
Ntenda & Chuang, 2018	Malawi	Analysis of individual-level and community level effects on childhood undernutrition in Malawi	To uncover the effects of a wide range of individual and community-level socioeconomic factors on the risks of child malnutrition in Malawi	6,384 mother pairs with children under 5 years old	Cross-sectional study	At the individual level, the risk of child malnutrition was significantly higher in males, children who were small at birth, with an episode of diarrhea in the last 2 weeks, the product of multiple births, born to mothers with low socioeconomic status, or low education, or underweight, and born in the year 2004. At the community level, children born in communities with low and medium wealth, and in communities with low and medium female education were more likely to be malnourished
Nshiyiryo et al., 2019	Ruanda	Risk factors for stunting among children under five years: a cross-sectional population-based study in Rwanda using the 2015 Demographic and Health Survey	To identify risk factors for stunting in Rwanda.	3,594 children under 5 years old	Cross-sectional study	In the adjusted analysis, the following factors were significant: boys, children 6 to 23 months and 24 to 59 months compared with ages 0–6 months, low birth weight, low maternal weight and height, primary schooling for mothers, illiterate mothers, poorer households. Family-level factors are the main drivers of stunting for children in Rwanda.
Ismawati et al., 2020	Lamongan City, Indonésia	Nutrition intake and causative factor of stunting among children aged under-5 years in Lamongan city	To analyze nutritional intake and the factor that causes stunting in children under 5 years of age	40 children under 5 years old	Cross-sectional study	The causative factor for short stature among children under 5 years of age was lower nutritional intake, infectious disease and parental characteristics.

Table 1 (*Continued*)

Author;Year	Place	Title	Objective	Population (Type/N)	Study design	Results
Campos et al., 2020	Mexico	Association Between Breast-feeding and Child Stunting in Mexico.	To examine the association between breastfeeding and other individual, family and environmental factors with stunting in children	2,089 children between 6 and 35 months	Cross-sectional study	Low birth weight children, low maternal stature, greater number of children <5 years per family, and moderate to severe food insecurity were consistent risk factors for child stunting in all models.
Dimitrova & Muttarak, 2020	India	After the floods: Differential impacts of rainfall anomalies on child stunting in India	To investigate the impact of climate variability on child malnutrition.	220,823 children under 5 years old	Cross-sectional study	Excessive rainfall increases the risk of stunting in India. Children born into disadvantaged castes, poorer families and to less educated mothers are more likely to be affected than children born into less socially disadvantaged groups.
Wu & Guo, 2020	China	An analysis of the nutritional status of left-behind children in rural China and the impact mechanisms of child malnutrition	To investigate how the state of abandonment affects child malnutrition.	7,459 rural children aged 0 to 15 years	Cross-sectional study	The results show that children whose mothers work are at higher risk for stunting and underweight Individual child factors (age, sex) and parental genetic factors (height, weight) have direct effects on rates of malnutrition and underweight children, while the parents' education indirectly influences through the mediator of family income and domestic facilities.
Silveira et al., 2020	Brazil	Malnutrition and associated factors among quilombola children under 60 months of age in two cities of the state of Maranhão, Brazil	To assess the prevalence of short stature in children younger than 60 months	372 children under 60 months	Cross-sectional study	Children whose mothers had short stature (< 1.497 m) were more likely to have a height-for-age déficit
Baye & Hirvonen, 2020	Ethiopia	Evaluation of Linear Growth at Higher Altitudes	To investigate whether altitude is associated with an increased risk of linear growth failure and to assess the implications associated with using the 2006 World Health Organization growth standards	964,299 children aged 0 to 59 months	Cross-sectional study	An altitude increase of 1,000 m above sea level was associated with a 0.163 unit decrease in height/age index.
Randell et al., 2020	Ethiopia	Stunted from the start: Early life weather conditions and child undernutrition in Ethiopia	To examine the relationship between climate conditions and child nutrition in Ethiopia	23,000 children aged 1 to 4 years	Cross-sectional study	Higher precipitation during the rainy seasons early in life is associated with higher height for age. Furthermore, higher temperatures in utero, particularly during the first and third trimesters, and more rainfall during the third trimester, are positively associated with severe stunting, although stunting decreases with temperature in early life. There is potential evidence for a number of pathways underlying the climate-child nutrition relationship, including agricultural livelihoods, heat stress, infectious disease transmission, and women's time use during pregnancy.
Nshimyiryo et al, 2019	Ruanda	Risk factors for stunting among children under five years: a cross-sectional population-based study in Rwanda using the 2015 Demographic and Health Survey	To identify risk factors for stunting in Rwanda.	3,594 children under 5 years old	Cross-sectional study	In the adjusted analysis, the following factors were significant: boys, children 6 to 23 months and 24 to 59 months compared with ages 0–6 months, low birth weight, low maternal weight and height, primary schooling for mothers, illiterate mothers, poorer households. Family-level factors are the main drivers of stunting for children in Rwanda.
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Randell et al., 2020	Ethiopia	Stunted from the start: Early life weather conditions and child undernutrition in Ethiopia	To examine the relationship between climate conditions and child nutrition in Ethiopia	23,000 children aged 1 to 4 years	Cross-sectional study	Higher precipitation during the rainy seasons early in life is associated with higher height for age. Furthermore, higher temperatures in utero, particularly during the first and third trimesters, and more rainfall during the third trimester, are positively associated with severe stunting, although stunting decreases with temperature in early life. There is potential evidence for a number of pathways underlying the climate-child nutrition relationship, including agricultural livelihoods, heat stress, infectious disease transmission, and women's time use during pregnancy.
Sk et al., 2021	Índia	Nutritional status and concomitant factors of stunting among pre-school children in Malda, India: A micro-level study using a multilevel approach	To know the risk factors for dwarfism among children aged 36 to 59 months in Malda.	731 mothers and children aged between 36 and 59 months	Cross-sectional study	The interval between births, low birth weight, short duration of breastfeeding, the mother's low age, the mother's low education and occupation are the risk factors associated with stunting.
Le & Nguyen, 2021	55 low and middle income countries	In-utero Exposure to Rainfall Variability and Early Childhood Health	To investigate the extent to which exposure to rainfall variability and shocks, including droughts and heavy rainfall events, in utero affects early childhood health	600,000 children under five	Cross-sectional study	Rainfall variability negatively affects the anthropometric status of children under five years of age in 55 low- and middle-income countries, disadvantaged families, such as poor and uneducated families, are especially vulnerable to rainfall variability during pregnancy.

Table 1 (*Continued*)

Author;Year	Place	Title	Objective	Population (Type/N)	Study design	Results
Edwards et al., 2021	Philippines	The influence of natural disasters on violence, mental health, food insecurity, and stunting in the Philippines: Findings from a nationally representative cohort	To study impacts of exposure to multiple natural disasters on children's development	4,952 children up to 10 years old	Cohort	Experiencing natural disasters was associated with higher levels of family violence in the last 12 months, parental stress, children witnessing physical violence and victims of physical abuse, short stature and greater food insecurity.
Ayelign & Zerfu, 2021	Ethiopia	Household, dietary and healthcare factors predicting childhood stunting in Ethiopia	To determine the main factors associated with the risk of stunting among children under five in Ethiopia.	1,023 children under 5 years old	Cross-sectional study	The results show that family and demographic factors, such as low maternal education, low wealth index, male gender of the child, lack of possession of a refrigerator and possession of a television and others such as the birth of twins, inappropriate material on the main floor of the house, unsuitable cooking fuel types were significantly associated with stunting. Among dietary factors, early initiation of breastfeeding; feeding with powdered or fresh milk; formula feeding; consumption of beta-carotene-rich meats and fruits and vegetables were significantly associated with lower odds of stunting. Inadequate prenatal care, deworming during pregnancy, institutional delivery, and inadequate birth size were among the health factors associated with stunted growth in children under five.
Namirembe et al., 2022	Uganda	Child stunting starts in utero: Growth trajectories and determinants in Ugandan infants	To identify growth patterns in Ugandan babies and assess pre- and postnatal factors associated with each pattern.	4,528 children up to 12 months	Cohort	The risk factors that increased the probability of being children with short stature were: increased home distance from a water source, being a poor home and being premature at birth.
Lai et al., 2022	Cambodia	Risk factors for early childhood growth faltering in rural Cambodia: a cross sectional study	To determine risk factors for stunting by assessing child nutrition and water, sanitation and home hygiene (WASH) variables and their association with the nutritional status of children under 24 months of age in rural Cambodia.	4,036 children under 24 months of age from 3,877 families (491 groups)	Cross-sectional study	The presence of soap and water at a household's handwashing station was positively associated with child growth; domestic use of an improved source of potable water and proper infant faeces disposal practices were protective against stunting. Among children 1—6 months of age: shared sanitation was negatively associated with growth; improved sanitation facilities were protective against dwarfism; and open defecation has been associated with dwarfism.
Argaw et al., 2022	Ethiopia	Stunting and associated factors among primary school children in Ethiopia: School-based cross-sectional study	To assess the prevalence and factors associated with stunting among primary school children.	500 children aged 6 to 14 years	Cross-sectional study	Stunting was significantly associated with low educational status, low dietary diversity, younger child age, larger family size, and dysfunctional families.
Oliveira et al., 2022	Brazil	Reduction of the height deficit and the purchase of food from family farming for school feeding in Brazil	To analyze the effect of the direct purchase of food from family farming for school feeding on the height deficit in children under five years old	4,488,230 children under 5 years old	Ecological study	For each percentage point of increase in the purchase of food from family farms for school meals, there was, on average, a decrease of 0.55 points in the prevalence of stunting.
Bliznashka & Jeong, 2022	13 countries	Investigating the direct and indirect associations between birth intervals and child growth and development: A cross-sectional analysis of 13 Demographic and Health Surveys	To investigate the associations between birth intervals and child growth and development and to examine childhood illness, child diet and maternal stimulation as potential mechanisms.	8,300 children aged 36 to 59 months	Cross-sectional study	Longer birth intervals (≥33 months) were associated with a higher height/age ratio (mean difference 0.23).

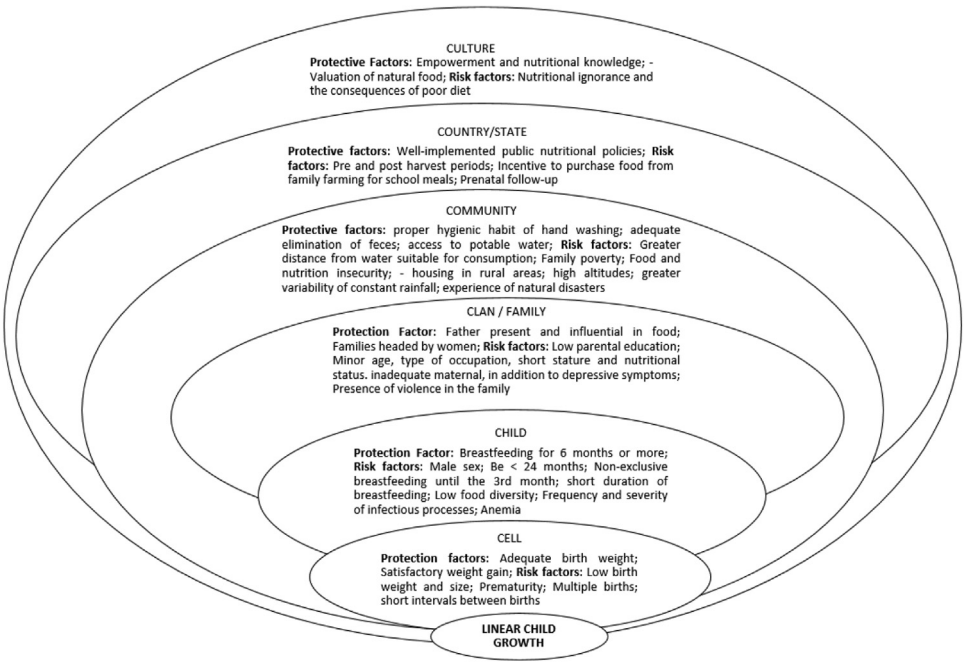

Figure. 2 Model 6C adapted to the determinants of children's linear growth.

interrelated within the subsystems - cell, child, clan, community, country/state and culture.

At the cellular level, processes coordinated and strongly orchestrated by the fetal genome (sum of maternal and paternal genomes) and modulated by the cellular microenvironment (gene-environment interaction) influence the normal growth and development of the fetus, including its organs and tissues. The cellular microenvironment is determined by the fetal environment, which, in turn, is determined by the maternal and external environments, so the environmental issue will reflect on the biology, physiology and metabolism of the newborn.[10]

The intrauterine environment aggregates cellular factors that can influence later growth and development of children. The pre-gestational nutritional status and maternal nutrition during this phase can influence the health conditions of the fetus, such as birth weight. Deviations in birth weight are related to increased child morbidity and mortality and should be evaluated early.[11] In the studies found, low birth weight was one of the variables most related to growth retardation, demonstrating its influence on future child growth.[12–20]

Other conditions related to pregnancy that influence child growth and development are prematurity[21], small size at birth, multiple births[22,23] and shorter birth intervals.[20,24] A single study found gestational factors that protected adequate linear growth were satisfactory birth weight and weight gain.[25]

The characteristics inherent to the child include sex and age and behavioral characteristics, such as history and duration of breastfeeding, minimum acceptable diet both in adequate diversity and frequency, in addition to the history of infections.

Sex is a biological factor that interferes with nutritional status, determining growth and differentiated energy stock between females and males, that is, lower linear growth and energy accumulation in the form of fat for girls and greater linear growth and greater protein supply for boys.[26] Thus, male children, because they have a higher protein-energy need than female children, are more subject to the development of short child stature, when the food supply is similar. Therefore, being a boy is a risk factor for children's linear growth.[18,22,23,27,28]

Regarding growth and age, some articles [27–30] have pointed out that age younger than 24 months is a risk factor for child growth, considering the fact that children under 2 years old have a high growth rate and, therefore, greater nutritional needs. Nshimyiryol et al.[18] state that age between six to 23 months and 24 to 59 months is a risk factor for developing short stature. This is because, when for some reason growth in early childhood is slow, the nervous system permanently "programs" itself to save energy, to ensure survival in adverse conditions, with adaptations including hormonal ones. After this phase, these adaptation mechanisms have already occurred and older children, who depend more on hormonal regulators, are able to make the most of the energy saved.[31]

With regard to dietary characteristics, breastfeeding is recognized as the ideal form of infant nutrition, especially in the first months of life. Children who are breastfed are healthier and have better cognitive development.[32] On the other hand, non-exclusive breastfeeding in the first six months of life is a risk factor for inadequate child growth.[33]

Four studies identified similar relationships. Rachimi et al.,[15] Garcia Cruz et al. [17] and Ayelign & Zerfu[23] point to breastfeeding for six months or more and its early onset as protective factors for adequate linear growth; Musaad et al.[34] reveal non-exclusive breastfeeding up to the 3rd month and Sk et al.[20] the short duration of breastfeeding as risk factors for short child stature.

After breastfeeding, at food introduction, when food supply is insufficient early in life, adaptations for survival occur

through saved energy, selectively preserving some tissues and organs over others. This adaptation is achieved by endocrine changes that affect growth, energy expenditure and body composition, which are influenced by the composition and quantitative and qualitative content of the diet.[31,35]

Some studies included in this review identified an association between low dietary diversity and short child stature,[29,30,36–39] as well as the time of initiation of complementary feeding was related to stunting, [17] indicating that in families that do not have a minimum diet acceptable in terms of adequate diversity and frequency, children are more likely to be stunted.

When taking into account the child's health status, the frequency and severity of infectious processes, as well as the occurrence of anemia, are related to child growth, as increased metabolism requires a greater protein energy supply; protein insufficiency was confirmed by three articles found in this review.[39–41]

Starting from the environment where children develop, the context in which the proximal processes associated with child development occur is the family. A harmonious family environment and the role of the support network have already been attested as protective effects against the consequences of poverty and social vulnerability.[42] The family, even experiencing an unfavorable context, has a crucial importance in child development, responsible for ensuring the children a healthy eating pattern and provide a stimulating psychosocial environment, indispensable for their full growth and development. Maternal height and nutritional status influence the linear growth of offspring. These influences likely comprise both genetic and non-genetic factors, including nutrition-related intergenerational influences, which have an impact on growth, making it difficult to achieve the genetic potential for maximum height in low- and middle-income countries.[43]

Thus, with regard to maternal characteristics that influence child growth, maternal and even parental education[13,15,17,18,20,22,23,25,27,30,36,38,41,44–46], mental health in the prepartum period, in addition to maternal age[38,47], occupation[17,20,28], short stature and maternal nutritional status[12,13,15,18,19,25,36,38,44,46,48–50] are factors that are directly related to children's linear growth, as confirmed by the studies found in this review.

Family size is also important, especially related to social vulnerability, as scarce resources are shared by more members. Another influential factor is whether this family is headed by women or men, as the mothers' decisions take into account factors that the fathers do not.[13,17,30,51] The presence of violence in the family also influences child growth, as the family structure at these times is weakened.[52]

In order to broaden horizons beyond the family environment, it is important to emphasize that children's linear growth reflects a multicausal process that is influenced by environmental, social and biological factors.[53] In this process, among the contexts that represent the environment, is the community where the child interacts with others outside the family. Therefore, the characteristics of the sanitary conditions of the community directly influence the development of this child. One review found consistent support in numerous previous studies showing that even children who are fed in sufficient amounts and are adequately breastfed, if exposed to intestinal inflammation caused by environmental enteric dysfunction, they will have their growth stunted.[54]

Recent articles demonstrate that environmental health conditions are associated with the development of environmental enteric dysfunction, and this in turn may contribute to inadequate infant linear growth, secondary to nutrient malabsorption, decreased immunity, and recurrent infections.[55–58] These findings highlight the importance of appropriate environmental sanitary conditions as one of the pillars in promoting adequate linear growth in childhood. The distance from a source of water suitable for consumption can be a risk factor; [21] on the other hand, the proper hygienic habit of washing hands, adequate elimination of feces and access to a source of potable water are protective factors for satisfactory growth.[44,59]

Another important fact to be considered is for the families that have unsatisfactory socioeconomic conditions. Studies have already shown that the individual's height reflects the socioeconomic and cultural conditions of the child's community, with linear growth retardation due to nutritional/environmental causes being one of the most sensitive indicators of social inequality between peoples.[31,60]

Socioeconomic and demographic variables such as per capita family income, maternal schooling, access to consumer goods, number of rooms, number of people in the household and type of household have already been associated with insufficient linear growth in children.[13,61,62] These characteristics are mediated. due to low purchasing power and low education, which leads to the acquisition and consumption of inadequate food.[61,63]

Studies have reported that when households and/or communities were considered poorer, there was a greater proportion of child growth retardation.[13,18,21–23,36,64,65] This condition can lead to the acquisition and consumption of inadequate food, which can lead to food insecurity. This insecurity has also been associated with stunting in children.[19,44]

Still in the community domain, when expanding the spectrum of factors involved, housing in rural areas, living at higher altitudes, greater variations in rainfall and the experience of natural disasters can be considered as risk factors for the development of short child stature.[15,65–69]

When looking at the context of the economy, state and federal policies related to child nutrition establish parameters that influence community resources and practices. Community and social factors are the only elements under the contextual determinants of child linear growth mentioned in the World Health Organization (WHO) framework. Sub-elements include political economy, state and health care, education, agriculture and food systems, and water, sanitation and environment. Related to these sub-elements, linear child growth is associated with many determinants of political economy, state and health care, water, sanitation, and the environment.[70]

Thus, it has been shown that severe food insecurity was associated with growth retardation even in the post-harvest period [29] and that, in the political sphere, a prenatal care program, when not implemented, proved to be a risk factor.[14,23] A policy of encouraging the purchase of food from family farming for school meals was seen to reduce the prevalence of stunting.[71] These studies illustrate how broad the determinants of this problem are.

Finally, society and culture include beliefs and norms, social support networks, and key concepts often influenced by other levels such as the media and public policies governed by the state. In this context, it is important to promote adequate conceptions to provide healthy behaviors at the levels of community, family and individual. [7]

Although, in the current review, no articles were found that related the extent to which cultural factors can interfere with linear growth, the lack of knowledge can be harmful. An example of that is the non-recognition of the problem that makes sense in a society where children with growth retardation are often offspring of parents with short stature, who, in turn, also had small parents, and this phenomenon is interpreted as a "family problem". The population, in general, is unaware of the relationship between poverty, chronic hunger, inadequate nutrition, poor quality of life and inadequate linear growth.

Conclusion

This review showed that children's linear growth is determined by interrelated factors that encompass aspects occurring beforethe child's birth, associated with pregnancy and the mother, which reflect on the child, as well as issues of the family nucleus and the community in which the child is inserted, and also for socioeconomic and political issues. In this way, the articulation between the six subsystems was evidenced and a 6Cs model was developed for the determining factors of children's linear growth.

Conflicts of interest

The authors declare no conflicts of interest.

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