Journal of Indonesian Specialized Nutrition | e-ISSN: 3032-3878
Vol. 04 No. 02, 2026

EARLY FEEDING CHALLENGES AS BARRIERS TO CATCH-UP GROWTH IN LOW BIRTH WEIGHT INFANTS: A NARRATIVE REVIEW

Selma Avianty[1*], Refani Alycia Kusuma[2], Hanna Audila[3]

[1] *Centre for Nutrition and Health Studies, Faculty of Public Health, Universitas Kusuma Husada, Surakarta, Central Java, Indonesia, 57136*
[2] *Department of Nutrition, Faculty of Medicine, Universitas Negeri Semarang, Semarang, Central Java, Indonesia, 50229*
[3] *Department of Epidemiology, Faculty of Public Health, Universitas Indonesia, Jakarta, Indonesia, 16424*

*Corresponding Author: selmaavianty@ukh.ac.id

Abstract

Background: Low birth weight (LBW) infants are highly vulnerable to postnatal growth failure due to physiological immaturity, increased metabolic demands, and feeding-related complications. Early feeding challenges may interfere with adequate nutritional intake during a critical period of growth and development, thereby impairing catch-up growth. **Objective:** This narrative review aimed to synthesize current evidence regarding early feeding challenges as barriers to catch-up growth in LBW infants. **Methods:** A narrative literature search was conducted using PubMed, Scopus, ScienceDirect, and Google Scholar databases. Relevant articles published between 2016 and 2026 were reviewed, focusing on feeding difficulties, nutritional management, and growth outcomes in LBW infants. **Results:** Early feeding challenges in LBW infants include impaired suck–swallow coordination, feeding intolerance, delayed enteral feeding progression, breastfeeding difficulties, and inadequate post-discharge feeding support. These factors may contribute to insufficient energy and protein intake, impaired nutrient utilization, and persistent growth faltering. Inadequate catch-up growth is associated with adverse neurodevelopmental, immunological, and metabolic outcomes. **Conclusion:** Early feeding challenges are major barriers to optimal catch-up growth in LBW infants. Comprehensive nutritional and multidisciplinary interventions are essential to support balanced postnatal growth and improve long-term health outcomes.

Keywords: Low birth weight; catch-up growth; feeding difficulties; infant nutrition; growth faltering

Introduction

Low birth weight (LBW), defined as a birth weight below 2500 g regardless of gestational age, remains a major global public health concern in neonatal and child nutrition.[1] According to recent joint estimates from the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), approximately 19.8 million infants worldwide were born with LBW in 2020, accounting for nearly 14.7% of all live births globally.[2] Despite ongoing international efforts to reduce maternal and neonatal malnutrition, the global prevalence of LBW has declined only modestly over the past two decades, suggesting that the WHO target of a 30% reduction in LBW may not be achieved in many regions.[3] The burden of LBW is disproportionately concentrated in low- and middle-income countries (LMICs), particularly in South Asia and Sub-Saharan Africa, where maternal undernutrition, infection, inadequate antenatal care, and socioeconomic vulnerability remain prevalent.[4,5] Prematurity remains one of the major contributors to LBW, particularly in LMIC settings. A recent meta-analysis from Indonesia identified multiple determinants of prematurity, including maternal health conditions, inadequate antenatal care, and socioeconomic factors, many of which overlap with risk factors for LBW.[6]

LBW infants are highly susceptible to adverse short- and long-term health outcomes. During the neonatal period, LBW is strongly associated with increased risks of mortality, respiratory complications, feeding intolerance, infection, and prolonged hospitalization.[7] Beyond infancy, LBW has also been linked to impaired neurodevelopment, persistent growth faltering, reduced cognitive performance, and a higher risk of chronic non-communicable diseases later in life. Consequently, promoting optimal postnatal growth among LBW infants has become a major priority in pediatric nutrition and neonatal care.[8]

Catch-up growth refers to an accelerated pattern of growth that occurs following a period of intrauterine or postnatal growth restriction, allowing infants to approach their genetically determined growth trajectory.[9] In LBW infants, adequate catch-up growth during early life is essential for improving survival, immune function, neurodevelopmental outcomes, and overall long-term health.[10] Previous studies have demonstrated that LBW and small-for-gestational-age (SGA) infants who achieve successful catch-up growth within the first two years of life tend to have better developmental and cognitive outcomes than those who

remain growth restricted.[11,12] However, catch-up growth in LBW infants is frequently suboptimal, particularly among infants with neonatal complications and those living in resource-limited settings.

Early nutrition plays a critical role in shaping postnatal growth trajectories in LBW infants. Due to limited nutrient reserves, immature gastrointestinal function, and increased metabolic demands, LBW infants require timely and adequate nutritional support immediately after birth.[13] Nevertheless, achieving sufficient nutrient intake during the neonatal period remains challenging. Several studies have identified early feeding difficulties as common complications among LBW and preterm infants, including poor suck–swallow–breathe coordination, feeding intolerance, delayed advancement of enteral feeding, gastrointestinal immaturity, and breastfeeding difficulties.[14,15] These feeding-related problems frequently result in inadequate energy and protein intake during a critical period of growth and organ development.[16,17]

Feeding intolerance has emerged as one of the major barriers to achieving optimal nutritional intake in vulnerable neonates.[18] Recent evidence suggests that feeding intolerance is associated with extrauterine growth restriction and adverse neurodevelopmental outcomes among preterm and small-for-gestational-age infants[19,20]. Similarly, observational studies have reported that suboptimal feeding practices during early infancy are associated with poor weight gain and growth faltering among LBW infants.[21,22] Persistent growth faltering during infancy may subsequently increase the risk of undernutrition, recurrent infection, impaired immune function, and long-term developmental deficits.[23]

In addition to physiological immaturity, the transition from hospital-based nutritional care to home feeding practices may further complicate postnatal growth recovery in LBW infants.[24] Maternal stress, delayed lactogenesis, inadequate breastfeeding support, limited caregiver knowledge, and inconsistent post-discharge follow-up may contribute to insufficient nutritional intake during early infancy. These barriers are particularly pronounced in LMIC settings, where healthcare limitations and food insecurity may further exacerbate the risk of growth failure.[25–27]

Although previous reviews have extensively discussed nutritional management strategies and growth outcomes in LBW infants, limited attention has been given to the

specific role of early feeding challenges as barriers to successful catch-up growth. Most existing reviews primarily focus on nutrient requirements, feeding protocols, or long-term metabolic consequences, rather than integrating the physiological and clinical mechanisms through which feeding difficulties impair postnatal growth recovery. Given the critical importance of early nutrition during the neonatal period, a comprehensive understanding of the mechanisms linking feeding challenges to impaired catch-up growth is essential for improving nutritional interventions and clinical management in LBW infants. Therefore, this narrative review aims to synthesize current evidence regarding early feeding challenges as major barriers to catch-up growth LBW infants, with particular emphasis on the physiological, nutritional, and clinical pathways underlying impaired postnatal growth outcomes.

Method

A narrative literature search was conducted using PubMed, Scopus, ScienceDirect, and Google Scholar databases. Relevant articles published in English between January 2016 and June 2026 were considered. The literature search was conducted on May 15th 2026. The search strategy included combinations of keywords such as “low birth weight,” “catch-up growth,” “feeding difficulties,” “feeding intolerance,” “breastfeeding,” and “infant nutrition.” Original studies, clinical trials, cohort studies, systematic reviews, and narrative reviews addressing feeding-related barriers and growth outcomes in LBW infants were included. Articles focusing exclusively on congenital anomalies or unrelated pediatric conditions were excluded. The selected literature was narratively synthesized to explore the relationship between early feeding challenges and impaired catch-up growth in LBW infants.

Catch-Up Growth on Low Birth Weight Infants

LBW infants represent a heterogeneous population consisting of both preterm infants and term infants with intrauterine growth restriction or SGA status. Although both groups share an increased risk of postnatal growth failure, the underlying mechanisms differ substantially.[28,29] Preterm LBW infants primarily experience physiological immaturity, including underdeveloped gastrointestinal, neurological, and metabolic functions, whereas term-SGA infants often exhibit altered fetal programming and limited nutrient reserves resulting from chronic intrauterine malnutrition. These differences may influence feeding

tolerance, nutritional requirements, and the capacity to achieve adequate catch-up growth.[30]

Catch-up growth is a critical adaptive process in LBW infants that aims to restore growth toward the child's genetically determined trajectory following intrauterine or early postnatal growth restriction.[31] In clinical practice, catch-up growth is commonly characterized by accelerated weight and linear growth during infancy, particularly within the first two years of life, which represents a sensitive developmental window for organ maturation and neurodevelopment.[32] Previous evidence has demonstrated that adequate catch-up growth is associated with improved immune competence, reduced infection risk, enhanced neurocognitive outcomes, and lower rates of persistent stunting among LBW infants.[33]

Nevertheless, successful catch-up growth is not consistently achieved in all LBW infants. Several longitudinal studies have reported that a substantial proportion of preterm and small-for-gestational-age infants fail to attain adequate linear or ponderal growth during early childhood.[11,34,35] A recent review reported that approximately 13–40% of preterm SGA children failed to achieve adequate catch-up growth by four years of age, highlighting the long-term vulnerability of this population.[29] This impaired growth trajectory is influenced by multiple biological and environmental determinants, including neonatal complications, chronic inflammation, inadequate nutrition, recurrent infection, and socioeconomic adversity.[36,37]

Although accelerated postnatal growth is generally considered beneficial in LBW infants, the quality and timing of catch-up growth remain clinically important. Excessively rapid weight gain during infancy has been associated with increased adiposity, insulin resistance, and later metabolic syndrome, supporting the developmental origins of health and disease (DOHaD) hypothesis.[38,39] Therefore, nutritional management in LBW infants should not solely aim to promote rapid weight gain, but rather to achieve balanced growth characterized by adequate lean body mass accretion and optimal neurodevelopmental outcomes.[40]

Early Feeding Challenges in Low Birth Weight Infants

Early feeding challenges are among the most common complications encountered in LBW infants and represent major barriers to achieving adequate postnatal growth.[41] Due to physiological immaturity, many LBW infants experience impaired suck–swallow–breathe

coordination, weak oral motor function, delayed gastric emptying, and immature gastrointestinal motility, all of which contribute to feeding difficulties during the neonatal period. These problems are particularly pronounced among preterm LBW infants requiring respiratory support or prolonged neonatal intensive care.[14,42] Previous neonatal studies have consistently shown that feeding difficulties often delay the establishment of full enteral feeding and increase the risk of cumulative nutritional deficits during the early postnatal period.[43,44]

Feeding intolerance is another major challenge frequently observed in LBW infants. Clinical manifestations such as gastric residuals, abdominal distension, regurgitation, and vomiting often lead clinicians to interrupt or slow enteral feeding advancement.[18] While cautious feeding progression is important to reduce the risk of necrotizing enterocolitis, prolonged feeding interruption may compromise nutrient delivery during a critical period of rapid growth and organ development.[45] Emerging evidence indicates that feeding intolerance is associated with extrauterine growth restriction and adverse neurodevelopmental outcomes among vulnerable neonates.[19,46]

Breastfeeding challenges also substantially contribute to inadequate nutritional intake in LBW infants. Maternal stress, delayed lactogenesis, maternal–infant separation during hospitalization, and poor infant latch frequently interfere with successful breastfeeding initiation and continuation.[47] Maternal psychological well-being may also influence feeding success. Emerging evidence suggests that inadequate attention to perinatal mental health may negatively affect breastfeeding practices, maternal confidence, and caregiving capacity, potentially contributing to feeding difficulties among high-risk infants.[48] In many LMIC settings, inadequate breastfeeding counseling and limited lactation support further exacerbate feeding problems after hospital discharge.[49] Observational studies have shown that inappropriate feeding practices and inadequate caloric intake during infancy are strongly associated with growth faltering and poor weight gain in LBW infants.[50,51]

The transition from hospital-based nutritional support to home feeding practices also represents a critical period of vulnerability. Following discharge, many caregivers face difficulties in maintaining optimal feeding frequency, formula preparation, breast milk expression, or responsive feeding practices.[52] Limited follow-up monitoring and poor

caregiver education may further contribute to insufficient nutrient intake and delayed growth recovery[53]. Caregiver nutrition literacy is increasingly recognized as a key determinant of infant feeding practices. Poor nutrition knowledge may compromise breastfeeding continuation, complementary feeding decisions, and adherence to nutritional recommendations, thereby increasing the risk of growth faltering among vulnerable infants.[54] These findings suggest that feeding challenges in LBW infants are not limited to physiological immaturity alone but are also influenced by healthcare, psychosocial, and socioeconomic factors.[55]

Because LBW infants enter postnatal life with limited nutrient reserves and elevated metabolic demands, achieving normal growth velocity requires substantially greater nutritional support compared with term infants with normal birth weight.[56] However, persistent feeding difficulties frequently prevent LBW infants from meeting these increased nutritional requirements, thereby impairing the attainment of optimal catch-up growth. The major feeding challenges identified across the reviewed literature and their potential implications for nutritional status and catch-up growth are summarized in **Table 1.**

Table 1. Major Early Feeding Challenges and Their Potential Impact on Catch-Up Growth in LBW Infants

Feeding Challenge	Key Features	Potential Nutritional Consequences	Potential Impact on Catch-Up Growth
Oral feeding difficulties	Poor suck–swallow–breathe coordination, weak oral motor function	Reduced feeding efficiency and milk transfer	Delayed weight gain and impaired growth recovery
Feeding intolerance	Gastric residuals, vomiting, abdominal distension	Interrupted or delayed enteral feeding	Cumulative energy and protein deficits
Gastrointestinal immaturity	Delayed gastric emptying, reduced digestive capacity	Reduced nutrient digestion and absorption	Impaired nutrient utilization and growth

Feeding Challenge	Key Features	Potential Nutritional Consequences	Potential Impact on Catch-Up Growth
Breastfeeding challenges	Delayed lactogenesis, maternal–infant separation, poor latch	Insufficient breast milk intake	Suboptimal nutritional intake during early infancy
Post-discharge feeding challenges	Limited caregiver knowledge, inadequate feeding support, poor follow-up	Inconsistent feeding practices and nutrient intake	Increased risk of persistent growth faltering

Each feeding challenge may impair growth through distinct physiological pathways. Oral feeding difficulties primarily reduce feeding efficiency and milk transfer, leading to inadequate energy intake. Feeding intolerance often results in delayed enteral feeding progression and cumulative nutrient deficits. Gastrointestinal immaturity compromises nutrient digestion and absorption, reducing nutrient bioavailability. Breastfeeding challenges may limit breast milk intake during a critical period of growth, while post-discharge feeding challenges can result in inconsistent feeding practices and prolonged nutritional inadequacy. Together, these mechanisms contribute to impaired catch-up growth in LBW infants.

Mechanisms Linking Feeding Challenges to Failure of Catch-Up Growth

The relationship between feeding difficulties and impaired catch-up growth in LBW infants is multifactorial and involves complex physiological, metabolic, and nutritional pathways. One of the primary mechanisms is inadequate energy and protein intake resulting from insufficient feeding tolerance or delayed feeding progression.[16] LBW infants have substantially higher nutritional requirements than term infants because of rapid tissue accretion, increased metabolic demand, and limited endogenous nutrient reserves. Consequently, even short periods of nutritional interruption may lead to cumulative deficits that impair growth velocity.[57–59]

Insufficient protein intake is particularly detrimental because protein is essential for lean tissue growth, organ maturation, and neurodevelopment.[60,61] Several neonatal nutrition studies have demonstrated that inadequate early protein provision is associated with poorer weight gain, reduced head circumference growth, and persistent extrauterine growth restriction.[62,63] Furthermore, inadequate caloric intake may impair anabolic signaling pathways involving insulin, insulin-like growth factor-1 (IGF-1), and growth hormone activity, thereby limiting compensatory growth mechanisms.[64,65]

In addition, gastrointestinal immaturity may compromise nutrient digestion, absorption, and utilization in LBW infants.[66] Delayed gastric emptying, reduced digestive enzyme activity, altered intestinal permeability, and intestinal dysbiosis may collectively reduce feeding efficiency and nutrient bioavailability.[66,67] Recurrent infection and chronic low-grade inflammation may further exacerbate growth failure by increasing metabolic expenditure while simultaneously suppressing appetite and anabolic metabolism. Several studies have suggested that inflammatory cytokines negatively affect growth hormone signaling and protein synthesis, thereby contributing to impaired postnatal growth. [68–71]

Neonatal complications such as respiratory distress, sepsis, and prolonged oxygen dependency may also increase resting energy expenditure, further widening the gap between nutritional requirements and actual intake. As a result, many LBW infants experience a combination of feeding intolerance, illness-related catabolism, and insufficient nutritional support, ultimately leading to persistent growth faltering despite clinical stabilization.[72] Collectively, the available evidence suggests that early feeding challenges contribute to failure of catch-up growth through interconnected physiological, nutritional, and metabolic pathways. These mechanisms involve inadequate nutrient intake, impaired nutrient utilization, inflammatory responses, and altered growth-regulating signaling pathways, ultimately leading to adverse growth and developmental outcomes. The proposed conceptual framework summarizing these pathways is presented in Figure 1.

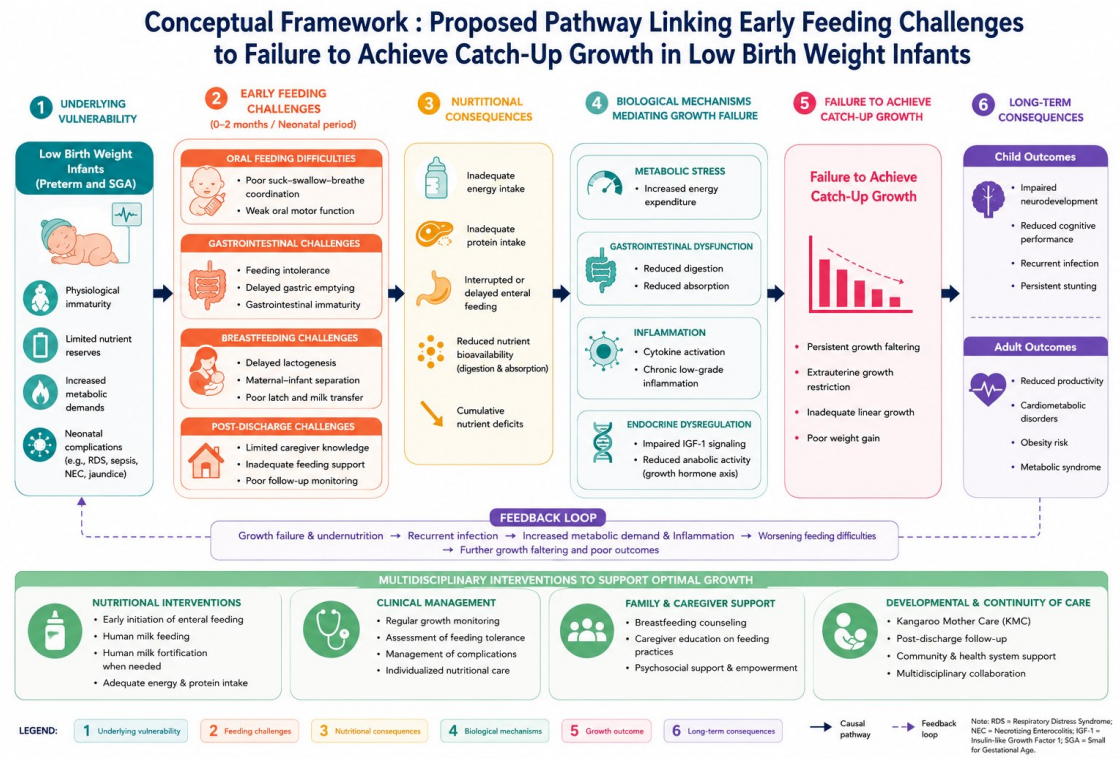

Figure 1. Proposed Pathway Linking Early Feeding Challenges to Failure of Catch-Up Growth in LWB Infants

Clinical Consequences and Nutritional Management

Failure to achieve adequate catch-up growth during infancy may have substantial long-term consequences for LBW infants. Persistent growth faltering is associated with impaired cognitive development, delayed psychomotor performance, weakened immune function, and increased susceptibility to recurrent infection. Inadequate postnatal growth has also been linked to poorer educational outcomes and reduced adult productivity later in life. Since the first two years of life represent a critical period of brain development, prolonged nutritional deficits during infancy may produce irreversible developmental consequences.[73–75]

Appropriate nutritional management is therefore essential to overcome feeding-related barriers and support optimal growth in LBW infants. Early initiation and gradual advancement of enteral feeding have been recommended to improve gastrointestinal adaptation and reduce cumulative nutritional deficits. Human milk remains the best, preferred feeding option because of its immunological, gastrointestinal, and neurodevelopmental benefits. However,

due to the high nutritional demands of LBW infants, human milk fortification is often necessary to ensure adequate protein and energy intake.[76–78]

In addition to nutritional intervention, non-nutritional support plays an important role in promoting successful catch-up growth among LBW infants. Kangaroo mother care, caregiver education, developmental care, breastfeeding counseling, and close post-discharge monitoring have been shown to improve feeding success, physiological stability, and growth outcomes.[79–81] Psychosocial support for mothers may also contribute to improved breastfeeding practices and long-term nutritional continuity.[82] Successful nutritional rehabilitation in vulnerable infants requires coordinated multidisciplinary care involving pediatricians, nutritionists, nurses, lactation consultants, and community health workers. Evidence from Indonesia highlights the importance of interprofessional collaboration (IPC) in improving nutrition-related outcomes through integrated assessment, counseling, monitoring, and follow-up services.[83] Consensus-based IPC guidelines further emphasize that effective growth monitoring and nutritional management require collaboration across healthcare disciplines and continuity of care between hospital and community settings, particularly for high-risk infants requiring long-term nutritional support.[84]

Furthermore, regular post-discharge growth monitoring is essential to facilitate early identification of growth faltering and timely nutritional intervention. Nevertheless, nutritional strategies should aim to achieve balanced growth rather than excessive weight acceleration. While inadequate growth increases the risk of undernutrition and developmental impairment, excessively rapid catch-up growth may predispose LBW infants to obesity and cardiometabolic disorders later in life.[85] Therefore, individualized nutritional management based on growth monitoring and developmental assessment remains critically important.

Future Perspective and Research Gap

Despite increasing recognition of the importance of early nutrition in LBW infants, several important research gaps remain. First, there is currently no universally accepted definition of feeding difficulty or feeding intolerance in LBW infants, resulting in considerable heterogeneity across studies. Variations in feeding protocols, nutritional assessment methods, and growth indicators also limit the comparability of existing evidence.

Second, most available studies focus primarily on short-term weight gain outcomes rather than long-term body composition, neurodevelopment, or metabolic health. Additional longitudinal studies are needed to determine how specific feeding challenges during infancy influence long-term growth trajectories and cardiometabolic risk. Furthermore, evidence from LMIC settings remains relatively limited despite the disproportionately high burden of LBW in these regions.

Another emerging area of interest involves the interaction between gut microbiota, inflammation, and feeding tolerance in LBW infants. Recent evidence suggests that intestinal dysbiosis may contribute to impaired nutrient absorption, chronic inflammation, and growth failure; however, the clinical implications of microbiota-targeted interventions remain insufficiently understood. Future research should therefore explore integrated mechanistic pathways linking feeding difficulties, gastrointestinal function, and postnatal growth outcomes.

Finally, future nutritional strategies should emphasize individualized and multidisciplinary approaches that integrate clinical care, caregiver education, breastfeeding support, and long-term developmental monitoring. Developing standardized feeding protocols and growth monitoring frameworks may improve the early identification of infants at risk of failed catch-up growth and facilitate more effective nutritional interventions.

In addition to addressing current research gaps, translating existing evidence into clinical practice is essential to improve growth outcomes among LBW infants. From a clinical perspective, healthcare providers should prioritize early identification of feeding difficulties, regular growth monitoring, individualized nutritional support, and breastfeeding counseling for LBW infants. Caregivers should receive education regarding feeding frequency, responsive feeding practices, breast milk expression, and recognition of feeding intolerance symptoms. Strengthening post-discharge follow-up and multidisciplinary collaboration may further improve catch-up growth outcomes among LBW infants.

Conclusion

Early feeding challenges, including oral feeding difficulties, feeding intolerance, gastrointestinal immaturity, breastfeeding problems, and post-discharge feeding barriers,

represent major obstacles to achieving adequate catch-up growth in LBW infants. These challenges impair growth through multiple physiological and nutritional pathways, resulting in inadequate nutrient intake and utilization. Early recognition, individualized nutritional management, caregiver support, and multidisciplinary interventions are essential to optimize growth outcomes. Future research should focus on developing effective feeding interventions and long-term strategies to support sustainable catch-up growth in this vulnerable population.

Acknowledgment

The authors would like to acknowledge the support and contributions of Yarsi Pratama University, Edukazi Indonesia Bergizi, Universitas Negeri Semarang, Faculty of Medicine Universitas Indonesia, and the Indonesia Health Development Center for their invaluable assistance in this study.

Conflict of Interest

There is no conflict interest of this publication.

References

1. Aga MA, Woldeamanuel BT. Nutritional and prenatal care factors associated with low birth weight among full-term infants in public hospitals of Addis Ababa, Ethiopia. BMJ Paediatr Open [Internet]. 2025;9(1):1–10. Available from: https://doi.org/10.1136/bmjpo-2025-003732
2. Okwaraji YB, Krasevec J, Bradley E, Conkle J, Stevens GA, Gatica-Domínguez G, et al. National, regional, and global estimates of low birthweight in 2020, with trends from 2000: a systematic analysis. Lancet [Internet]. 2024;403(10431):1071–80. Available from: https://doi.org/10.1016/S0140-6736(23)01198-4
3. World Health Organization (WHO), United National Children's Funds (UNICEF). Global nutrition targers 2030 : Low birth weight brief. World Health Organization. Geneva; 2025.
4. World Health Organization (WHO), United National Children's Funds (UNICEF). Country Consultation on Low Birthweight and Preterm Birth Estimates : Technical Notes. Geneva,

Switzerland; 2023. 1–60 p.

5. Kassie GA, Gebrekidan AY, Adella GA, Woldegeorgis BZ, Haile KE, Workineh A, et al. Socioeconomic inequality and determinants of low birth weight in Kenya: a multilevel analysis using 2022 demographic and health survey. Ital J Pediatr [Internet]. 2025;51(1):1–10. Available from: https;//doi.org/10.1186/s13052-025-02074-9
6. Marsubrin PMT, Ibrahim NAA, Dilmy MAF, Ariani Y, Wiweko B, Irwinda R, et al. Determinants of prematurity in urban Indonesia: a meta-analysis. J Perinat Med [Internet]. 2024;52(3):270–82. Available from: https://doi.org/10.1515/jpm-2023-0151
7. Haksari EL, Irawan G, Lusyati SD, Wibowo T, Yunanto A, Rukmono P, et al. Neonatal mortality and survival of low-birth-weight infants at hospitals in indonesia, a multi center study. Sci Rep [Internet]. 2025;15(1):1–12. Available from: https://doi.org/10.1038/s41598-025-16401-x
8. Frontera W, Spicer CM, Applegate A. Low birth weight babies and disability [Internet]. Low Birth Weight Babies and Disability. Washington, DC: National Academies Press; 2024. 1–246 p. Available from: https://doi.org/10.17226/27375.
9. van Wyk L, Boers KE, van Wassenaer-Leemhuis AG, van der Post JAM, Bremer HA, Delemarre FMC, et al. Postnatal Catch-Up Growth After Suspected Fetal Growth Restriction at Term. Front Endocrinol (Lausanne) [Internet]. 2019;10(June):1–10. Available from: https://doi.org/10.3389/fendo.2019.00274
10. Martin A, Connelly A, Bland RM, Reilly JJ. Health impact of catch-up growth in low-birth weight infants: systematic review, evidence appraisal, and meta-analysis. Matern Child Nutr [Internet]. 2017;13(1):1–13. Available from: https://doi.org/10.1111/mcn.12297
11. Reva Audria Khairani, Tri Faranita, Yanti Harjono Hadiwiardjo, Fachri Razi Arslan. Effect of gestational age on growth of low birth weight infant: retrospective cohort study. Pediatr Sci J [Internet]. 2024;5(2):56–9. Available from: https://doi.org/10.51559/pedscij.v5i2.101
12. Lestari H, As'ad S, Yusuf I, Umboh A, Febriani ADB. Developmental performance in small for gestational age children with and without catch-up growth. Pediatr Indones [Internet]. 2015;55(4):199–202. Available from: https://doi.org/10.14238/pi55.4.2015.199-202

13. Chen CY, Lai MY, Lee CH, Chiang MC. Nutritional Management for Preterm Infants with Common Comorbidities: A Narrative Review. Nutrients [Internet]. 2025;17(12):1–20. Available from: https://doi.org/10.3390/nu17121959
14. Kamity R, Kapavarapu PK, Chandel A. Feeding problems and long-term outcomes in preterm infants—A systematic approach to evaluation and management. Children [Internet]. 2021;8(12):1–16. Available from: https://doi.org/10.3390/children8121158
15. Sawasawa C, Naidoo L, Hoosen SS. Feeding and swallowing difficulties in previously hospitalised premature infants in the neonatal intensive care unit: Perspectives from South African caregivers. South African J Commun Disord [Internet]. 2025;72(2):1–9. Available from: https://doi.org/10.4102/sajcd.v72i2.1119
16. Tang M, Wang Y, Yang F, Xiang Y, Wu J. Etiological Patterns of Protein-Energy Malnutrition in a Pediatric Clinic in China. Med Sci Monit [Internet]. 2025;31(e946284):1–7. Available from: https://doi.org/10.12659/MSM.946284
17. Rahayu A, Yulidasari F, Anggraini L, Rahman F, Laily N, Sari AR, et al. Energy and Protein Intake-Related Risks Affected the Occurrence of Stunting Among Young Children. Adv Heal Sci Res [Internet]. 2020;22(Ishr 2019):330–6. Available from: https://doi.org/10.2991/ahsr.k.200215.063
18. Ortigoza EB. Feeding intolerance. Early Hum Dev [Internet]. 2022;171(105601):1–17. Available from: https://doi.org/10.1016/j.earlhumdev.2022.105601
19. Zhao H, Guo C, Xie G, Tong Y, Wu Y. Feeding intolerance as an independent risk factor for extrauterine growth restriction and neurodevelopmental impairment in small for gestational age preterm infants : a retrospective cohort study. Eur J Med Res [Internet]. 2026;31(589):1–12. Available from: https://doi.org/10.1186/s40001-026-04197-z
20. Zhao H, Qi H, Xu R, Xie G. Risk factors and clinical features of feeding intolerance in preterm infants and the effect of multimodal oral–sucking–oromotor training: a single-center retrospective analysis. J Matern Neonatal Med [Internet]. 2026;39(1):1–15. Available from: https://doi.org/10.1080/14767058.2026.2617714
21. Vesel L, Bellad RM, Manji K, Saidi F, Velasquez E, Sudfeld CR, et al. Feeding practices and growth patterns of moderately low birthweight infants in resource-limited settings:

results from a multisite, longitudinal observational study. BMJ Open [Internet]. 2023;13(2):1–12. Available from: https://10.0.4.112/bmjopen-2022-067316

22. Amaniyo L, Dektar B, Nakibuuka V, Nankunda J, Opoka R, Kiguli S. Prevalence of sub-optimal feeding practices and associated factors in very low birth weight infants admitted to the special care unit, Kawempe Hospital in Uganda. Front Pediatr [Internet]. 2025;13(June):1–14. Available from: https://doi.org/10.3389/fped.2025.1558163
23. Mertens A, Benjamin-Chung J, Colford JM, Coyle J, van der Laan MJ, Hubbard AE, et al. Causes and consequences of child growth faltering in low-resource settings. Nature [Internet]. 2023;621(7979):568–76. Available from: https://doi.org/10.1038/s41586-023-06501-x
24. Alur P, Ramarao S. Transition phase of nutrition—optimizing nutrient administration. Front Pediatr [Internet]. 2025;13(September):1–6. Available from: https://doi.org/10.3389/fped.2025.1658550
25. Latif S, Khalid N. Challenges and management of nutrition in preterm infants with reference to developing countries. Nutr Health [Internet]. 2025;31(2):335–8. Available from: https://doi.org/10.1177/02601060251347036
26. Moret-Tatay A, Pérez-Bermejo M, Asins-Cubells A, Moret-Tatay C, Murillo-Llorente MT. A Systematic Review of Multifactorial Barriers Related to Breastfeeding. Healthc [Internet]. 2025;13(11):1–15. Available from: https://doi.org/10.3390/healthcare13111225
27. Jiang S, Sung J, Sawhney R, Cai J, Xu H, Ng SK, et al. The determinants of growth failure in children under five in 25 low and middle-income countries. J Glob Health [Internet]. 2023;13(04077):1–15. Available from: https://doi.org/10.7189/JOGH.13.04077
28. Kale PL, Fonseca SC. Intrauterine growth restriction, prematurity, and low birth weight: risk phenotypes of neonatal death, Rio de Janeiro State, Brazil. Cad Saude Publica [Internet]. 2023;39(6):1–13. Available from: https://doi.org/10.1590/0102-311XEN231022
29. Lin CY, Chang HY, Chang JH, Hsu CH, Jim WT, Peng CC, et al. The impact of small-for-gestational-age Status on the outcomes in very-Low-birth-weight (VLBW) premature infants: a prospective cohort study in Taiwan. Front Pediatr [Internet]. 2023;11(July):1–

11. Available from: https://doi.org/10.3389/fped.2023.1209765

30. Zhu L, Yao D. Small for Gestational Age and Motor Development in Children: A Narrative Review of Risk Factors, Brain Mechanisms, and Early Interventions. Dev Neurosci [Internet]. 2025 Oct 27;1(1):1–15. Available from: https://doi.org/10.1159/000548975
31. Gupta P, Paul PG, Jain V. Catch-up growth in low birth weight infants. J Pediatr Endocrinol Diabetes [Internet]. 2025;5(2):73–81. Available from: https://doi.org/10.25259/jped_45_2024
32. Cooke R, Goulet O, Huysentruyt K, Joosten K, Khadilkar AV, Mao M, et al. Catch-Up Growth in Infants and Young Children With Faltering Growth: Expert Opinion to Guide General Clinicians. J Pediatr Gastroenterol Nutr [Internet]. 2023;77(1):7–15. Available from: https://doi.org/10.1097/MPG.0000000000003784
33. Stenson CL, Wood CL, Embleton ND. Catch-up growth and the developmental origins of health in preterm infants. Infant. 2016;12(3):82–6.
34. Christian P, Lee SE, Angel MD, Adair LS, Arifeen SE, Ashorn P, et al. Risk of childhood undernutrition related to small-for-gestational age and preterm birth in low- and middle-income countries. Int J Epidemiol [Internet]. 2013;42(5):1340–55. Available from: https://doi.org/10.1093/ije/dyt109
35. Nguyen PT, Nguyen PH, Tran LM, Khuong LQ, Van Nguyen S, Young MF, et al. Growth patterns of preterm and small for gestational age children during the first 10 years of life. Front Nutr [Internet]. 2024;11(February):1–12. Available from: https://doi.org/10.3389/fnut.2024.1348225
36. González-Fernández D, Cousens S, Rizvi A, Chauhadry I, Soofi SB, Bhutta ZA. Infections and nutrient deficiencies during infancy predict impaired growth at 5 years: Findings from the MAL-ED study in Pakistan. Front Nutr [Internet]. 2023;10(February):1–15. Available from: https://doi.org/10.3389/fnut.2023.1104654
37. Simone Thanh Nguyen, Marcelle Thrinh. The Role of Chronic Inflammation in Stunting-Associated Cognitive Impairment in Hanoi, Vietnam. Sci J Pediatr [Internet]. 2023;1(2):102–15. Available from: https://doi.org/10.59345/sjped.v1i2.68
38. Inadera H. Developmental origins of obesity and type 2 diabetes: Molecular aspects and role of chemicals. Environ Health Prev Med [Internet]. 2013;18(3):185–97. Available

from: https://doi.org/10.1007/s12199-013-0328-8

39. Hoffman DJ, Powell TL, Barrett ES, Hardy DB. Developmental Origins of Metabolic Diseases. Physiol Rev [Internet]. 2021;101(3):739–95. Available from: https://doi.org/10.1152/physrev.00002.2020
40. Hartati KU, Margono M, Purborini N. Nutrition care in baby with low birth weight. Proceeding Int Conf Adv Nurs Care. 2025;2(1):1–4.
41. Manuaba IAWKD, Dharma BDI. Feeding Therapy in Preterm Infants. Surabaya Phys Med Rehabil J [Internet]. 2023;5(1):37–42. Available from: https://doi.org/10.20473/spmrj.v5i1.33905
42. Astuti DD, Rustina Y, Wanda D. Oral feeding skills in premature infants: A concept analysis. Belitung Nurs J [Internet]. 2022;8(4):280–6. Available from: https://doi.org/10.33546/bnj.2107
43. Nakubulwa C, Musiime V, Namiiro FB, Tumwine JK, Hongella C, Nyonyintono J, et al. Delayed initiation of enteral feeds is associated with postnatal growth failure among preterm infants managed at a rural hospital in Uganda. BMC Pediatr [Internet]. 2020;20(1):1–9. Available from: https://doi.org/10.1186/s12887-020-1986-5
44. Salasa AA, Travers CP. The practice of enteral nutrition. Clin Perinatol [Internet]. 2023;50(3):607–23. Available from: https://doi.org/10.1016/j.clp.2023.04.005.
45. Young L, Oddie S, McGuire W. Delayed introduction of progressive enteral feeds to prevent necrotising enterocolitis in very low birth weight infants. Cochrane Database Syst Rev [Internet]. 2022 Jan 20;2022(1):1–10. Available from: https://doi.org/10.1002/14651858.CD001970.pub6
46. Albraik RK, Shatla E, Abdulla YM, Ahmed EH. Neonatal Feeding Intolerance and Its Characteristics: A Descriptive Study. Cureus [Internet]. 2022;14(9):1–6. Available from: https://doi.org/10.7759/cureus.29291
47. Chen L, Shang Y, Tian X, Huang Y, Sun Y, Fu C, et al. The struggles of breastfeeding mothers of preterm infants: a qualitative study. BMC Pregnancy Childbirth [Internet]. 2025;25(472):1–13. Available from: htpps://doi.org/10.1186/s12884-025-07597-x
48. Wasir R, Rahma F, Apriningsih, Basrowi RW, Saputra H, Zaid M. Implementation of perinatal mental health policy in Indonesia: a systematic review. Gen Med / Obs Med.

2025;27(6):65–70.

49. Gianni ML, Bettinelli ME, Manfra P, Sorrentino G, Bezze E, Plevani L, et al. Breastfeeding difficulties and risk for early breastfeeding cessation. Nutrients [Internet]. 2019;11(10):1–10. Available from: https://doi.org/10.3390/nu11102266
50. Sithamparapillai K, Samaranayake D, Wickramasinghe VP. Timing and pattern of growth faltering in children up-to 18 months of age and the associated feeding practices in an urban setting of Sri Lanka. BMC Pediatr [Internet]. 2022;22(1):1–10. Available from: https://doi.org/10.1186/s12887-022-03265-7
51. Yanti ES, Yunus EM. Low Birth Weight and Inappropriate Feeding Variation Caused Nutritional Disorders Based on the Composite Index of Anthropometric Failure (Ciaf). Media Gizi Indones [Internet]. 2024;19(3):311–21. Available from: https://doi.org/10.20473/mgi.v19i3.311-321
52. Killion KE, Corcoran A, Romo-Palafox MJ, Harris JL, Kagan I, Gilbert L, et al. Responsive Feeding Practices to Promote Healthy Diets: A Mixed Method Study among Low-Income Caregivers with Toddlers. Nutrients [Internet]. 2024;16(6):1–19. Available from: https://doi.org/10.3390/nu16060863
53. Sharn AR, Oliveros E, Lai S, Sanchez CP, Villa-Real Guno MJ, Rojas Montenegro C. Multi-faceted nutritional interventions are imperative to reduction of stunting among children in low- and middle-income countries. Front Nutr [Internet]. 2025;12(September):1–11. Available from: https://doi.org/10.3389/fnut.2025.1479850
54. Wahyuni FC, Karomah U, Basrowi RW, Sitorus NL, Lestari LA. The Relationship between Nutrition Literacy and Nutrition Knowledge with the Incidence of Stunting: A Scoping Review. Amerta Nutr [Internet]. 2023;7(3SP):71–85. Available from: https://doi.org/10.20473/amnt.v7i3SP.2023.71-85
55. Hariati S, Erfina, Lusmilasari L. Related factors of postnatal growth failure upon hospital discharge among low-birth-weight infants in Eastern Indonesia. Pediomaternal Nurs J [Internet]. 2026;12(1):17–24. Available from: https://doi.org/10.20473/pmnj.v12i1.74789
56. Raturi S, Daniel LM, Shi L, Rajadurai VS, Agarwal PK. Nutritional intake and growth velocity in preterm extremely low-birthweight infants in Asia: Are we doing enough? J

Pediatr Child Heal [Internet]. 2017;53(1):1199–1207. Available from: https://doi.org/10.1111/jpc.13630

57. Muelbert M, Harding JE, Bloomfield FH. Nutritional policies for late preterm and early term infants – can we do better? Semin Fetal Neonatal Med [Internet]. 2019;24(1):43–7. Available from: https://doi.org/10.1016/j.siny.2018.10.005
58. Abbas A. Feeding of low birth weight (LBW) and very low birth weight (VLBW) Infants. Fetal, Neonatal Dev Med [Internet]. 2017;1(1):1–2. Available from: https://doi.org/10.15761/fndm.1000102
59. World Health Organization. Guidelines on optimal feeding of low birth-weight infants in low-and middle-income countries. Geneva: WHO. Geneva, Switzerland: WHO; 2011. 16–45 p.
60. Escobedo-Monge MF, Parodi-Román J, Escobedo-Monge MA, Marugán-Miguelsanz JM. The Biological Value of Proteins for Pediatric Growth and Development: A Narrative Review. Nutrients [Internet]. 2025;17(13):1–23. Available from: https://doi.org/10.3390/nu17132221
61. Hay WW. Amino acids and protein for preterm infants: How much and for what? Semin Fetal Neonatal Med [Internet]. 2025;30(2):101633. Available from: https://doi.org/10.1016/j.siny.2025.101633
62. Uberos-Fernández J, Ruiz-López A, Carrasco-Solis M, Fernandez-Marín E, Garcia-Cuesta A, Campos-Martínez A. Extrauterine growth restriction and low energy intake during the early neonatal period of very low birth weight infants are associated with decreased lung function in childhood. Br J Nutr [Internet]. 2023;130(12):2095–103. Available from: https://doi.org/10.1017/S0007114523001332
63. Brinkis R, Albertsson-Wikland K, Tamelienė R, Vinskaitė A, Šmigelskas K, Verkauskienė R. Nutrient Intake with Early Progressive Enteral Feeding and Growth of Very Low-Birth-Weight Newborns. Nutrients [Internet]. 2022;14(6):1–15. Available from: https://doi.org/10.3390/nu14061181
64. Vitale G, Pellegrino G, Vollery M, Hofland LJ. Role of IGF-1 system in the modulation of longevity: Controversies and new insights from a centenarians' perspective. Front Endocrinol (Lausanne) [Internet]. 2019;10(FEB):1–11. Available from:

https://doi.org/10.3389/fendo.2019.00027

65. Hawkes CP, Grimberg A, Health C. Insulin-Like Growth Factor-I is a Marker for the Nutritional State. Pediatr Endocrinol Rev. 2015;13(2):499–511.
66. Indrio F, Neu J, Pettoello-Mantovani M, Marchese F, Martini S, Salatto A, et al. Development of the Gastrointestinal Tract in Newborns as a Challenge for an Appropriate Nutrition: A Narrative Review. Nutrients [Internet]. 2022;14(7):1–15. Available from: https://doi.org/10.3390/nu14071405
67. Marsubrin PMT, Firmansyah A, Rohsiswatmo R, Munasir Z, Bardosono S, Malik SG, et al. Association between feeding intolerance and intestinal dysbiosis in very premature infants. Clin Exp Pediatr [Internet]. 2023;66(11):501–3. Available from: https://doi.org/10.3345/cep.2023.00829
68. DeBoer MD, Scharf RJ, Leite AM, Férrer A, Havt A, Pinkerton R, et al. Systemic inflammation, growth factors, and linear growth in the setting of infection and malnutrition. Nutrition [Internet]. 2017;33:248–53. Available from: https://doi.org/10.1016/j.nut.2016.06.013
69. Dargenio VN, Sgarro N, Grasta G La, Begucci M, Castellaneta SP, Dargenio C, et al. Hidden Hunger in Pediatric Obesity: Redefining Malnutrition Through Macronutrient Quality and Micronutrient Deficiency. Nutrients. 2025;17(22):1–37.
70. Cammisa I, Rigante D, Cipolla C. A Theoretical Link Between the GH/IGF-1 Axis and Cytokine Family in Children: Current Knowledge and Future Perspectives. Children [Internet]. 2025;12(4):1–20. Available from: https://doi.org/10.3390/children12040495
71. Möllers LS, Yousuf EI, Hamatschek C, Morrison KM, Hermanussen M, Fusch C, et al. Metabolic-endocrine disruption due to preterm birth impacts growth, body composition, and neonatal outcome. Pediatr Res [Internet]. 2022;91:1350–60. Available from: https://doi.org/10.1038/s41390-021-01566-8
72. Tan JBC, Boskovic DS, Angeles DM. The Energy Costs of Prematurity and the Neonatal Intensive Care Unit (NICU) Experience. Antioxidants [Internet]. 2018;7(3):1–13. Available from: https://doi.org/10.3390/antiox7030037
73. Farajdokht F, Sadigh-Eteghad S, Dehghani R, Mohaddes G, Abedi L, Bughchechi R, et al. Very low birth weight is associated with brain structure abnormalities and cognitive

function impairments: A systematic review. Brain Cogn [Internet]. 2017;118:80–9. Available from: https://doi.org/10.1016/j.bandc.2017.07.006

74. Soliman A, De Sanctis V, Alaaraj N, Ahmed S, Alyafei F, Hamed N, et al. Early and long-term consequences of nutritional stunting: From childhood to adulthood. Acta Biomed [Internet]. 2021;92(1):1–12. Available from: https://doi.org/10.23750/abm.v92i1.11346
75. Medise BE. Growth and development in preterm infants: what is the long-term risk? Amerta Nutr [Internet]. 2021;5(Supl.27033):27–33. Available from: https://doi.org/10.20473/amnt.V5i1SP.2021.27-33
76. Walsh V, Brown JVE, Copperthwaite BR, Oddie SJ, McGuire W. Early full enteral feeding for preterm or low birth weight infants. Cochranr Database Systeatic Rev [Internet]. 2020;12:1–10. Available from: https://doi.org/10.1002/14651858.CD013542.pub2
77. Yang J, Tang Q, Zhou P. Narrative review of methodological advances in human milk fortification: for better preterm infant growth. Front Pediatr [Internet]. 2024;12:1–7. Available from: https://doi.org/10.3389/fped.2024.1466528
78. Rinawati R. Nutritional Management and Recommendation for Preterm Infants : A Narrative Review. Amerta Nutr [Internet]. 2021;5(Supp1-13):1–13. Available from: https://doi.org/10.20473/amnt. V5i1SP.2021.1-13
79. Mekonnen AG, Yehualashet SS, Bayleyegn AD. The effects of kangaroo mother care on the time to breastfeeding initiation among preterm and LBW infants: a meta-analysis of published studies. Int Breastfeed J [Internet]. 2019;14(12):1–6. Available from: https://doi.org/10.1186/s13006-019-0206-0
80. K SM, H CE, J SM, M SJ, Ping WY, E BNS, et al. Caregiver feeding practices and child weight outcomes: a systematic review. Am J Clin Nutr [Internet]. 2019;109(1):990S-1002S. Available from: https://doi.org/10.1093/ajcn/nqy276
81. Hastuti D, Anggorowati, Zubaidah Z. Developmental care for preterm infants: a scoping review of interventions, outcomes, and implementation contexts. Front Pediatr [Internet]. 2026;14:1–13. Available from: https://doi.org/10.3389/fped.2026.1730571
82. Dagla M, Mrvoljak-Theodoropoulou I, Vogiatzoglou M, Giamalidou A, Tsolaridou E, Mavrou M, et al. Association between Breastfeeding Duration and Long-Term Midwifery-Led Support and Psychosocial Support: Outcomes from a Greek Non-

Randomized Controlled Perinatal Health Intervention. Int J Environ Res Public Health [Internet]. 2021;18(4):1–17. Available from: https://doi.org/10.3390/ijerph18041988

83. Sentika R, Setiawan T, Kusnadi, Rattu DJ, Yunita I, Masita BM, et al. The Importance of Interprofessional Collaboration (IPC) Guidelines in Stunting Management in Indonesia: A Systematic Review. Healthc [Internet]. 2024;12(22):1–16. Available from: https://doi.org/10.3390/healthcare12222226
84. Sentika R, Setiawan T, Kusnadi, Rattu DJ, Yunita I, Basrowi RW, et al. Expert Consensus on Interprofessional Collaboration (IPC) Guidelines on Stunting Management in Indonesian Primary Healthcare (Puskesmas). Open Public Health J [Internet]. 2024;17(1):1–12. Available from: https://doi.org/10.2174/0118749445352608241119164446
85. Ja´nczewska I, Wierzba J, Ja´nczewska A, Szczurek-Gierczak M, Domzalska-Popadiuk I. Prematurity and Low Birth Weight and Their Impact on Childhood Growth Patterns and the Risk of Long-Term Cardiovascular Sequelae. Children [Internet]. 2013;10(10):1–15. Available from: https://doi.org/10.3390/children10101599