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REVIEW

The combined effect of neonatal hypothyroidism and low family income on intellectual disability: A review of mechanisms and interventions

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ABSTRACT

This review investigates the combined effect of neonatal hypothyroidism and low family income on the prevalence of intellectual disability, drawing insights from existing literature, including specific findings from studies involving neonatal cases such as 15 cases at Wangaya Regional Hospital Denpasar. Neonatal hypothyroidism significantly impacts cognitive development due to the critical role of thyroid hormones in brain maturation. Concurrently, low family income acts as a risk factor for intellectual disability by limiting access to essential healthcare, education, and developmental resources. The review explores the epidemiology of neonatal hypothyroidism, highlighting global and regional variations influenced by genetic, environmental, and socioeconomic factors. It delves into the mechanisms by which neonatal hypothyroidism affects brain and cognitive function, leading to deficits in intelligence, memory, attention, and executive function. Furthermore, the review examines the relationship between socioeconomic status and intellectual disability, emphasizing the role of resource scarcity and environmental factors associated with poverty. Findings from the reviewed literature suggest a compounding effect of neonatal hypothyroidism and low family income on a child's cognitive development and intellectual disability risk. Addressing this complex interplay necessitates a multifaceted approach, including early detection, prompt treatment, and integrated interventions spanning healthcare, education, and social support services. The review underscores the importance of equitable access to newborn screening, comprehensive early intervention programs, and family-centered support for children from low-income households.

Keywords: neonatal hypothyroidism, low family income, intellectual disability

INTRODUCTION

Intellectual disability is a complex condition that affects an individual's cognitive and adaptive functioning, often with significant limitations in both intellectual and practical skills. The development of intellectual disability can be influenced by various factors, including genetic, environmental, and socioeconomic conditions. Two key factors that have been extensively studied in relation to intellectual disability are neonatal hypothyroidism and low family income.[1,2] Neonatal hypothyroidism is a condition where infants are born with an underactive thyroid gland, resulting in a deficiency of thyroid hormones. These hormones play a crucial role in the development of the brain and central nervous system during the critical early stages of life. Numerous studies have demonstrated that untreated or poorly managed neonatal hypothyroidism can lead to significant cognitive impairments and the development of intellectual disability.[3,4]

Previous studies encountered several challenges related to data limitations. Researchers were unable to obtain essential maternal health information, including diagnoses or treatments for thyroid disorders, as well as details concerning lifestyle factors such as tobacco and alcohol use or dietary habits during pregnancy. These limitations were primarily due to confidentiality constraints. Furthermore, data regarding medical procedures performed on newborns during or after delivery, as well as information on their health status, were often incomplete in the databases utilized. This lack of comprehensive data, again attributable to confidentiality restrictions, may have resulted in the misclassification of some participants with incomplete health records as disease-free..[5,6] The presence of intellectual disability was measured by the Weschler

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Intelligence Scale. The diagnosis of neonatal hypothyroidism was identified using specific diagnostic and prescription codes. Family income was estimated based on the average monthly insurance premium paid.[7]

On the other hand, low family income has also been identified as a risk factor for intellectual disability. Socioeconomic status, as measured by factors such as household income, parental education, and occupation, can have a profound impact on a child's cognitive and developmental outcomes. Children from low-income families often face a range of challenges, including limited access to quality healthcare, education, and other resources that are essential for healthy development. While the individual effects of neonatal hypothyroidism and low family income on intellectual disability have been well-documented, the combined impact of these two factors has not been extensively explored.9 It is possible that the presence of both neonatal hypothyroidism and low family income may have a compounding effect on a child's cognitive development, leading to a higher risk of intellectual disability. This study aims to investigate the combined effect of neonatal hypothyroidism and low family income on the prevalence of intellectual disability in children.[8]

By understanding the interplay between these two factors, researchers and healthcare professionals can develop more targeted interventions and support systems to address the unique needs of this population. The findings of this study will contribute to the growing body of knowledge on the complex etiology of intellectual disability, and may inform the development of more effective prevention and treatment strategies. Additionally, the insights gained from this research can inform policy decisions and resource allocation to ensure that children from low- income families with neonatal hypothyroidism receive the necessary support and interventions to optimize their cognitive development and overall well-being.[9]

DISCUSSION

Epidemiology of neonatal hypothyroidism

Neonatal hypothyroidism is a relatively rare but serious condition that affects the proper functioning of the thyroid gland in newborn infants. Understanding the epidemiology of this disorder is crucial for early detection, timely intervention, and the prevention of long-term cognitive and developmental consequences. Globally, the incidence of congenital hypothyroidism, which includes neonatal hypothyroidism, is estimated to be around 1 in 2,000 to 4,000 live births. However, the prevalence can vary significantly across different regions and populations due to various genetic, environmental, and socioeconomic factors.[10]

In the United States, the incidence of congenital hypothyroidism is approximately 1 in 2,000 to 4,000 newborns. The condition is more common in certain ethnic groups, with higher rates observed in Hispanic and Native American populations compared to other racial/ethnic groups. Geographical variations in the incidence of neonatal hypothyroidism have also been reported. For instance, some regions with iodine-deficient diets or high levels of environmental pollutants have been associated with higher rates of the condition. Additionally, areas with limited access to prenatal care and newborn screening programs may have higher rates of undiagnosed and untreated neonatal hypothyroidism. Certain genetic factors can also contribute to the development of neonatal hypothyroidism. Mutations in genes responsible for the production and regulation of thyroid hormones, such as the TSHR, TSHB, and PAX8 genes, have been linked to congenital hypothyroidism. These genetic predispositions can be inherited or occur spontaneously.[11]

Maternal factors, such as age, pre-existing medical conditions, and exposure to certain medications or environmental toxins during pregnancy, can also increase the risk of neonatal hypothyroidism. For example, maternal autoimmune disorders, such as Hashimoto's thyroiditis, can lead to the transfer of antibodies that disrupt fetal thyroid function. Early detection and prompt treatment of neonatal hypothyroidism are crucial, as the condition can have severe and irreversible consequences on a child's cognitive and physical development if left untreated.[12] Most developed countries have implemented universal newborn screening programs to identify and treat affected infants within the first few weeks of life. Despite these screening efforts, some cases of neonatal hypothyroidism may go undetected, particularly in regions with limited access to healthcare or where screening programs are not yet fully implemented. Ongoing efforts to improve the accessibility and reliability of newborn screening tests are essential to ensure that all affected infants receive timely diagnosis and appropriate treatment.[13]

Many middle- and high-income countries have established national screening programs for congenital hypothyroidism (CH), which involve testing newborns' blood for thyroid hormone levels. Medical experts recommend retesting infants at increased risk, including those who are premature, have very low birth weight, are twins, or are otherwise medically fragile. Although these screening programs are both effective and cost-efficient, many low- and middle-income countries have yet to fully implement them. As of 2021 and 2023, approximately 70% of newborns worldwide still lack access to this essential metabolic screening.

A substantial proportion of these underserved infants reside in regions affected by iodine deficiency, which further increases their risk of severe neurodevelopmental impairments during a critical period of brain development.[14]

Continued research and surveillance on the epidemiology of neonatal hypothyroidism are necessary to identify risk factors, monitor trends, and inform public health policies and interventions aimed at reducing the burden of this condition and its associated long-term consequences. The epidemiology of neonatal hypothyroidism highlights the importance of understanding the global and regional variations in incidence, as well as the genetic, environmental, and socioeconomic factors that contribute to the development of this condition. Effective screening, early intervention, and comprehensive support systems are crucial for mitigating the impact of neonatal hypothyroidism on children's cognitive and developmental outcomes.[15]

Impact of neonatal hypothyroidism on cognitive development

Neonatal hypothyroidism, a condition characterized by an underactive thyroid gland at birth, significantly impairs cognitive development in infants. This impairment arises because thyroid hormones play a critical role in brain growth and maturation during early life. Specifically, thyroxine (T4) and triiodothyronine (T3) are essential for the proper development and functioning of the central nervous system. These hormones regulate various cellular processes, including neuronal migration, myelination, and synapse formation, which are crucial for the establishment of neural pathways and cognitive abilities.[16]

In neonatal hypothyroidism, the deficiency of thyroid hormones can disrupt these essential developmental processes. The lack of thyroid hormones can lead to delayed neuronal maturation, impaired myelination, and altered synaptic connectivity, all of which can contribute to cognitive impairments. Furthermore, thyroid hormones play a crucial role in the regulation of gene expression related to brain development. The disruption of this hormonal regulation can result in the dysregulation of genes involved in neuronal differentiation, axonal guidance, and synaptic plasticity, further compromising cognitive function. Specific cognitive domains impacted by neonatal hypothyroidism: Neonatal hypothyroidism has been associated with deficits in various cognitive domains, including intelligence, memory, attention, and executive function.[14,15]

Intelligence Quotient (IQ): Numerous studies have consistently demonstrated that children with untreated or poorly managed neonatal hypothyroidism often exhibit significantly lower IQ scores compared to their healthy counterparts. The degree of cognitive impairment can range from mild to severe, depending on the severity and duration of the thyroid hormone deficiency. Memory and Attention: Neonatal hypothyroidism has been linked to impairments in short-term and long-term memory, as well as attention and concentration. These cognitive deficits can affect a child's ability to learn, retain information, and focus on tasks, which can have far-reaching consequences on their academic and social development. Executive Function: Neonatal hypothyroidism has also been associated with deficits in executive function, which includes skills such as problem-solving, decision-making, and cognitive flexibility. These higher-order cognitive abilities are crucial for successful adaptation and independent living in adulthood. Long-term developmental outcomes of children with untreated or poorly managed neonatal hypothyroidism: The long-term consequences of neonatal hypothyroidism on cognitive development can be severe and often irreversible if the condition is not promptly detected and effectively treated.[17]

For newborns diagnosed with congenital hypothyroidism (CH), early identification and initiation of treatment within the first two weeks of life are critical. Timely intervention significantly enhances brain development, physical growth—including stature—and the timing and progression of puberty. Beyond the individual clinical impact, untreated CH imposes a substantial economic burden on families, employers, and society at large, primarily due to increased healthcare expenditures and losses in income and productivity. Encouragingly, over the past two decades, advances in early diagnosis and comprehensive management of CH have resulted in cognitive and motor development outcomes comparable to those of unaffected children. In cases of central hypothyroidism, levothyroxine therapy should be commenced promptly upon diagnosis. It is important to consider other potential causes of abnormal thyroid function tests, such as a rare form of primary hypothyroidism characterized by delayed TSH elevation, systemic illness, or transient hypothyroxinemia in premature infants. Additionally, certain medications, including dopamine and high-dose glucocorticoids, may induce low serum T4 levels in critically ill neonates. A deficiency in thyroid-binding globulin (TBG) can also present with low total T4 but normal TSH levels; however, this condition does not necessitate treatment. A study by Nam et al.[14] demonstrated a significantly increased risk of intellectual disability among infants with hypothyroidism. This risk was further exacerbated by low

socioeconomic status, with infants affected by both hypothyroidism and low family income exhibiting a markedly higher risk compared to those without hypothyroidism and from higher-income families.

Children with untreated or poorly managed neonatal hypothyroidism may experience persistent cognitive impairments, including lower academic achievement, difficulties in social interactions, and challenges in independent living skills. These developmental delays can have a significant impact on the individual's quality of life, educational and employment opportunities, and overall well-being. In some cases, the cognitive deficits associated with neonatal hypothyroidism may lead to the development of intellectual disability, a condition characterized by significant limitations in intellectual and adaptive functioning. The severity of the intellectual disability can range from mild to profound, depending on the extent and duration of the thyroid hormone deficiency. Early detection and prompt treatment of neonatal hypothyroidism are crucial to mitigate the long-term cognitive and developmental consequences. With appropriate and timely intervention, including thyroid hormone replacement therapy and targeted educational and developmental support, many children with neonatal hypothyroidism can achieve improved cognitive outcomes and lead more fulfilling lives.[17] Ongoing research and clinical efforts are focused on enhancing our understanding of the mechanisms underlying the impact of neonatal hypothyroidism on cognitive development, as well as developing more effective strategies for early identification and comprehensive management of this condition.

Socioeconomic status and intellectual disability

The relationship between socioeconomic status (SES) and intellectual disability is a complex and multifaceted topic that has been extensively studied in the field of developmental psychology and public health. Socioeconomic status, as measured by factors such as household income, parental education, and occupation, can have a profound impact on a child's cognitive and developmental outcomes. Children from low-income families often face a range of challenges that can contribute to the development of intellectual disability.[15]

One of the primary mechanisms by which low SES can lead to intellectual disability is through limited access to quality healthcare, education, and other resources that are essential for healthy child development. Families with low incomes may struggle to afford adequate nutrition, healthcare services, and early intervention programs, all of which are crucial for supporting cognitive and developmental milestones. Additionally, children from low-income households are more likely to be exposed to environmental toxins, such as lead and air pollution, which can have detrimental effects on brain development and cognitive function. Chronic stress and adverse life experiences associated with poverty can also negatively impact a child's neurological and psychological well-being, further contributing to the risk of intellectual disability.[15,16]

Parental education level is another important factor in the relationship between SES and intellectual disability. Children of parents with lower educational attainment may have fewer opportunities for cognitive stimulation, language development, and exposure to enriching learning experiences, all of which can influence intellectual abilities. Furthermore, the stress and challenges associated with living in poverty can also impact parenting practices and the home environment, which can indirectly affect a child's cognitive and social-emotional development. Factors such as parental mental health, parenting styles, and the availability of educational resources in the home can all play a role in shaping a child's intellectual capacities.[13]

Maternal education significantly influences child health. Lower maternal education is associated with an increased risk of perinatal complications, including stillbirths, low Apgar scores at five minutes, and neural tube defects. Despite limited and inconsistent data regarding the association between congenital hypothyroidism (CH) and maternal education, a study from Tianjin, China, demonstrated a strong correlation between higher maternal education and improved neonatal thyroid function. This correlation encompassed a predictive relationship with average neonatal TSH levels and a reduced risk of CH, especially when employing a screening threshold of TSH exceeding 20 µIU/ml. Although this research indicates a statistical association, the precise biological mechanisms underlying the connection between maternal education and the development of CH remain unclear. The prevalence of birth defects in CH suggests the involvement of multiple factors influencing intrauterine growth and development. Higher maternal education may confer advantages such as improved socioeconomic status, greater access to prenatal care, a stronger propensity to avoid harmful behaviors, and enhanced nutritional practices for both mothers and

their children. Although overall maternal smoking rates are low, they are marginally higher among mothers with lower educational attainment.[12]

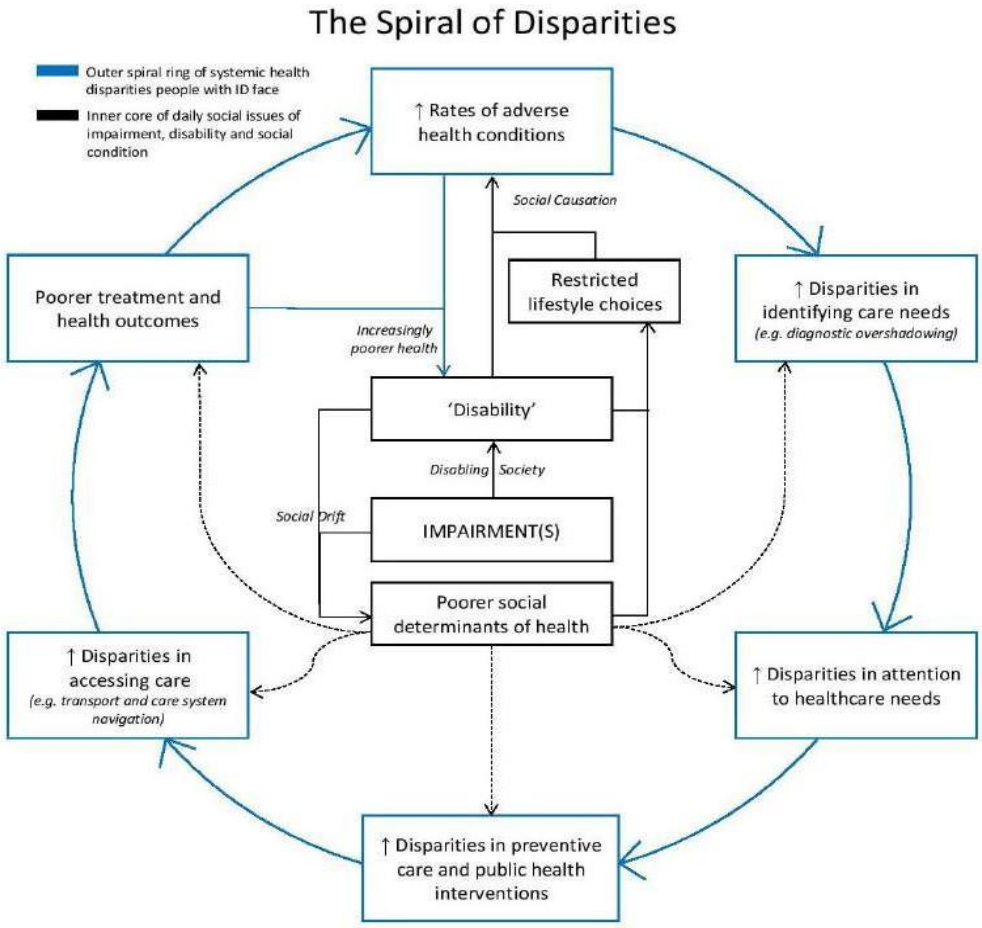

Figure 1. Relationship between socioeconomic status (SES) and intellectual disability

It is important to note that the relationship between SES and intellectual disability is not deterministic; rather, it represents a complex interplay of various environmental, social, and biological factors. Many children from low-income families do not develop intellectual disabilities, and some children from higher-income families may still experience cognitive challenges. Interventions aimed at addressing the socioeconomic disparities in intellectual disability often focus on improving access to quality healthcare, education, and early childhood programs, as well as providing support and resources to families living in poverty. These efforts can help to mitigate the negative impact of low SES on a child's cognitive development and overall well-being.[15]

Ongoing research in this area continues to explore the specific mechanisms and pathways through which socioeconomic status influences the prevalence and severity of intellectual disability. By understanding these complex relationships, policymakers and healthcare professionals can develop more targeted and effective strategies to support children and families in need, ultimately promoting better cognitive and developmental outcomes. The relationship between socioeconomic status and intellectual disability highlights the importance of addressing the social determinants of health and ensuring equitable access to resources and opportunities for all children, regardless of their family's economic circumstances.[14]

Interaction between neonatal hypothyroidism and low family income

The combination of neonatal hypothyroidism and low family income can have a compounding effect on a child's cognitive development and the risk of intellectual disability. Understanding the interplay between these two factors is crucial for developing targeted interventions and support systems to address the unique needs of this population. When neonatal hypothyroidism and low family income co-occur, the

negative impact on a child's cognitive and developmental outcomes can be exacerbated. The underlying mechanisms behind this synergistic effect are multifaceted and can be attributed to various factors.[10,11]

Firstly, the lack of access to timely and comprehensive healthcare services for children from low-income families can delay the diagnosis and treatment of neonatal hypothyroidism. This delay in intervention can lead to a prolonged period of thyroid hormone deficiency, which is particularly detrimental during the critical early stages of brain development.[18] Additionally, families with limited financial resources may struggle to afford the necessary medical care, including regular monitoring, thyroid hormone replacement therapy, and follow-up assessments. This can result in suboptimal management of neonatal hypothyroidism, further compromising the child's cognitive and developmental trajectories.[7]

Moreover, the stressors and challenges associated with living in poverty, such as food insecurity, unstable housing, and limited access to educational resources, can exacerbate the negative impact of neonatal hypothyroidism on a child's cognitive development. These environmental factors can interact with the biological effects of thyroid hormone deficiency, leading to a compounded risk of intellectual disability. Parental education and involvement in the child's care can also play a role in the interaction between neonatal hypothyroidism and low family income. Parents with lower educational attainment may have less knowledge about the importance of early intervention and may face barriers in advocating for their child's needs within the healthcare system. Furthermore, the stress and mental health challenges experienced by parents living in poverty can indirectly affect their ability to provide the necessary support and stimulation for their child's cognitive development, further compounding the impact of neonatal hypothyroidism.[1,2,19]

Even with early initiation and administration of high-dose treatment during childhood, children born with congenital hypothyroidism in Zurich demonstrated persistently reduced full-scale IQ scores extending into adolescence. Similarly, other studies have reported that children who receive early treatment for congenital hypothyroidism may exhibit lower neurological performance, including diminished global, verbal, and performance IQ scores, poorer academic achievements during early childhood, and continuing intellectual difficulties throughout childhood and into adulthood. Furthermore, an Iranian study observed that 9-year-old children with a history of transient congenital hypothyroidism scored significantly lower on global IQ assessments compared to matched controls, although their psychomotor abilities remained comparable.[7]

Although the coexistence of low family income and neonatal hypothyroidism does not invariably lead to adverse outcomes, protective factors may mitigate their effects. Nevertheless, it is crucial to acknowledge the potential synergistic interaction between these risk factors. Such insight is fundamental for the development of targeted and effective interventions.[6] Addressing the combined impact of neonatal hypothyroidism and low family income requires a multifaceted approach that integrates healthcare, education, and social support services. Early detection and prompt treatment of neonatal hypothyroidism, coupled with targeted interventions and resources for low-income families, can help to optimize cognitive and developmental outcomes for children at risk. By recognizing and addressing the complex interplay between these factors, healthcare professionals, policymakers, and community organizations can work together to ensure that all children, regardless of their socioeconomic background, have the opportunity to reach their full cognitive potential.[5,6]

Neonatal hypothyroidism and low family income can significantly affect a child's developmental outcomes. Neonatal hypothyroidism is a preventable cause of intellectual disability; however, timely and adequate treatment within the first two to six weeks after birth is critical for ensuring normal growth and neurodevelopment. In the absence of prompt intervention, or if symptoms manifest later within the first year of life, delays in motor skills and intellectual impairments are inevitable. Moreover, children who receive insufficient treatment during the initial two to three years often exhibit lower intelligence quotient (IQ) scores compared to their healthy peers. Diagnosing neonatal hypothyroidism remains challenging because most affected newborns do not present with overt symptoms due to residual thyroid function, and the clinical signs of hypothyroidism are frequently nonspecific.[1,4,19]

Implications for early intervention and support services

The findings from the research on the combined effect of neonatal hypothyroidism and low family income on intellectual disability have significant implications for the development and implementation of early intervention and support services. Early detection and timely intervention are crucial in mitigating the long-term cognitive and developmental consequences of neonatal hypothyroidism. Universal newborn screening programs play a vital role in the early identification of affected infants, allowing for prompt

initiation of thyroid hormone replacement therapy and other necessary interventions. However, for children from low-income families, the accessibility and utilization of these screening services may be limited due to various barriers, such as lack of access to healthcare, transportation challenges, and cultural or language differences. Addressing these barriers and ensuring equitable access to newborn screening is a crucial first step in providing timely support for this vulnerable population.[3,4,19]

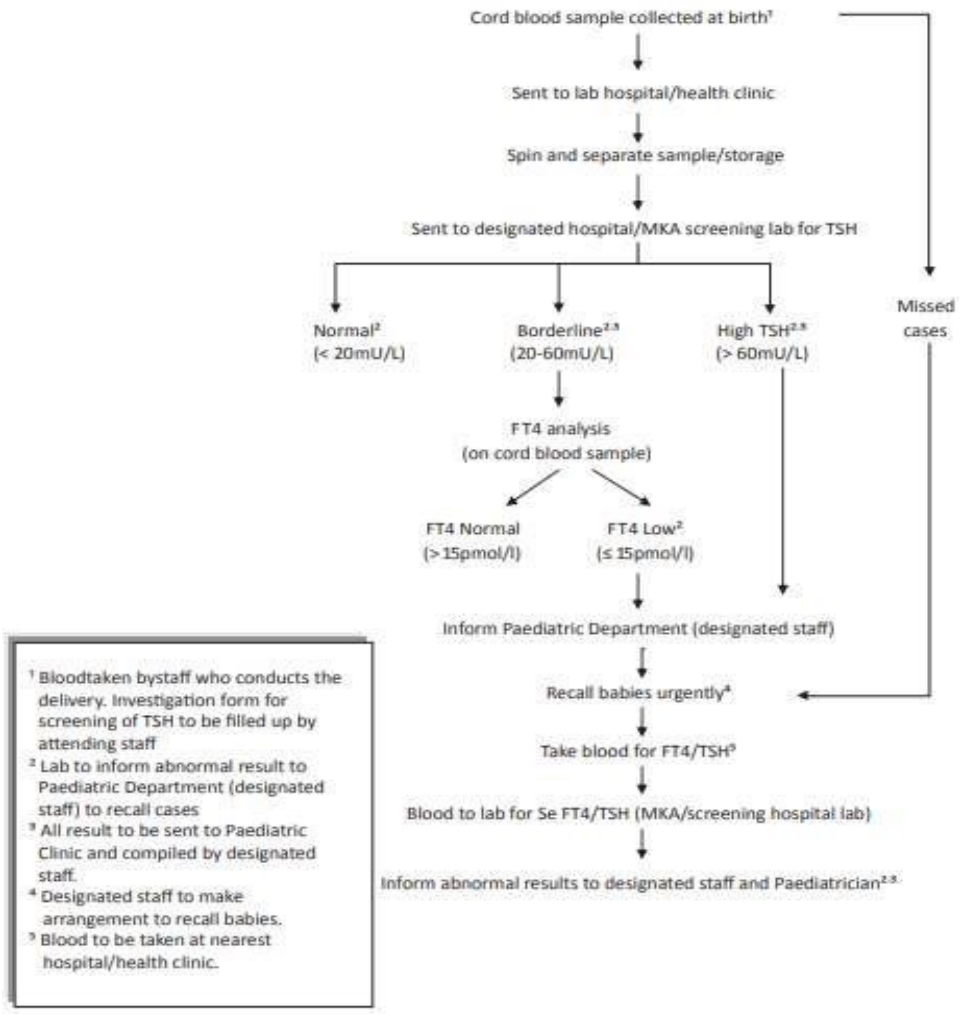

Figure 2. Screening For Congenital Hypothyroidism for Home/Health clinic/ Low Risk Birthing Centre Delivery[10]

Once neonatal hypothyroidism is detected, comprehensive and coordinated early intervention services become essential. This may include regular monitoring of thyroid function, ongoing medication management, and targeted developmental therapies to support cognitive, motor, and language skills. Integrating these services within a family-centered approach can help to address the unique needs of children from low-income households. In addition to medical and therapeutic interventions, early childhood education programs and family support services play a crucial role in promoting cognitive development and mitigating the impact of low family income. High-quality preschools, home-visiting programs, and parent education initiatives can provide essential resources, skill-building opportunities, and social-emotional support for both the child and the family. In some countries such as the United Kingdom, a visiting nurse collects the specimen at the time of the first home visit in the first days after birth.[10,18]

Collaboration between healthcare providers, educators, and social service agencies is essential to ensure a comprehensive and coordinated approach to supporting children with neonatal hypothyroidism from low-income families. This interdisciplinary collaboration can help to identify and address the multifaceted needs of these children, including access to healthcare, educational resources, and community-based support services.[10] Ongoing professional development and training for healthcare providers, educators, and social service professionals can also enhance their understanding of the unique challenges faced by children with neonatal hypothyroidism from low-income families. This knowledge can inform the

design and implementation of more effective and tailored interventions to support the cognitive and developmental needs of this population.[12]

In today's global healthcare landscape, analyzing the costs and benefits of health policies is essential for their effective implementation. Economic evaluations in health play a critical role in guiding the optimal allocation of limited resources and in determining the viability of new healthcare interventions, particularly under budgetary constraints. Despite global efforts toward achieving universal health coverage, developing countries such as Sri Lanka continue to face significant limitations in healthcare resources. Consequently, it is imperative to allocate and utilize these resources in a cost-effective manner, especially in priority areas like maternal and child health, where effective interventions are urgently needed. Sri Lanka exemplifies strong health system performance, with nearly all births attended by skilled professionals and a relatively low infant mortality rate of 11.3 deaths per 1,000 live births. This underscores the importance for Sri Lankan health authorities to thoroughly understand the costs associated with newborn screening. Such knowledge enables a rigorous assessment of the cost-effectiveness of existing child health (CH) programs and facilitates the identification of opportunities to enhance these programs through expanded screening initiatives. A standard economic evaluation method, benefit-cost analysis, compares costs and benefits expressed in monetary terms. A benefit-cost ratio greater than 1.0 signifies a positive return on investment for the country or sector. This ratio is influenced by multiple factors, including the prevalence of the condition, the number of individuals screened, currency exchange rates, inflation, financial management by government and private sectors, availability of health insurance, and overall healthcare expenditure.[12,13]

The overall cost of the program is categorized into two main components: screening and treatment for congenital hypothyroidism. Screening costs encompass equipment expenses (including purchase, maintenance, and test kits), sample collection (forms, heel-prick procedures, and transportation), follow-up management (reporting and confirmatory testing), and personnel salaries (nursing, administrative, medical, and technical staff). Treatment costs comprise follow-up testing, medication, and additional diagnostic procedures.[13,14]

At the policy level, the findings from this research can inform the development of initiatives and funding mechanisms that prioritize early intervention and support services for children with neonatal hypothyroidism, particularly those from low-income households. This may include expanding access to newborn screening, increasing reimbursement for comprehensive care, and allocating resources for community-based programs that address the social determinants of health. By addressing the combined impact of neonatal hypothyroidism and low family income through a multifaceted and collaborative approach, healthcare systems, educational institutions, and social service organizations can work together to provide the necessary support and resources to optimize the cognitive and developmental outcomes for this vulnerable population of children. Future research should examine longitudinal outcomes in low- income children with congenital hypothyroidism.[6]

CONCLUSION

Early detection and timely intervention are crucial in mitigating the long-term cognitive and developmental consequences of neonatal hypothyroidism. Universal newborn screening programs play a vital role in the early identification of affected infants, allowing for prompt initiation of thyroid hormone replacement therapy and other necessary interventions. Once neonatal hypothyroidism is detected, comprehensive and coordinated early intervention services become essential. This may include regular monitoring of thyroid function, ongoing medication management, and targeted developmental therapies to support cognitive, motor, and language skills. Integrating these services within a family-centered approach can help to address the unique needs of children from low-income households.

REFERENCES

1. Zdraveska N, Kocova M, Nicholas AK, Anastasovska V, Schoenmakers N. Genetics of Gland-in-situ or Hypoplastic Congenital Hypothyroidism in Macedonia. Front Endocrinol (Lausanne). 2020 Jul 14;11.
2. Peters C, van Trotsenburg ASP, Schoenmakers N. Diagnosis of endocrine disease: Congenital hypothyroidism: update and perspectives. Eur J Endocrinol. 2018 Dec;179(6):R297–317.
3. Kollati Y, Akella RRD, Naushad SM, Thalla M, Reddy GB, Dirisala VR. The rs1991517 polymorphism is a genetic risk factor for congenital hypothyroidism. 3 Biotech. 2020 Jun 1;10(6):285.
4. Eng L, Lam L. Thyroid Function During the Fetal and Neonatal Periods. Neoreviews. 2020 Jan 1;21(1):e30–6.
5. Ehsani R, Alijanpour M, Salehiomran M, Kheirkhah F, Moslemi L, Aghajanpour F. Evaluation of the developmental outcome in

children with congenital hypothyroidism. Casp J Intern Med. 2021 Apr;12(3):315–22.
6. Habib A, Shojazadeh A, Molayemat M, Habib A, Jeddi M, Arabsolghar R, et al. Prevalence and predictive factors of transient and permanent congenital hypothyroidism in Fars province, Iran. BMC Pediatr. 2021 Dec 5;21(1):264.
7. Alvarez OA, Hustace T, Voltaire M, Mantero A, Liberus U, Saint Fleur R. Newborn Screening for Sickle Cell Disease Using Point-of-Care Testing in Low-Income Setting. Pediatrics. 2019 Oct 1;144(4).
8. Perin J, Mulick A, Yeung D, Villavicencio F, Lopez G, Strong KL, et al. Global, regional, and national causes of under-5 mortality in 2000–19: an updated systematic analysis with implications for the Sustainable Development Goals. Lancet Child Adolesc Heal [Internet]. 2022 Feb 1;6(2):106–15. Available from: https://doi.org/10.1016/S2352-4642(21)00311-4
9. Ordunez P, Martinez R, Soliz P, Giraldo G, Mujica OJ, Nordet P. Rheumatic heart disease burden, trends, and inequalities in the Americas, 1990–2017: a population-based study. Lancet Glob Heal [Internet]. 2019 Oct 1;7(10):e1388–97. Available from: https://doi.org/10.1016/S2214-109X(19)30360-2
10. Cheong JL, Spittle AJ, Burnett AC, Anderson PJ, Doyle LW. Have outcomes following extremely preterm birth improved over time? Semin Fetal Neonatal Med. 2020 Jun;25(3):101114.
11. Costeira MJ, Costa P, Roque S, Carvalho I, Vilarinho L, Palha JA. History of Neonatal Screening of Congenital Hypothyroidism in Portugal. Int J Neonatal Screen. 2024 Feb 20;10(1):16.
12. Bowden SA, Goldis M. Congenital Hypothyroidism. Treasure Island (FL): StatPearls Publishing; 2023.
13. Vidavalur R. Human and Economic Cost of Disease Burden Due to Congenital Hypothyroidism in India: Too Little, but Not Too Late. Front Pediatr. 2022 May 3;10.
14. Nam JY, Choi Y, Jung MK, Shin J, Cho KH, Kim W, et al. The effect of neonatal hypothyroidism and low family income on intellectual disability: A population-based cohort study. Soares P, editor. PLoS One. 2018 Nov 7;13(11):e0205955.
15. Leng J, Shao P, Zhang S, Li N, Pan L, Liu H, et al. Maternal education and newborn thyroid-stimulating hormone level in a congenital hypothyroidism screening program. J Matern Neonatal Med. 2020 Aug 17;33(16):2730–4.
16. Pakunwanich N, Mazurek J. Intellectual disabilities: how current conceptions of "disability" interpret and perpetuate existing health inequities. 2020.
17. Therrell BL, Padilla C. Screening of Newborns for Congenital Hypothyroidism: Guidance for Developing Programmes. International Atomic Energy Agency; 2005.
18. Jarjour IT. Neurodevelopmental Outcome After Extreme Prematurity: A Review of the Literature. Pediatr Neurol. 2015 Feb;52(2):143–52.
19. van Trotsenburg P, Stoupa A, Léger J, Rohrer T, Peters C, Fugazzola L, et al. Congenital Hypothyroidism: A 2020–2021 Consensus Guidelines Update—An ENDO-European Reference Network Initiative Endorsed by the European Society for Pediatric Endocrinology and the European Society for Endocrinology. Thyroid. 2021 Mar 1;31(3):387–419.