Journal of Health, Population and Nutrition

RESEARCH

Open Access

Socio-economic inequality in the nutritional deficiencies among the world countries: evidence from global burden of disease study 2019

Mohsen Bayati[1], Elham Arkia[2] and Mehrnoosh Emadi[3*]

Abstract

Background Socioeconomic inequality in nutritional status as one of the main social determinants of health can lead to inequality in health outcomes. In the present study, the socioeconomic inequality in the burden of nutritional deficiencies among the countries of the world using Global Burden of Disease (GBD) data was investigated.

Methods Burden data of nutritional deficiencies and its subsets including protein-energy malnutrition, iodine deficiency, vitamin A deficiency, and dietary iron deficiency form GBD study and Human Development Index (HDI), a proxy for the socio-economic status of countries, from united nations database were collected. After descriptive statistics, the concentration index (CI) curve was used to measure socioeconomic inequality. CI for nutritional deficiencies was estimated based on Disability Adjusted Life Years (DALY), Years Lived with Disability (YLD), Years of Life Lost (YLL), prevalence, incidence and death indices. Moreover, CI of DALY and prevalence was estimated and reported for four nutritional deficiencies subgroups.

Results CIs for DALY, YLD, YLL, prevalence, incidence and death rate show negative values and their, which indicates the concentration of nutritional deficiencies burden among lower HDI countries. The highest value of CI (lowest inequality) for DALY was related to iodine deficiency (-0.3401) and the lowest (highest inequality) was related to vitamin A deficiency (-0.5884). Also, the highest value of CI for prevalence was related to protein-energy malnutrition (-0.1403) and the lowest was related to vitamin A deficiency (-0.4308). Results also show the inequality in DALY was greater than the disparity in prevalence for all subgroups of nutritional deficiencies.

Conclusions Inequality in burden of nutritional deficiencies and protein-energy malnutrition, iodine deficiency, vitamin A deficiency and dietary iron deficiency are concentrated in countries with low HDI, so there is pro- poor inequality. Findings indicate that although malnutrition occurs more in low-income countries, due to the weakness of health care systems in these countries, the inequality in the final consequences of malnutrition such as DALY becomes much deeper. More attention should be paid to the development of prevention and primary treatment

*Correspondence:
Mehrnoosh Emadi
mehrnoosh.emadi73@gmail.com

Full list of author information is available at the end of the article

measures in low HDI countries, such as improving nutrition-related health education, nutritional support and early aggressive treatment, and also eliminating hunger.

Keywords Socioeconomic disparities in Health, Health inequities, Inequality, Malnutrition, Nutritional status

Background

Access to nutrition has been recognized as one of the basic rights of every person. One of the important issues in nutritional access is malnutrition. The negative effects of malnutrition on the performance of the brain have been proven. Paying special attention to children's nutrition is one of the priorities of the health policies of most of the world's societies because children are considered as one of the most important social assets in any country [1]. It is estimated that malnourishment is the cause of almost half (45%) of children's deaths [2].

According to the global nutrition report (2022), the global nutrition crisis, exacerbated after Covid-19 pandemic, has significantly worsened, with rising rates of malnutrition, hunger, and obesity. Since 2019, the number of people affected by hunger increased by 150 million, reaching 768 million in 2021. Additionally, 3.1 billion people were unable to afford a healthy diet in 2020, a rise of 112 million. By 2021, approximately 2.3 billion individuals, representing 29.3% of the global population, experienced moderate to severe food insecurity [3]. Although the global incidence of malnutrition decreased by 23% from 2010 to 2019, a significant number of children under five years of age (more than 160 million in 2019) worldwide were undernourished. According to the results of the Global Burden of Diseases (GBD) study in 2019, nutritional deficiencies were responsible for about 16 million Disability Adjusted Life Years (DALYs) [4].

Lack of micronutrients is one of the important factors in malnutrition. Micronutrients are substances that make up less than 0.01% of body weight and include vitamins and trace elements. These elements have a necessary function in the body. Based on the classification of the GBD study, nutritional deficiencies include protein-energy malnutrition, iodine deficiency, vitamin A deficiency, and dietary iron deficiency [5]. Meanwhile, iron deficiency anemia is the most common nutritional deficiency in the world [6]. Harmful consequences of iron deficiency anemia, including a decrease in IQ, decrease in learning ability, impairment in physical growth, and ultimately a decrease in mental and physical capabilities, have endangered the development process of countries. Also, iodine is an essential element for the production of thyroid hormones and the growth and development of the human brain, and its deficiency is considered one of the most common preventable causes of brain damage in the world [7]. In addition to this, the high prevalence of vitamin A deficiency and its related complications, which include weak immune system function and increased incidence and severity of infection, impaired growth of nerve cells, anemia, blindness, and xerophthalmia, can also lead to increased mortality [8]. Malnutrition related to protein-energy can also cause harmful consequences such as short stature, cognitive and behavioral disorders and even death [9].

Nutritional deficiencies usually occur in situations where there is economic poverty along with housing problems, illiteracy of parents and behavioral and mental disorders. In addition, not having stimulating and strengthening factors of intellectual powers is more than the cause. In these conditions, children are exposed to all kinds of infections and nutritional deficiencies, so that as the level of poverty increases, the amount of risk factors for brain damage also increases [10].

Limited studies have been done on the level of socioeconomic inequality in nutritional deficiencies or malnutrition. Most of these studies, which have been conducted at the micro level, have examined and confirmed the socioeconomic inequality in various indicators of malnutrition. For example, a study in Bangladesh found that malnutrition is profoundly affecting children under five, particularly in the poorest economic class. The research revealed that these children are nearly twice as likely to be underweight or stunted compared to those in the wealthiest class [11–13].

It is also important to note that inequality in health outcomes is linked to inequality in social determinants of health (SDH). Therefore, understanding and analyzing the inequality situation in nutrition as one of the most important SDH, especially child health, can help provide solutions to reduce inequality in outcomes such as child death and disability. It seems that the study of socioeconomic inequality in various indicators of nutritional deficiencies and the burden caused by it at the macro level can provide appropriate evidence for global policymakers to reduce nutritional inequality and its burden in the world. The present study was conducted with this aim.

Methods

In the current cross-sectional ecological study, the required data for all the countries of the world were collected using global databases. For the variable indicating the socio-economic status, the Human Development Index (HDI) [14] and for the variables related to the burden of nutritional deficiencies, the disease burden indices from the GBD study result tool was used [15].

The Global Burden of Disease Study is the most comprehensive epidemiological study worldwide, providing a tool to quantify the amount of health lost from hundreds of diseases, injuries, and risk factors. This study by the Institute for Health Metrics and Evaluation consisting of 3600 researchers in more than 145 countries of the world has estimated the death and disability data of more than 350 diseases and injuries in 204 countries in terms of age and gender from 1990 until now [16].

In the current study, the required information was collected based on the classification of the diseases causes in the GBD study for nutritional deficiencies and its subsets (protein-energy malnutrition, iodine deficiency, vitamin A deficiency, and dietary iron deficiency) in all ages. The burden of nutritional deficiencies was extracted according to the mentioned groups using DALY, Years Lived with Disability (YLD), Years of Life Lost (YLL), prevalence, incidence and death rate per 100,000 population [15].

The HDI was used as a proxy for the socio-economic status of countries. The numerical value of the HDI is between 0 and 1, and the closer the value of this index is to one, the higher the human development. HDI considers the three dimensions of long and healthy life, knowledge and living standards. More precisely, it is the geometric mean of life expectancy, education and gross national product. In the human development report, countries are divided into groups of countries with very high human development (0.800 or higher), high (0.799-0.700), medium (0.699 – 0.550) and low (HDI < 0.550) based on the value of the HDI. The HDI data was extracted from the United Nations database [14].

First, the descriptive statistics of the nutritional deficiencies burden indicators were reported based on the HDI group of the countries. Then concentration index (CI) was used to measure social economic inequality. CI for nutritional deficiencies was calculated based on DALY, YLD, YLL, prevalence, incidence and death indices. Moreover, CI of DALY and prevalence was estimated and reported for 4 nutritional deficiencies subgroups.

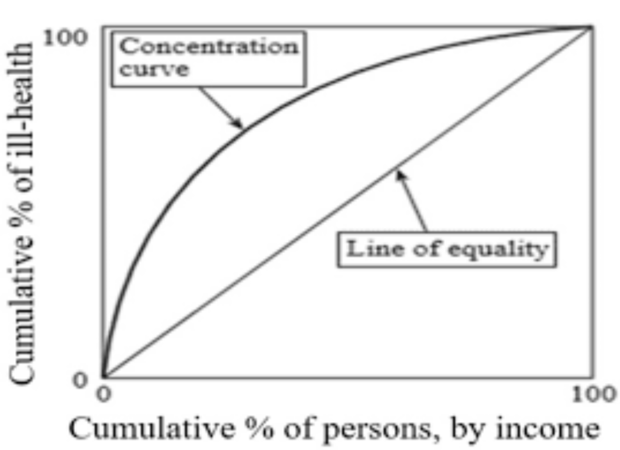

Fig. 1 Concentration curve of health

The CI is one of the most common methods for measuring inequality. The CI is created based on the concentration curve (CC). The CC indicates the cumulative percentage of the health variable (y-axis) against the cumulative percentage of the population sorted by economic status from the poorest to the richest (x-axis). If all people, regardless of their economic status, enjoy the same level of health variable, the CC will be a 45-degree line, which is called the "equality line". If the health variable is more concentrated among the poor, the CC will be above the equality line, which indicates the existence of pro-poor inequality, and vice versa. The more the CC is away from the inequality line, the greater the level of inequality. According to the definition, the CI is twice the area enclosed between the CC and the 45-degree line. Therefore, if the equality line and the CC coincide, the CI will be zero. The amount of CI changes between + 1 and − 1. The Fig. 1 schematically shows the concept of a CC and CI. To estimate the CI, the covariance method was used as follows [17]:

$$\mathrm{CI} = \frac{2}{\mu}\,\mathrm{cov}(yi,\ Ri)$$

Where, cov and y show the covariance and health outcome. R is the rank of country i in the socioeconomic distribution, and μ is the average of health outcome. In the present study, negative values (CC above line 45) indicate that bad health outcomes (burden of nutritional deficiencies) are concentrated among countries with low levels of human development, and vice versa. Stata 15 software was used for statistical analysis of data.

The research was found to be in accordance to the ethical principles and the national norms and standards for conducting medical research. The study protocol was approved by the Ethics Committee of Shiraz University of Medical Sciences under code IR.SUMS.NUMIMG.REC.1400.077.

Results

Findings about the distribution of the burden of different nutritional deficiencies by country in different HDI groups is shown in Table 1. The result show that the burden of nutritional deficiencies and its subgroups including protein-energy malnutrition, Iodine deficiency, vitamin A deficiency and dietary iron deficiency are higher in countries with low HDI.

The analytical findings of the study in the form of CI and CC of burden of total nutritional deficiencies are shown in Table 2; Fig. 2. CIs for DALY, YLD, YLL, prevalence, incidence and death rate show negative values and their CCs are above the equality line, which indicates the concentration of nutritional deficiencies burden among lower HDI countries (pro-poor inequality).

In nutritional deficiencies subgroups, DALY and prevalence CIs also show negative values (CCs above the

Table 1 Distribution of the burden of nutritional deficiencies among countries by HDI groups, 2019

	Very high HDI	High HDI	Medium HDI	Low HDI
All nutritional deficiencies				
DALY*	113.3 (88.6 to 138.0)	337.5 (283.0 to 392.0)	729.4 (582.8 to 876.0)	1563.1 (1208.5 to 1917.8)
YLD*	104.8 (81.9 to 127.7)	270.7 (230.6 to 310.8)	502.8 (408.8 to 596.8)	793.6 (708.8 to 878.5)
YLL*	8.5 (5.2 to 11.8)	66.8 (41.2 to 92.4)	226.6 (141.4 to 311.7)	769.4 (464.8 to 1074.1)
Prevalence*	5065.3 (3971.6 to 6158.9)	12166.2 (10796.3 to 13536.0)	19584.6 (17284.9 to 21884.3)	23686.7 (21884.6 to 25488.8)
Incidence*	712.7 (546.6 to 878.7)	1169.3 (926.5 to 1412.0)	1555.1 (1288.4 to 1821.9)	1833.8 (1632.1 to 2035.5)
Death*	1.0 (0.6 to 1.3)	2.1 (1.5 to 2.7)	4.4 (3.1 to 5.8)	11.8 (7.9 to 15.7)
Protein-energy malnutrition				
DALY*	45.5 (38.6 to 52.5)	97.7 (72.1 to 123.2)	250.5 (166.5 to 334.6)	806.0 (503.1 to 1108.8)
Prevalence*	998.0 (895.5 to 1100.6)	1104.7 (888.0 to 1321.4)	1496.6 (1267.2 to 1726.0)	1943.5 (1711.7 to 2175.2)
Iodine deficiency				
DALY*	6.3 (4.7 to 7.9)	7.3 (5.4 to 9.3)	22.4 (13.6 to 31.2)	38.0 (25.4 to 50.6)
Prevalence*	552.3 (407.5 to 697.2)	482.8 (339.5 to 626.2)	1623.3 (859.6 to 2386.9)	2517.6 (1442.9 to 3592.4)
Vitamin A deficiency				
DALY*	1.0 (0.5 to 1.6)	6.3 (5.0 to 7.5)	24.2 (18.4 to 30.0)	57.9 (46.3 to 69.5)
Prevalence*	1969.4 (1346.3 to 2592.5)	4395.7 (3497.7 to 5293.8)	11655.5 (8465.5 to 14845.6)	20444.1 (17517.7 to 23370.6)
Dietary iron deficiency				
DALY*	101.3 (80.9 to 121.6)	244.5 (211.0 to 278.1)	441.9 (367.0 to 516.7)	636.6 (561.6 to 711.7)
Prevalence*	6120.6 (5179.7 to 7061.4)	11672.7 (10433.9 to 12911.5)	17028.9 (14958.9 to 19099.0)	21014.0 (19217.7 to 22810.2)

*All indices are presented as rate per 100,000 populations. Figures in () show the 95% uncertainty interval

Table 2 Concentration index for burden of total nutritional deficiencies

Nutritional deficiencies					
DALY*	YLD*	YLL*	Prevalence*	Incidence*	Death*
-0.4545 (-0.5662 to -0.3428)	-0.3752 (-0.4310 to -0.3194)	-0.5841 (-0.7980 to -0.3702)	-0.2856 (-0.3320 to -0.2392)	-0.1896 (-0.2409 to -0.1383)	-0.4381 (-0.5901 to -0.2861)

*Figures in () show the confidence intervals at 90% for CIs

equality line), which indicates the concentration of these nutritional deficiencies among lower HDI countries. The highest value (lowest inequality) of DALY CI was related to iodine deficiency (-0.3401) and the lowest (highest inequality) was related to vitamin A deficiency (-0.5884). Also, the highest value (lowest inequality) of prevalence CI was related to protein-energy malnutrition (-0.1403) and the lowest (highest inequality) was related to vitamin A deficiency (-0.4308). Results also show the inequality in DALY was greater than the disparity in prevalence for all subgroups of nutritional deficiencies. (Table 3; Fig. 3)

Discussion

Reducing health inequality at the global level has long been a priority for health policymakers. This study aimed to assess socioeconomic inequality in the burden of nutritional deficiencies across countries, utilizing the Global Burden of Disease (GBD) data from 2019. Our findings indicate that the burden of nutritional deficiencies and their subsets is predominantly concentrated in countries with lower human development indices (HDI).

Consistent with our results, Seferidi et al. (2022) found that the double burden of malnutrition was notably higher among poorer households in 55 low- and

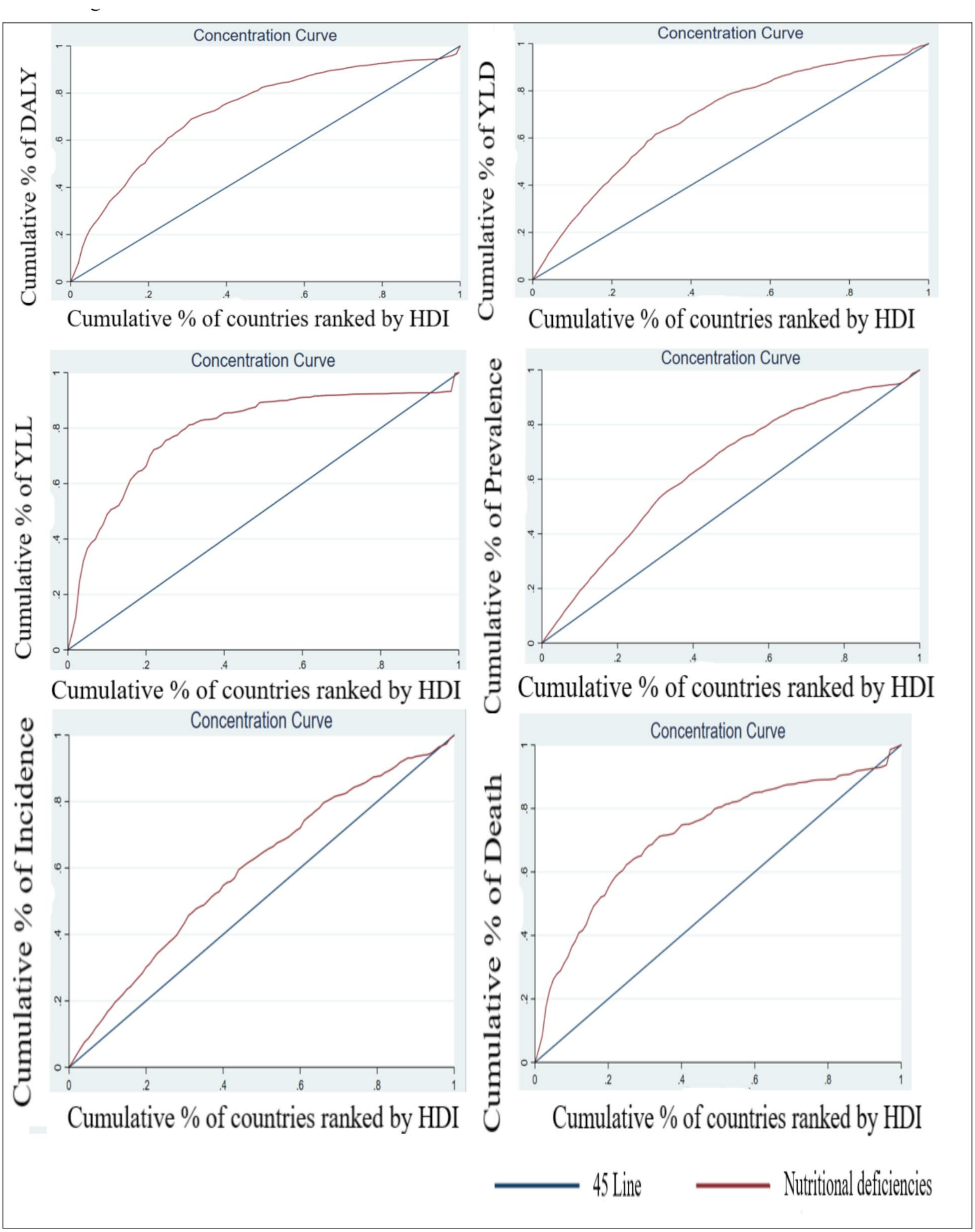

Fig. 2 Concentration curves for the burden of total nutritional deficiencies

Table 3 Concentration index for burden of nutritional deficiencies subgroups

	DALY*	Prevalence*
Protein-energy malnutrition	-0.5048 (-0.6942 to -0.3154)	-0.1403 (-0.1792 to -0.1014)
Iodine deficiency	-0.3401 (-0.5309 to -0.1493)	-0.3029 (-0.5030 to -0.1029)
Vitamin A deficiency	-0.5884 (-0.7117 to -0.4651)	-0.4308 (-0.5473 to -0.3144)
Dietary iron deficiency	-0.3525 (-0.3991 to -0.3059)	-0.2459 (-0.2817 to-0.2100)

*Figures in () show the confidence intervals at 90% for CIs

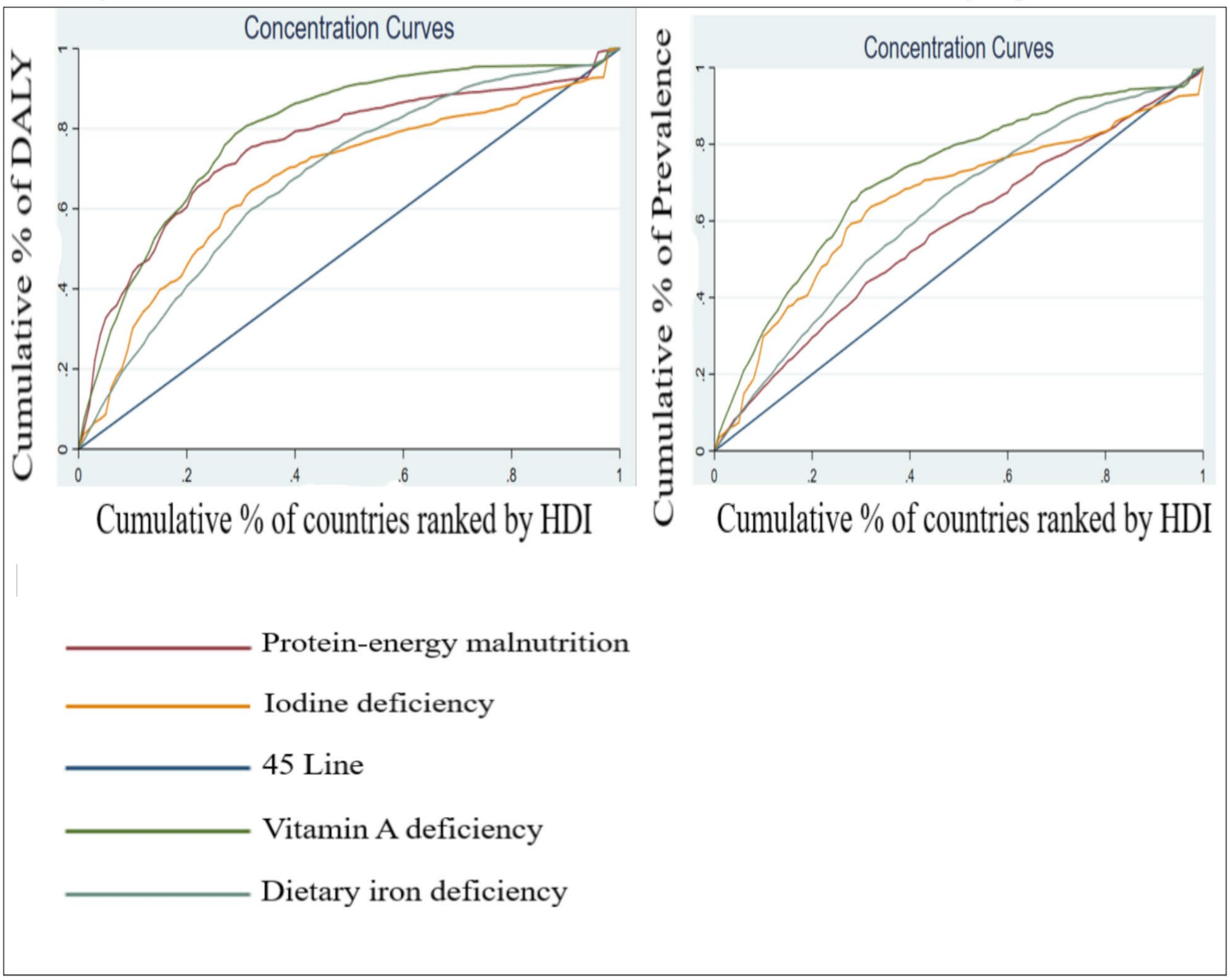

Fig. 3 Concentration curves for the burden of nutritional deficiencies subgroups

middle-income countries (LMICs) [18]. Similarly, Emadi et al. (2021) reported that nutritional deficiencies are disproportionately prevalent in nations with lower HDI [19]. In Australia, a study demonstrated that individuals with low socioeconomic status experienced a higher prevalence of nutritional deficiencies, highlighting the intersection of health and economic status [20]. Furthermore, research conducted in India revealed that malnutrition rates in rural, impoverished communities were nearly double those in urban areas, underscoring the geographic and economic disparities in nutritional health [21]. A study in Iran, echoed these findings, showing higher rates of nutritional deficiencies among citizens with lower socioeconomic status [22]. Van de Poel et al. also noted that in Ghana, socioeconomic inequality in malnutrition was closely linked to poverty, maternal education, healthcare access, and regional characteristics, reinforcing the idea that SDH significantly influence health outcomes [23].

The interplay between SDH and health outcomes, particularly malnutrition, is evident in the relationship between poverty and food insecurity [24]. Poverty exacerbates adverse health conditions by limiting access to nutritious food, as individuals in low-income brackets are often constrained by financial limitations that hinder their ability to maintain a healthy diet [25]. Studies have shown that low-income individuals are less likely to consume a balanced diet, often resorting to energy-dense, nutrient-poor foods diet [26, 27]. Additionally, dietary patterns among low-income groups tend to lack essential nutrients, including energy, fiber, and vitamins [28].

Our analysis revealed that the DALY and prevalence of protein-energy malnutrition were significantly higher in countries with low HDI. Zhang et al. (2022) corroborated our findings, indicating that the burden of protein-energy malnutrition is particularly severe among children, the elderly, and in nations with a low social demographic index [29]. In a study on the 38 countries, the prevalence of protein-energy malnutrition was twice as high in poor, rural communities compared to urban settings [30]. This suggests that socioeconomic factors, including living conditions, parental education, maternal occupation, prenatal care, and cultural influences, play critical roles in the prevalence of protein-energy malnutrition [31]. In another study it is stated that regions with a low Socio-Demographic Index (SDI) displayed lower Age-Standardized Incidence Rate (ASR) for protein-energy malnutrition. South Asia among regions and Maldives among countries exhibits the highest ASR for protein-energy malnutrition, respectively [32].

Similarly, our findings regarding iodine deficiency align with Ji et al. (2024), who showed a negative correlation between iodine deficiency incidence and socio-demographic status, noting that Central Sub-Saharan Africa had the highest ASR for iodine deficiency, reaching 459 per 100,000 population, followed by South Asia and Eastern Sub-Saharan Africa. Moreover, Equatorial Guinea recorded the highest rate of iodine deficiency incidence rate, which primarily affected adolescents and young [32]. In Tanzania, it was observed that individuals from the poorest income groups had a higher likelihood of iodine deficiency, with pregnant women particularly affected [33, 34]. This may be attributed to limited access to iodized salt and iodine-rich foods, further exacerbating health risks associated with iodine deficiency [35]. In Ethiopia, as one of the low-income countries, a high prevalence of iodine deficiency was reported. In a meta-analysis of 15,611 school-age children, the iodine deficiency prevalence was reported to be 58%. The consumption of goitrogenic foods and the child's sex were key factors determining the prevalence of iodine deficiency among children [36].

The concentration of DALY and prevalence related to vitamin A deficiency in low HDI countries is also noteworthy. A study in India highlighted that lower income groups faced a higher prevalence of vitamin A deficiency [37]. The global burden of vitamin A deficiency is particularly pronounced among women and children in LMICs, with DALY rates significantly higher in countries with low socio-demographic indices [38]. Factors contributing to vitamin A deficiency include inadequate dietary intake, malabsorption issues, and health conditions that exacerbate nutrient loss [39]. Another study on the burden of vitamin A deficiency in the Middle East and North Africa (MENA) region, revealing 30.6 million prevalent cases in 2019 and an age-standardized prevalence rate of 5,249.9 per 100,000. The YLD rate were below the global average, and a negative correlation was found between SDI and YLD rates [40]. An ecological study found that Central Sub-Saharan Africa had the greatest prevalence of vitamin A deficiency, especially among males. Cameroon reported the highest ASR of vitamin A deficiency, which predominantly impacted children and adolescents [32]. Although vitamin A supplementation programs have been implemented, challenges remain in achieving comprehensive coverage, especially in countries with large populations and poor sanitation, which can lead to increased susceptibility to infectious diseases that further deplete vitamin A levels [41, 42].

Lastly, our study found a significant concentration of dietary iron deficiency in countries with low HDI. Research in India has shown that dietary iron deficiency is more prevalent among low-income families with weaker food security, exacerbated by insufficient iron supplementation in children from disadvantaged backgrounds [43]. International studies reinforce this finding, indicating that dietary iron deficiency is a widespread issue among women and children in LMICs, particularly in nations with low socio-demographic indices [44]. In South Korea, children from low socioeconomic backgrounds exhibited higher rates of dietary iron deficiency, leading to increased anemia prevalence among adolescent girls [45]. This highlights the multifaceted nature of dietary deficiencies, where lifestyle, geographic factors, socioeconomic status, and maternal education significantly influence nutritional outcomes [46, 47]. Educated mothers are more likely to ensure their children receive adequate micronutrients, thereby improving overall health [48]. Another recent study (2024) indicated that from 1990 to 2019, the global age-standardized prevalence rate (ASPR) of dietary iron deficiency declined, with an average annual percent change (AAPC) of -0.14. However, the overall number of cases saw a slight increase, rising by 5.5% over the past thirty years. Nearly half of those affected were children under the age of five. The highest ASPRs were recorded in Western Sub-Saharan Africa and South Asia, with Bhutan having the highest national ASPR, followed by Mali and Gambia [49].

For all subgroups of nutritional deficiencies, the disparity in DALY was greater than the disparity in prevalence. This shows that although malnutrition occurs more in low-income countries, due to the weakness of health care systems in these countries, the inequality in the final consequences of malnutrition such as DALY becomes much deeper.

In the present study, we comprehensively examined the socioeconomic inequality in all health outcome indicators of nutritional deficiencies and its subcategories and found which type of nutritional deficiencies have greater pro-poor inequality. This is a major strength of current research that can guide global health policy makers to reduce nutritional inequality among countries. One of the main limitations of this research is the ecological nature of the study. Considering that this study was conducted at the macro level, although it provides a general picture of the between-country inequality in the burden of nutritional deficiencies, more studies at the micro/individual level are needed for policy making within each country.

Conclusions

Inequality in incidence, prevalence, YLD, YLL, death, and DALY of nutritional deficiencies and DALY and prevalence of protein-energy malnutrition, iodine deficiency, vitamin A deficiency and dietary iron deficiency are concentrated in countries with low HDI, so there is pro-poor inequality. Considering that nutritional deficiencies have a relatively serious burden in the low HDI countries, more attention should be paid to the development of prevention and primary treatment measures for nutritional deficiencies in these countries, such as improving nutrition-related health education, nutritional support and early aggressive treatment, and also eliminating hunger.

Abbreviations

ASPR	Age-Standardized Prevalence Rate
AAPC	Average Annual Percent Change
CC	Concentration Curve
CI	Concentration Index
DALY	Disability-Adjusted Life Years
GBD	Global Burden of Disease
HDI	Human Development Index
IHME	Institute for Health Metrics and Evaluation
IQ	Intelligence Quotient
LIMICs	Low and Middle-Income Countries
MENA	Middle East and North Africa
SDH	Social Determinants of Health
SDI	Socio-Demographic Index
ASR	Standardized Incidence Rate
YLD	Years Lived with Disability
YLL	The Years of Life Lost

Acknowledgements

The authors would like to thank IHME for providing GBD data. We also would like to thank Shiraz University of Medical Sciences.

Author contributions

MB was involved in study idea and design, data analysis and interpretation, manuscript drafting and final review of manuscript. EA was involved in data interpretation, manuscript drafting and final review of manuscript. ME was involved in data collection, statistical analysis and interpretation, manuscript drafting and final review of manuscript. All authors have read and approved the final manuscript.

Funding

This paper was financially supported by Shiraz University of Medical Sciences with grant number 24431. The funder had no role in the study design, data collection, analysis, and interpretation, and writing of the manuscript.

Data availability

The data used in this study are publicly available in IHME (http://ghdx.healthdata.org/gbd-results-tool) and UN (http://hdr.undp.org/en/2019-report) databases.

Declarations

Ethics approval and consent to participate

The project was found to be in accordance to the ethical principles and the national norms and standards for conducting medical research. The study protocol was approved by the Ethics Committee of Shiraz University of Medical Sciences under code IR.SUMS.NUMIMG.REC.1400.077.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Health Human Resources Research Center, School of Health Management and Information Sciences, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Student Research Committee, Shiraz University of Medical Sciences, Shiraz, Iran
[3]Student Research Committee, School of Health Management and Information Sciences, Shiraz University of Medical Sciences, Shiraz, Iran

Received: 12 April 2023 / Accepted: 3 January 2025
Published online: 13 January 2025

References

1. Nutrition and Infant/Child Development. Public Health Nutrition 2nd Edition: Wiley. 2017. pp. 137 – 58.
2. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, De Onis M, et al. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382(9890):427–51.
3. Micha R, Di Cesare M, Ghosh S, Zanello G. Global nutrition report: stronger commitments for Greater Action. Bristol, UK: Development Initiatives Poverty Research Ltd.; 2022.
4. Yue T, Zhang Q, Li G, Qin H. Global Burden of Nutritional Deficiencies among children under 5 years of age from 2010 to 2019. Nutrients. 2022;14(13):2685.
5. Liu J, Qi X, Wang X, Qin Y, Jiang S, Han L, et al. Evolving patterns of nutritional deficiencies Burden in Low- and Middle-Income countries: findings from the 2019 global burden of Disease Study. Nutrients. 2022;14(5):931.
6. Leung AK, Lam JM, Wong AH, Hon KL, Li X. Iron deficiency anemia: an updated review. Curr Pediatr Reviews. 2024;20(3):339–56.
7. Korczak A, Wójcik E, Olek E, Łopacińska O, Stańczyk K, Korn A, et al. The Long-Term effects of Iron Deficiency in Early Infancy on Neurodevelopment. J Educ Health Sport. 2024;70:51104.

8. Brown KH, Engle-Stone R, Kagin J, Rettig E, Vosti SA. Use of optimization modeling for selecting National Micronutrient intervention strategies. FoodNutr Bull. 2015;36(3suppl):S141–8.
9. Bringas Vega ML, Guo Y, Tang Q, Razzaq FA, Calzada Reyes A, Ren P, et al. An age-adjusted EEG source classifier accurately detects School-aged Barbadian children that had protein Energy Malnutrition in the First Year of Life. Front Neurosci. 2019;13:1222.
10. Abbott MB, Vlasses CH. Nelson Textbook of Pediatrics. JAMA. 2011;306(21).
11. Ahmmed M. Impact of wealth inequality on child nutrition in Bangladesh. Paediatr Indonesiana. 2013;53(6):299–304.
12. Das S, Gulshan J. Different forms of malnutrition among under five children in Bangladesh: a cross sectional study on prevalence and determinants. BMC Nutr. 2017;3(1).
13. Miranda VIA, da Silva Dal Pizzol T, Silveira MPT, Mengue SS, da Silveira MF, Lutz BH, Bertoldi AD. The use of folic acid, iron salts and other vitamins by pregnant women in the 2015 Pelotas birth cohort: is there socioeconomic inequality? BMC Public Health. 2019;19(1):889.
14. Human Development Data [Internet]. 2022. Available from: https://hdr.undp.org/data-center
15. GBD Results [Internet]. 2019 [cited 2022]. Available from: http://ghdx.healthdata.org/gbd-results-tool
16. Evaluation IfHMa. Global Burden of Disease (GBD) 2024 [Available from: http://www.healthdata.org/gbd/about
17. O'Donnell O, van Doorslaer E, Wagstaff A, Lindelow M. Analyzing Health Equity using Household Survey Data. The World Bank; 2007.
18. Seferidi P, Hone T, Duran AC, Bernabe-Ortiz A, Millett C. Global inequalities in the double burden of malnutrition and associations with globalisation: a multilevel analysis of demographic and health surveys from 55 low-income and middle-income countries, 1992–2018. Lancet Glob Health. 2022;10(4):e482–90.
19. Emadi M, Delavari S, Bayati M. Global socioeconomic inequality in the burden of communicable and non-communicable diseases and injuries: an analysis on global burden of disease study 2019. BMC Public Health. 2021;21(1):1771.
20. Siddiqui F, Salam RA, Lassi ZS, Das JK. The intertwined relationship between malnutrition and poverty. Front Public Health. 2020;8:453.
21. Singh S, Srivastava S, Upadhyay AK. Socio-economic inequality in malnutrition among children in India: an analysis of 640 districts from National Family Health Survey (2015-16). Int J Equity Health. 2019;18(1):203.
22. Fateh M, Emamian MH, Asgari F, Alami A, Fotouhi A. Socioeconomic inequality in hypertension in Iran. J Hypertens. 2014;32(9):1782–8.
23. Van de Poel E, Hosseinpoor AR, Jehu-Appiah C, Vega J, Speybroeck N. Malnutrition and the disproportional burden on the poor: the case of Ghana. Int J Equity Health. 2007;6:21.
24. Gundersen C, Ziliak JP. Food insecurity and health outcomes. Health Aff. 2015;34(11):1830–9.
25. Tanumihardjo SA, Anderson C, Kaufer-Horwitz M, Bode L, Emenaker NJ, Haqq AM, et al. Poverty, obesity, and Malnutrition: An International Perspective recognizing the Paradox. J Am Diet Assoc. 2007;107(11):1966–72.
26. Fisher JO, Hughes SO, Miller AL, Horodynski MA, Brophy-Herb HE, Contreras DA, et al. Characteristics of eating behavior profiles among preschoolers with low-income backgrounds: a person-centered analysis. Int J Behav Nutr Phys Activity. 2022;19(1):91.
27. Darmon N, Drewnowski A. Does social class predict diet quality? Am J Clin Nutr. 2008;87(5):1107–17.
28. Nikolić M, Glibetić M, Gurinović M, Milešević J, Khokhar S, Chillo S, et al. Identifying critical nutrient intake in groups at risk of poverty in Europe: the CHANCE project approach. Nutrients. 2014;6(4):1374–93.
29. Zhang X, Zhang L, Pu Y, Sun M, Zhao Y, Zhang D, et al. Global, Regional, and National Burden of Protein-Energy Malnutrition: a systematic analysis for the global burden of Disease Study. Nutrients. 2022;14(13):2592.
30. Crichton M, Craven D, Mackay H, Marx W, de van der Schueren M, Marshall S. A systematic review, meta-analysis and meta-regression of the prevalence of protein-energy malnutrition: associations with geographical region and sex. Age Ageing. 2018.
31. Gachhadar R, Shah T, Yadav B, Shrestha S. Prevalence of protein-energy malnutrition among under-five Dalit children in selected VDCs of Morang District. J Karnali Acad Health Sci. 2021;4(3).
32. Ji S, Zhou Y, Zhao Q, Chen R, Su Z. Trends in three malnutrition factors in the global burden of disease: iodine deficiency, vitamin A deficiency, and protein-energy malnutrition (1990–2019). Front Nutr. 2024;11:1426790.
33. Ba DM, Ssentongo P, Na M, Kjerulff KH, Liu G, Du P, et al. Factors Associated with urinary iodine concentration among women of Reproductive Age, 20–49 years Old, in Tanzania: a Population-based cross-sectional study. Curr Dev Nutr. 2020;4(5):nzaa079–nzaa.
34. Mtumwa AH, Ntwenya JE, Paul E, Huang M, Vuai S. Socio-economic and spatial correlates of subclinical iodine deficiency among pregnant women age 15–49 years in Tanzania. BMC Nutr. 2017;3:47.
35. Samanta SD, Nayak A, Pongen I, Choudhary M. Iodine Deficiency. Causes and management of Nutritional Deficiency disorders. IGI Global; 2024. pp. 219–34.
36. Baffa LD, Angaw DA, Abriham ZY, Gashaw M, Agimas MC, Sisay M, et al. Prevalence of iodine deficiency and associated factors among school-age children in Ethiopia: a systematic review and meta-analysis. Syst Reviews. 2024;13(1):142.
37. Kundu S, Rai B, Shukla A. Prevalence and determinants of vitamin A deficiency among children in India: findings from a national cross-sectional survey. Clin Epidemiol Global Health. 2021;11:100768.
38. Zhao T, Liu S, Zhang R, Zhao Z, Yu H, Pu L, et al. Global Burden of Vitamin A Deficiency in 204 countries and territories from 1990–2019. Nutrients. 2022;14(5):950.
39. Organization WH. Global prevalence of vitamin A deficiency in populations at risk 1995–2005. 2009. 2024.
40. Safiri S, Mousavi SE, Nejadghaderi SA, Motlagh Asghari K, Karamzad N, Sullman MJ, et al. Vitamin A deficiency in the MENA region: a 30-year analysis (1990–2019). Front Nutr. 2024;11:1413617.
41. Imdad A, Mayo-Wilson E, Haykal MR, Regan A, Sidhu J, Smith A, Bhutta ZA. Vitamin a supplementation for preventing morbidity and mortality in children from six months to five years of age. Cochrane Database Syst Rev. 2022;3(3):CD008524–CD.
42. Strunz EC, Suchdev PS, Addiss DG. Soil-transmitted helminthiasis and vitamin A Deficiency: two problems, one policy. Trends Parasitol. 2016;32(1):10–8.
43. Srivastava S, Kumar S. Does socio-economic inequality exist in micro-nutrients supplementation among children aged 6–59 months in India? Evidence from National Family Health Survey 2005-06 and 2015-16. BMC Public Health. 2021;21(1):545.
44. Christian P, Smith Emily R. Adolescent undernutrition: global burden, physiology, and nutritional risks. Annals Nutr Metabolism. 2018;72(4):316–28.
45. Kim JY, Shin S, Han K, Lee KC, Kim JH, Choi YS, et al. Relationship between socioeconomic status and anemia prevalence in adolescent girls based on the fourth and fifth Korea National Health and Nutrition Examination Surveys. Eur J Clin Nutr. 2013;68(2):253–8.
46. Nazari M, Mohammadnejad E, Dalvand S, Ghanei Gheshlagh R. Prevalence of iron deficiency anemia in Iranian children under 6 years of age: a systematic review and meta-analysis. J Blood Med. 2019;10:111–7.
47. Gao M, Ma W, Chen X-B, Chang Z-W, Zhang X-D, Zhang M-Z. Meta-analysis of Green Tea drinking and the prevalence of gynecological tumors in women. Asia Pac J Public Health. 2013;25(4suppl):S43–8.
48. Harding KL, Aguayo VM, Masters WA, Webb P. Education and micronutrient deficiencies: an ecological study exploring interactions between women's schooling and children's micronutrient status. BMC Public Health. 2018;18(1):470.
49. Jiang W, Li X, Wang R, Du Y, Zhou W. Cross-country health inequalities of four common nutritional deficiencies among children, 1990 to 2019: data from the global burden of Disease Study 2019. BMC Public Health. 2024;24(1):486.

Publisher's note