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Spatiotemporal Dynamics of Hidden Hunger among Children and Reproductive-Age Women in China from 2000 to 2020

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Abstract

Hidden hunger compromises immune systems, hinders child growth and development and affects human potential worldwide. However, to our knowledge, the existing estimate of the hidden hunger burden is global and national but lacks sub-national work. We aimed to explore spatiotemporal dynamics and its drivers of the provincial burden of hidden hunger for iron and zinc deficiency among children (aged 0 - 14 years) and women of reproductive age (aged 20 - 29 years) in China from 2000 to 2020. We collected provincial representative disease data of iron and zinc deficiency status based on Statistical Yearbook Data and researches of latest Chinese medical investigations to calculate Disability-Adjusted Life Years (DALYs). The results show the situation of hidden hunger in China is worse than estimated, and the discrepancy among regions still consists of the main discrepancy in the country. Complementary macro-level economic interventions are required to end hidden hunger of vulnerable population, even all groups.

Keywords

Hidden Hunger, Dynamics, Reproductive-Age Women, Children, China

1. Introduction

Micronutrient deficiencies cause morbidity and mortality in individuals, affecting human potential worldwide (Bailey et al., 2015); it is one of the triple burdens of malnutrition, often referred to as a hidden hunger and globally recognized as a serious health problem that deprives children and women of their lives and health (Bailey et al., 2015; Lowe, 2021). Iron and zinc are the two micronutrient deficiencies

of greatest public health concern globally, due to their high prevalence and associated health and developmental consequences. Iron deficiency is the most common cause of nutritional anemia, and zinc deficiency is associated with low birth weight, poor fetal neurodevelopment, premature birth, and increased neonatal mortality (UNICEF, 2019). Globally, 38% of pregnant women and 43% of children under five years of age suffer from anemia (Stevens et al., 2013), and about 20% of the global population is at risk of zinc deficiency (Warthon-Medina et al., 2015), which threatens the health of children, women in pregnancy and lactation, and other vulnerable people.

Reproductive-age women and children's health is a cornerstone of healthy development for the next generation and driving force for the progress of population and society in the future. *The Global Health Strategy for Women*, *Children and Adolescent* (2016-2030), which was developed under the framework of the Sustainable Development Goals (SDGs), explicitly recognized the need to extend the focus beyond mortality alone and to promote health across the developmental years (Qiao et al., 2021). Our study's age groups, 0 - 14 years for children and 20 - 29 years for women, align with the UN's definition of childhood and the reproductive phase for women, respectively. These selections capture critical stages of growth, learning, and significant physiological changes. The 0 - 14 age bracket is pivotal for pediatric health research, particularly in nutrient deficiencies, while the 20 - 29 range highlights reproductive and maternal health issues. This focus facilitates comparisons with established literature and informs targeted health policies and interventions.

The elimination of hunger in all its forms including micronutrient deficiencies is the second goal of the SDGs, which have also extended the focus from maternal and child survival alone to improvement of health across the life span. In past decades, a series of landmark publications in the *Lancet* have provided a sharp focus on the previously unprecedented level of detail on the scale of the challenges the international nutrition research community faces to reduce malnutrition in all its forms of women and children (Black et al., 2013a, 2013b; Hawkes et al., 2020; Ruel & Alderman, 2013). However, in the case of hidden hunger, many researches just use Global Burden of Disease (GBD) Database or the World Health Organization (WHO) Database to simulate trends at global and national levels (Goedecke et al., 2018; Lenaerts & Demont, 2021; Muthayya et al., 2013; Ruel-Bergeron et al., 2015), while provincial studies are lacking, due to the low extensiveness of individual-level biomarker data. Looking to the future, China is acting responsibly to create a healthy and friendly environment for every women, child and adolescent for their own sake and as important partners in SDGs global governance. Due to accelerating progress towards Millennium Development Goals (MDGs) 4 and 5 (to improve maternal and child health), the World Health Organization (WHO) rated China as one of the top 10 "fast-track" countries in women's and children's health (World Health Organization, 2014). In fact, China has a large population, large inter-provincial development differences, and prominent regional imbalance.

Although the national average level of micronutrient deficiency can explain China's overall development, it cannot explain sub-national differences.

Figuring out hidden hunger of women and children not only plays a role in guaranteeing the health of each individual woman, and children, but also a cornerstone for the development of the next generation and the evenly sustainable development of national society. Despite the prevalence of anemia and zinc deficiency in Chinese women and children has improved over the past decades showed in some researches (Bi et al., 2020; Wu et al., 2019), multiple forms of malnutrition still exist and the globally real situation may be more serious than these findings suggest, especially under the impact of the pandemic on nutritional structure (FAO et al., 2022). In the next ten years, China has committed to achieving both the SDGs and Healthy China 2030 goals. Clarifying the provincial distribution and evolution of hidden hunger of women and children is a significant topic in China.

To estimate the scales of the provincial hidden hunger of the women and children in China, Disability-Adjusted Life Years (DALYs) are suggested as a more nuanced and comprehensive measure to calculate the burden of hidden hunger (Stein et al., 2005; Sulser et al., 2021). It is widely used in terms of disease burden as the characteristic of comparison and calculation. Since relevant provincial data about the micronutrient element of hidden hunger is not available in GBD Database. Further, we comprehensively consider a combination of indigenous medical survey and literal meta-analysis data to determine the morbidity and mortality of iron deficiency-related anemia and iron deficiency anemia (IDA) and zinc deficiency-related pneumonia, diarrhea and stunning, which is used as the basis for DALYs calculation.

In this study, we first estimate hidden hunger DALYs of women of reproductive age (aged 20 - 29 years) and children(aged 0 - 14 years) in 31 provinces from 2000 to 2020, and analyze the spatiotemporal dynamics. We then evaluate the Dagum Gini ratio of DALYs and age-standardized DALY rate in four main regions of China to explore the sources of variation differences (Liu et al., 2021). Finally, we evaluate the relative contributions of changes in diet quality, consumption structure, urban-rural structure and benefiting level on hidden hunger using the identity decomposition method developed by Kaya (Uerge-Vorsatz et al., 2015; Yang et al., 2020).

The results showed that the DALYs and DALY rate of hidden hunger has increased slightly and presented the characteristic of "high in the west and low in the east" between 2000 and 2020. Regional differences are most prominent. Firstly, progress in the western region has contributed the most to the improvement of hidden hunger among women of reproductive age and children across the country. The second, the number of hidden hunger in central and eastern regions is large and the incidence is increasing significantly, while the number of hidden hunger is sharply reduced in northeast region due to the decline in natural population growth rates. In drivers factor analysis, iron and zinc supplementation

in diet does not seem to play a role, while consumption structure, urban-rural development, and the policies to benefit the people have a positive effect on the improvement of hidden hunger in the study population. These results suggest that macro interventions are required to eradicate the burden of hidden hunger for the vulnerable populations.

2. Methods

2.1. Measuring the Population of Iron and Zinc Hidden Hunger with DALYs

Using the studies of (Goedecke et al., 2018; Sulser et al., 2021), we assessed DALYs due to more comparability and universality in disease burden evaluation than in Muthayya et al. (2013) and Ruel-Bergeron et al. (2015). DALYs lost are related to the sum of the "years of life lost" (YLL) due to cause-specific mortality and the sum of the "years lived with disability" (YLD). To add up disability and death, years of life lived with a disability are weighted with "severity" or "disability" weights. These weights range from 0 to 1 and 1 presenting death. Taking account of different levels of severity and of the varying extent of disease among groups within a population, the complete formula can be represented more formally as:

$$\mathrm{DALYs} = \mathrm{YLL} + \mathrm{YLD} \tag{1}$$

$$\mathrm{YLL} = \sum_i RT_j M_j \left(\frac{1 - \mathrm{e}^{-rL_j}}{r} \right) \tag{2}$$

$$\mathrm{YLD} = \sum_i \sum_j RT_j I_{ij} D_{ij} \left(\frac{1 - \mathrm{e}^{-rd_{ij}}}{r} \right) \tag{3}$$

where R is proportion of the population in the corresponding age and gender group in target area. T_j is total number of people in target group j. M_j is mortality rate associated with the deficiency in target group j. L_j is average remaining life expectancy for target group j. I_{ij} is incidence rate of disease i in target group j. D_{ij} is disability weight for disease i in target group j. d_{ij} is the duration of disease i in target group j. r is the discount for future life years.

In this paper, the demographic data are from the local statistical yearbook (resident population) between 2000 and 2020, supplemented by census or sample survey data bulletins. Considering the requires that data is mainly reflected in the characteristic age and gender group in iron and zinc deficiencies, the data is collected that include towns and villages of gender in each age for enhancing computability and matching with disease data.

Iron and zinc micronutrient have a huge impact on human growth and social public health. In terms of the iron and zinc micronutrient deficiencies, many native researches have increased awareness of the role iron and zinc micronutrient play in public health. Hu (2013) explained the physiological function of iron, the development stage of iron deficiency in the body that the last stage is IDA and its prevalence and causes at all ages. Furthermore, Du et al. (2022) retrieved for all relevant studies on the prevalence of iron deficiency anemia in children under 5

years in Western China and obtain the result about high level were reported in the subgroup of children aged 6 - 12 months. Thus, for iron deficiency, we focused on infants (0 - 1 years), adolescents (10 - 14 years), and women of childbearing age (20 - 29 years). On the hand of zinc, Chen (2005) and Huang et al. (2009) studied the physiological function of zinc and the health effects of zinc deficiency, similarly, especially on the growth and development of children, as well as the related measures of zinc supplementation on food. In addition to, acute respiratory disease and diarrhoea are among the most important public health problem around the country and the leading cause of death among adolescents and children (Liu et al., 2020b). Therefore, the main symptoms of zinc deficiency in children and teenagers can be summarized as low immunity (common disease is pneumonia and diarrhea) and stunted growth in this study (Table 1).

Table 1. Parameters corresponding to specific groups.

Target group	Age	Adverse function outcomes	Duration (year)	Attributable proportion of deaths	Disability weight	Attribution
Infant	0 - 1	Mild IDA	0.25	-	0.011	Iron
		Moderate and Severe IDA	0.5		0.087	Iron
		Diarrhea	3/365		0.2	Zinc
		Pneumonia	4/365		0.3	Zinc
		Stunning	Remaining life expectancy		0.0001	Zinc
Child	1 - 5	Mild IDA	0.25		0.011	Iron
		Moderate and Severe IDA	0.5		0.087	Iron
		Diarrhea	4/365		0.15	Zinc
		Pneumonia	4/365		0.2	Zinc
Youngster	6 - 14	Mild IDA	0.25		0.011	Iron
		Moderate and Severe IDA	0.5		0.087	Iron
Women of reproductive age	20 - 29	Mild IDA	0.5		0.011	Iron
		Moderate IDA	1		0.09	Iron
People with a lower life expectancy	-	Death from anemia	-	0.85	-	Iron
People susceptible to pneumonia	0 - 14	Pneumonia and related respiratory diseases	-	0.40	-	Zinc

Data on anemia, stunning, diarrhea, pneumonia, IDA of varying degrees (mild, moderate and severe) incidence were chosen on the basis of their contribution to

hidden hunger, as well as the national availability provincial representative estimates. Evaluating of anemia death, stunning, diarrhea and pneumonia incidence were obtain from China Health Statistics Yearbook (CHSY). We use meta-analysis methods and results developed by Liu et al. (2020a) to analyze prevalence of IDA and pneumonia in 0 - 14 years children from 2000 to 2020, also use their data result weighted for region, age and years.

2.2. Estimated Spatial and Temporal Distribution of Hidden Hunger

In this paper, we use Matlab software to calculate the Dagum Gini ratio of and inter-provincial hidden hunger DALYs and age-standardized DALY rate in China, and explore the causes and sources of regional disparities. According to the definition of the Dagum Gini ratio by Dagum (1998), we divided the research object into k groups, including a total of n research objects, and a and b represent different groups in this paper. In line with China's regional coordinated development layout during the 14th Five-Year Plan period, we divided 31 provinces into 4 groups, which are East, Central, West, and Northeast region. n_a and n_b represent the number of objects in groups a and b, respectively, y_{ai} and y_{bj} respectively represent the variable data of any research object in groups a and b as well. They refer to hidden hunger DALYs or age-standardized DALY rate in this paper. y represents the mean of total DALYs or age-standardized DALY rate. Dagum Gini ratio calculation formula is as follows:

$$G = \frac{\sum_{a=1}^{k}\sum_{b=1}^{k}\sum_{i=1}^{n_a}\sum_{j=1}^{n_b}\left|y_{ai} - y_{bi}\right|}{2n^2 y} \tag{4}$$

By decomposing the Dagum Gini ratio, the sources and causes of regional differences can be obtained. The Gini ratio is divided into three components: 1) the Gini inequality within groups (G_w); 2) the net contribution of the extended Gini inequality between groups (G_{nb}); 3) the contribution of the intensity of transvariation between groups (G_t). The latter two constitute the total contribution of the differences between groups, and there is an equation: $G = G_w + G_{nb} + G_t$. In this paper, G_w represents the difference of provincial hidden hunger within four regions, G_{nb} represents the difference of hidden hunger between four regions, and the intensity of transvariation reprensents a residual Gini ratio of the cross-influence of hidden hunger in four regions. G_{aa} and G_{ab} represent the Gini ratio within group A and the Gini ratio between groups A and B, respectively.

$$G_{aa} = \frac{\sum_{i=1}^{n_a}\sum_{j=1}^{n_b}\left|y_{ai} - y_{aj}\right|}{2n^2 y} \tag{5}$$

$$G_{ab} = \frac{\sum_{i=1}^{n_a}\sum_{j=1}^{n_b}\left|y_{ai} - y_{bj}\right|}{n_a n_b\left(y_a + y_b\right)} \tag{6}$$

$$G_w = \sum_{a=1}^{k} G_{aa} p_a s_a \tag{7}$$

$$G_{nb} = \sum_{a=2}^{k} \sum_{b=1}^{a=1} G_{ab} \left(p_b s_a + p_a s_b \right) D_{ab} \tag{8}$$

$$G_t = \sum_{a=2}^{k} \sum_{b=1}^{a=1} G_{ab} \left(p_b s_a + p_a s_b \right) \left(1 - D_{ab} \right) \tag{9}$$

And among that, $p_a = \frac{n_a}{n}, s_a = \frac{n_a \overline{y_a}}{n\overline{y}}, a = 1, 2, \cdots, k$, D_{ab} represents the relative influence between region *a* and *b*. $D_{ab} = \left(h_{ab} - q_{ab} \right) / \left(h_{ab} + q_{ab} \right)$ represents the difference value associated with hidden hunger between regions, which can be understood as the mathematical expectation of the sum of all $y_{ai} - y_{bi} > 0$ sample values in region *a* and *b*. q_{ab} stands for supervariant-order moment, as the mathematical expectation of the sum of the sample values of $y_{ai} - y_{aj} < 0$ in region *a* and *b*, the relative equation follow as:

$$h_{ab} = \int_0^{\infty} \mathrm{d}F_a \left(y \right) \int_0^{y} \left(y - x \right) \mathrm{d}F_b \left(x \right) \tag{10}$$

$$q_{ab} = \int_0^{\infty} \mathrm{d}F_b \left(y \right) \int_0^{y} \left(y - x \right) \mathrm{d}F_a \left(x \right) \tag{11}$$

F_a and F_b respectively represented the cumulative density distribution function in region a and b. Based on the above calculation methods, the Dagum Gini ratio of hidden hunger in 31 provinces and regions of China from 2000 to 2020 can be obtained.

2.3. Determinants of the Burden of Hidden Hunger

At the first IPCC symposium, Japanese scholars proposed the equation of factoring CO_2 emissions, and then established a link between CO_2 emissions and GDP, energy consumption, and population, revealing the driving factors affecting CO_2 emissions. In this paper, we introduce Kaya identity decomposition into the analysis of the driving effect of the decomposition of hidden hunger in China. We extend the Kaya equation to:

$$\begin{aligned} H &= \sum_{i=1}^{31} \sum_{j=1}^{2} \frac{DALYsEco_{ij}}{FCons_{ij}} \times \frac{FCons_{ij}}{Income_{ij}} \times \frac{Income_{ij}}{Income_i} \times \frac{Income_i}{GDP_i} \\ &= 2 \sum_{i=1}^{31} \frac{DALYs_i}{Population_i} \end{aligned} \tag{12}$$

where the *i* and *j* represent 31 provinces and areas (rural or urban) respectively, the *H* represents the level of hidden hunger in a given year, *DALYsEco* represents the economic burden of hidden hunger, following WHO guidelines, we used a value of twice Chinese per capita GDP to value each $DALY_{lost}$ annually to hidden hunger in China. The *FCons* represents the resident food consumption expenses and the first income represents resident disposable personal income in rural or urban, the latter income represent resident disposable personal income in all province, and the last argument is GDP represents provincial economic index.

Some papers have said that malnutrition due to micronutrient deficiency may be related to diet quality, consumption structure, urban and rural development and the level of benefit. To better understand the factors that change the level of development of hidden hunger, we break down it into four effects. The equation

follows as:

$$H = \sum_{i=1}^{31} \sum_{j=1}^{2} d_{ij} c_{ij} u_{ij} b_i \tag{13}$$

where the d_{ij} represents the diet quality of hidden hunger, the c_{ij} represents consumption structure, the u_{ij} represents urban and rural structure, the b_i represents benefit level.

LMDI Factor Decomposition Method

The LMDI was proposed by Ang. B.W and has the advantages of no complete decomposition of residuals. We adopt the method in the form of addition. There the t is used to indicate the initial year and the T stands for the last year in a calculation. The change value of level of hidden hunger ΔH from the year t to T can be broken down into 4 types of effects, ΔH_d, ΔH_c, ΔH_u *and* ΔH_b represents the change of diet quality effect, consumption structure effect, urban and rural structure effect and level of benefit effect. Since H is twice the national incidence of DALY combined, we take 1/2 treatment to give a clearer picture of its drivers.

$$\Delta H' = \frac{1}{2}\Delta H = \frac{1}{2}\left(H_T - H_t\right) = \frac{1}{2}\left(\Delta H_d + \Delta H_c + \Delta H_u + \Delta H_b\right) \tag{14}$$

$$\Delta H'_d = \frac{1}{2}\Delta H_d = \frac{1}{2}\sum_{i=1}^{31}\sum_{j=1}^{2} \frac{H_T - H_t}{\ln H_T - \ln H_t} \times \ln \frac{d_{ij,T}}{d_{ij,t}} \tag{15}$$

$$\Delta H'_c = \frac{1}{2}\Delta H_c = \frac{1}{2}\sum_{i=1}^{31}\sum_{j=1}^{2} \frac{H_T - H_t}{\ln H_T - \ln H_t} \times \ln \frac{c_{ij,T}}{c_{ij,t}} \tag{16}$$

$$\Delta H'_u = \frac{1}{2}\Delta H_u = \frac{1}{2}\sum_{i=1}^{31}\sum_{j=1}^{2} \frac{H_T - H_t}{\ln H_T - \ln H_t} \times \ln \frac{u_{ij,T}}{u_{ij,t}} \tag{17}$$

$$\Delta H'_b = \frac{1}{2}\Delta H_b = \frac{1}{2}\sum_{i=1}^{31}\sum_{j=1}^{2} \frac{H_T - H_t}{\ln H_T - \ln H_t} \times \ln \frac{b_{ij,T}}{b_{ij,t}} \tag{18}$$

Further, we can calculate their respective relative contributions to hidden hunger levels.

$$\rho_d = \frac{\Delta H'_d}{\left|\Delta H'_d + \Delta H'_c + \Delta H'_u + \Delta H'_b\right|} \tag{19}$$

$$\rho_c = \frac{\Delta H'_c}{\left|\Delta H'_d + \Delta H'_c + \Delta H'_u + \Delta H'_b\right|} \tag{20}$$

$$\rho_u = \frac{\Delta H'_u}{\left|\Delta H'_d + \Delta H'_c + \Delta H'_u + \Delta H'_b\right|} \tag{21}$$

$$\rho_b = \frac{\Delta H'_b}{\left|\Delta H'_d + \Delta H'_c + \Delta H'_u + \Delta H'_b\right|} \tag{22}$$

3. Result

We aggregated the results from 31 provinces to get the total number of DALYs in the country, as shown in **Figure 1**. The histogram is the result of this study, and the band is the statistical chart of iron and zinc deficiency DALYs in the

corresponding age and sex groups in the GBD2019 Database. The GBD in China was established as part of the broader GBD study, which is a comprehensive and systematic analysis of global health trends. However, due to the diversity of statistical analysis methods, such as data collection and modeling estimation, the results obtained by GBD2019 through national data simulation estimation highlight the importance of our use of more accurate provincial population and incidence data. It could be found that the data of this study match the simulation results of GBD Database by orders of magnitude, and indicated that the calculation results of this study were credible and could illustrate the hidden hunger of women of reproductive age and children in China. Whether DALYs lost (Figure 1(a)) or DALY rate (Figure 1(b)), the quantity of this study were approximate to those of GBD in 2000. The hidden hunger DALYs lost were 805 thousands, DALY rate were 0.69 per thousand capita in this study, and in GBD, they were 780 (489 - 1162) thousands and 0.62 (0.39 - 0.92) per thousand capita, respectively. However, the histograms showed the tendency of climb up and then decline diverged from the patter of reduction of bands from 2000 to 2020. The DALYs lost and DALY rate reached maximum in 2010, with a slight increase overall between 2000 and 2020. Compared to the GBD projections, our findings suggested that iron and zinc hidden hunger of women of reproductive age and children may be more severe.

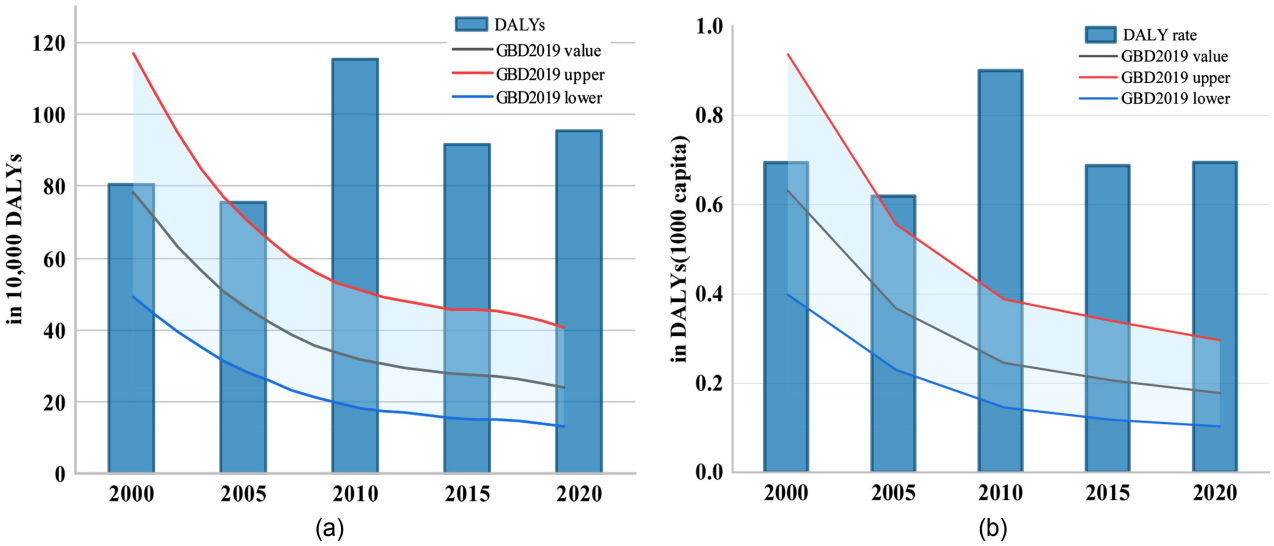


Figure 1. Development of the vulnerable populations hidden hunger over time in China. (a) DALYs lost due to hidden hunger between 2000 and 2020; (b) DALYs per 1000 capita lost due to hidden hunger between 2000 and 2020. DALYs, Disability Adjusted Life Years.

At the provincial level, Figure 2(a) showed the average value of DALYs lost during study period. The provinces that were among the top in the country were Henan, Guangdong and Sichuan Province, with 78 thousands, 66 thousands, 62 thousands, respectively. The provinces at the end of the country were Hainan (6.2 thousands), Qinghai (5.5 thousands), Tibet (3.8 thousands), and Beijing, Shanghai and Tianjin also ranked last in the country as less than 10 thousands. The average

value of DALYs lost in all provinces of the country was 29.6 thousands. The provinces, which value of DALYs lost above the average accounted for 69.2% of the national summation, aggregated the total population accounted for 65% of the country's. The DALYs lost of hidden hunger would be greater in areas with a large number of people, which is consistent with the research conclusions of Goedecke et al. (2018). **Figure 2(b)** illustrates the national distribution map of the average DALY rate. In western region, most of the rate were above 0.7, followed by most provinces in central region between 0.5 - 0.7, and the rate in eastern region and northeastern region locating around 0.4 were the smallest. The distribution pattern displayed a characteristic of "high-West, low-East" as a whole.

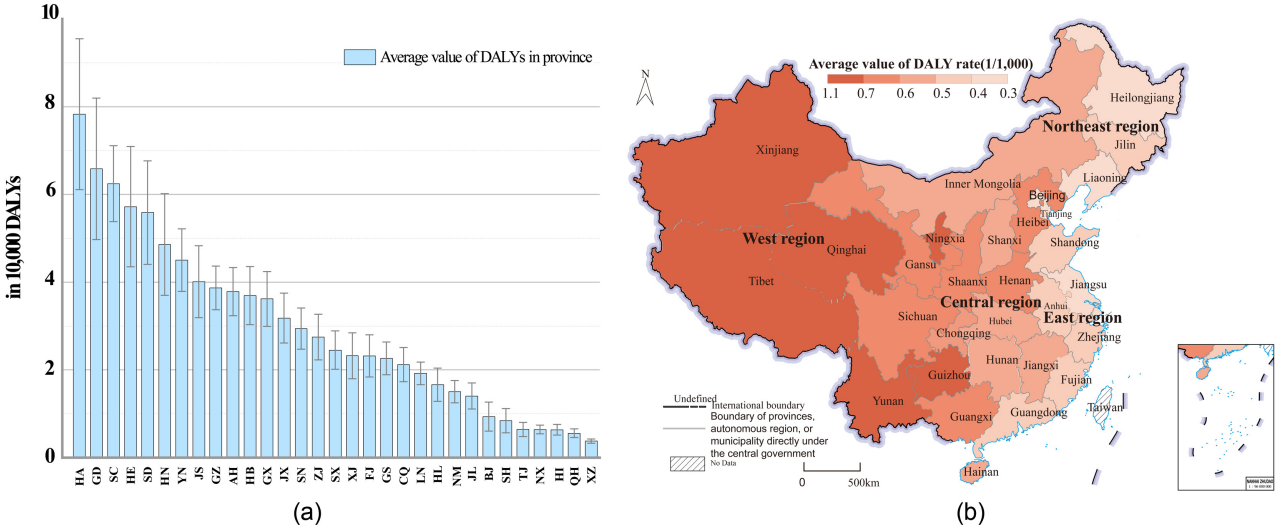
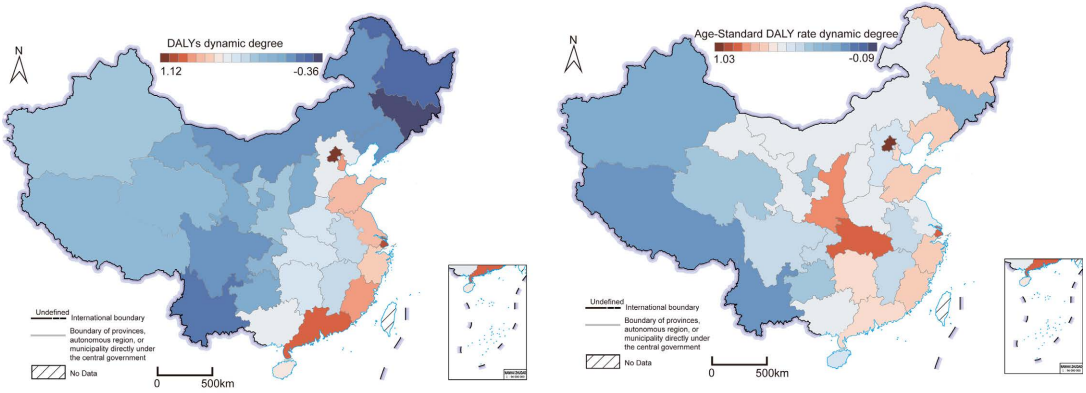


Figure 2. The distribution of the vulnerable population hidden hunger in provinces. (a) Average value of DALYs lost due to hidden hunger between 2000 and 2020; (b) Average value of DALYs per 1000 capita lost due to hidden hunger between 2000 and 2020.

The dynamics analysis can truly reflect the intensity of the variation of provincial hidden hunger during the specific study period (Cai et al., 2019). **Figure 3(a)** sketched the distributed characteristic—"high in central and eastern, low in western and northeastern" of the DALYs lost dynamics in China from 2000 to 2020. It revealed that iron-zinc hidden hunger DALYs of women of reproductive age and children increased mainly in central and eastern parts of China in the past 20 years. Especially, such as Beijing, Shanghai, Guangdong, Tianjin and Fujian Province, their dynamics were greater than 0.5, which was equivalent to more than 1.5 times that of DALYs lost in 2020 compared with 2000. Additionally, the decreasing of DALYs lost in Yunnan, Jilin, Heilongjiang Province were significantly reduced, their dynamics were less than −0.2. By and large, the main source of the increase in the number of hidden hunger occurred in central and eastern region. **Figure 3(b)** illustrates the dynamics distribution of age-standardized DALY rate excluding changes in population size and age composition and making DALY rate comparable over time (Chen et al., 2022). Unlike the transformation of DALYs lost, the age-standardized DALY rate increased in eastern,

central and northeastern regions, while the decreasing was principally concentrated in the western region but not noticeable. Only the dynamics of Tibet, Yunnan and Xinjiang were lower than 0. From Figure 3(c) and Figure 3(d), there were clarify expression of the dynamics of DALYs lost and age-standardized DALY rate for each periods and provinces. Combined with various time periods, the number and incidence of hidden hunger of central and eastern region have increased sharply, and it is likely to become "highland of hidden hunger" in future.



(a)

(b)

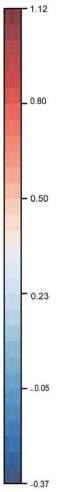
DALYs dynamic degree

	2000-2005	2005-2010	2010-2015	2015-2020	2000-2020
JL	-0.34	0.44	-0.23	-0.13	-0.36
HL	-0.03	0.34	-0.36	-0.13	-0.28
YN	-0.23	0.34	-0.28	0.05	-0.21
NM	-0.10	0.47	-0.27	-0.03	-0.07
SC	-0.04	0.32	-0.27	0.02	-0.06
LN	-0.13	0.41	-0.22	0.01	-0.03
SX	-0.14	0.54	-0.31	0.07	-0.01
GZ	-0.13	0.38	-0.25	0.12	0.01
GS	-0.09	0.45	-0.31	0.11	0.01
CQ	-0.15	0.62	-0.27	0.04	0.05
XZ	-0.20	0.39	-0.17	0.18	0.09
QH	-0.02	0.50	-0.27	0.04	0.13
XJ	-0.10	0.72	-0.11	-0.17	0.15
NX	-0.01	0.43	-0.24	0.06	0.15
SN	-0.11	0.53	-0.20	0.06	0.15
AH	-0.01	0.40	-0.20	0.06	0.19
JX	0.06	0.46	-0.24	0.00	0.19
HN	0.07	0.66	-0.28	-0.02	0.26
HA	-0.05	0.70	-0.27	0.07	0.26
HB	0.05	0.48	-0.18	-0.01	0.27
HE	0.02	0.72	-0.26	0.00	0.29
GX	0.02	0.47	-0.15	0.03	0.31
HI	-0.03	0.54	-0.10	0.01	0.35
ZJ	-0.04	0.52	-0.16	0.16	0.42
JS	0.01	0.56	-0.11	0.02	0.43
SD	-0.06	0.63	-0.16	0.13	0.45
FJ	-0.02	0.50	-0.01	0.02	0.50
TJ	-0.18	0.85	-0.12	0.12	0.50
GD	-0.11	0.63	-0.04	0.16	0.62
SH	0.05	0.97	-0.07	0.01	0.96
BJ	0.02	0.95	0.06	0.00	1.12

(c)

Age-Standard DALY rate dynamic degree

	2000-2005	2005-2010	2010-2015	2015-2020	2000-2020
XZ	-0.21	0.43	-0.23	0.04	-0.09
YN	-0.21	0.49	-0.24	0.03	-0.08
XJ	-0.06	0.81	-0.24	-0.26	-0.03
JL	-0.12	0.69	-0.24	-0.06	0.06
NX	-0.00	0.60	-0.26	0.00	0.18
GZ	-0.07	0.63	-0.22	0.02	0.20
QH	0.02	0.65	-0.28	0.01	0.23
CQ	-0.09	0.90	-0.28	-0.01	0.24
SC	0.00	0.68	-0.26	-0.00	0.25
JX	0.06	0.58	-0.23	-0.02	0.26
HE	0.23	0.74	-0.33	-0.09	0.30
HI	0.00	0.71	-0.19	-0.06	0.32
HA	0.14	0.72	-0.30	-0.03	0.33
NM	0.07	0.72	-0.23	-0.05	0.34
SX	-0.02	0.76	-0.23	0.02	0.35
GX	0.13	0.61	-0.21	-0.05	0.36
ZJ	0.02	0.60	-0.16	-0.02	0.36
GS	0.02	0.81	-0.27	0.02	0.37
GD	-0.08	0.75	-0.10	-0.04	0.38
HN	0.27	0.57	-0.28	-0.03	0.39
TJ	-0.01	0.92	-0.31	0.05	0.39
SD	0.15	0.59	-0.22	-0.01	0.43
LN	0.04	0.67	-0.22	0.05	0.44
HL	0.19	0.62	-0.27	0.03	0.45
FJ	0.13	0.69	-0.17	-0.08	0.45
SN	0.09	0.95	-0.26	-0.06	0.47
AH	0.06	0.80	-0.22	-0.01	0.48
JS	0.19	0.78	-0.20	-0.07	0.59
HB	0.22	0.95	-0.26	-0.04	0.67
SH	0.15	0.80	-0.15	-0.02	0.72
BJ	0.19	1.08	-0.10	-0.09	1.03



(d)

Figure 3. The dynamic degree of the DALYs lost and Age-Standard DALY rate in provinces. (a) The dynamic degree distribution map of vulnerable populations hidden hunger DALYs lost from 2000 to 2020; (b) The dynamic degree distribution map of vulnerable populations hidden hunger DALY rate from 2000 to 2020; (c) The each period dynamic degree table of vulnerable population hidden hunger DALYs lost from 2000 to 2020; (d) The each period dynamic degree table of vulnerable population hidden hunger DALY rate from 2000 to 2020.

In order to further perspicuity the dynamical evolution trend of iron-zinc hidden hunger of women of reproductive age and children, we calculated the Dagum Gini ratio of DALYs lost and DALY rate in national four regions. Firstly, **Figure 4(a)** presented a slight upward trend of G_w in all provinces, Dagum Gini ratio increased from 0.36 in 2000 to 0.38 in 2020, indicating discrepancy of DALYs between Chinese provinces only had a tiny widening in 20 years. The horizontal comparison based on the mean of ratio demonstrated the discrepancy within eastern region and between four major regions were the basic reason for the overall gap in the country, because only eastern region had a value above the national Gini ratio. There is a reason why the discrepancy in eastern region is more significant was the disparities in the population of eastern region is large, the population gap such as Guangdong, Shandong Province versus Shanghai and Beijing. The changing trend of discrepancy in eastern and central region during survey period was not obvious, it different with western and northeastern region. The G_{nb} of DALYs in western region changed from 0.38 in 2000 to 0.35 in 2020, and from 0.02 to 0.12 in northeastern region. While the discrepancy in western region was decreasing, the northeastern was widening. There is a crucial reason about the DALYs disparity was gradually expanding over time in northeastern region that Jilin and Heilongjiang have such a huge DALYs decline and decline in the natural growth rate of the population and reduced proportion of people aged 0 - 14 years and women of reproductive age became the reasons for that. Secondly, **Figure 3(b)** presents the discrepancy among northeastern region with eastern and central region were principally source composing the discrepancy between regions, due to their G_{nb} was the most 0.44 higher than the national Dagum Gini ratio. Dynamically, except for the eastern and central region, the rest of the discrepancy of inter-regions were fluctuating upward trend, of which the central and northeastern regions, eastern and northeastern region, western and northeastern region were forefront. Combined with the dynamic analysis of DALYs (**Figure 3(c)**), the decline in northeastern and the increase in eastern and central region were main reason for the increase of the interregional discrepancy.

On the aspect of age-standardized DALY rate, **Figure 4(c)** shows the national G_w decreased from 0.14 to 0.07, explaining the incidence of iron-zinc hidden hunger of women of reproductive age and children represent a downward tendency from 2000 to 2020 substantially. Overall, G_w within four major regions were less than the national value, inter-regional discrepancy also constituted an important part of the whole discrepancy in the country. At the meanwhile, **Figure 4(c)** visualizes that northeastern region had the smallest discrepancy and the other regions were approximate. During the past twenty years virtually all discrepancy decreased within the four major regions, and northeastern with an overall decrease of 84% saw the biggest change, western region with an overall decrease of 55.6% ranked second. Combined with dynamic analysis, the inter-provincial discrepancy in northeastern region decreased dramatically because the age-standardized DALY rate in Jinlin, Liaoning and Heilongjiang province all were growing

until reached 0.81 per thousands capita in 2020. In western region, due to areas with a high incidence of hidden hunger, such as Tibet, Xinjiang and Yunnan, which age-standardized DALY rate were decreasing, while other areas had a slight increase, the pattern of "two ends tends to the middle" between western provinces reduced the regional discrepancy. The provinces in the central and eastern regions had shown a trend of common growth, reducing their regional discrepancy.

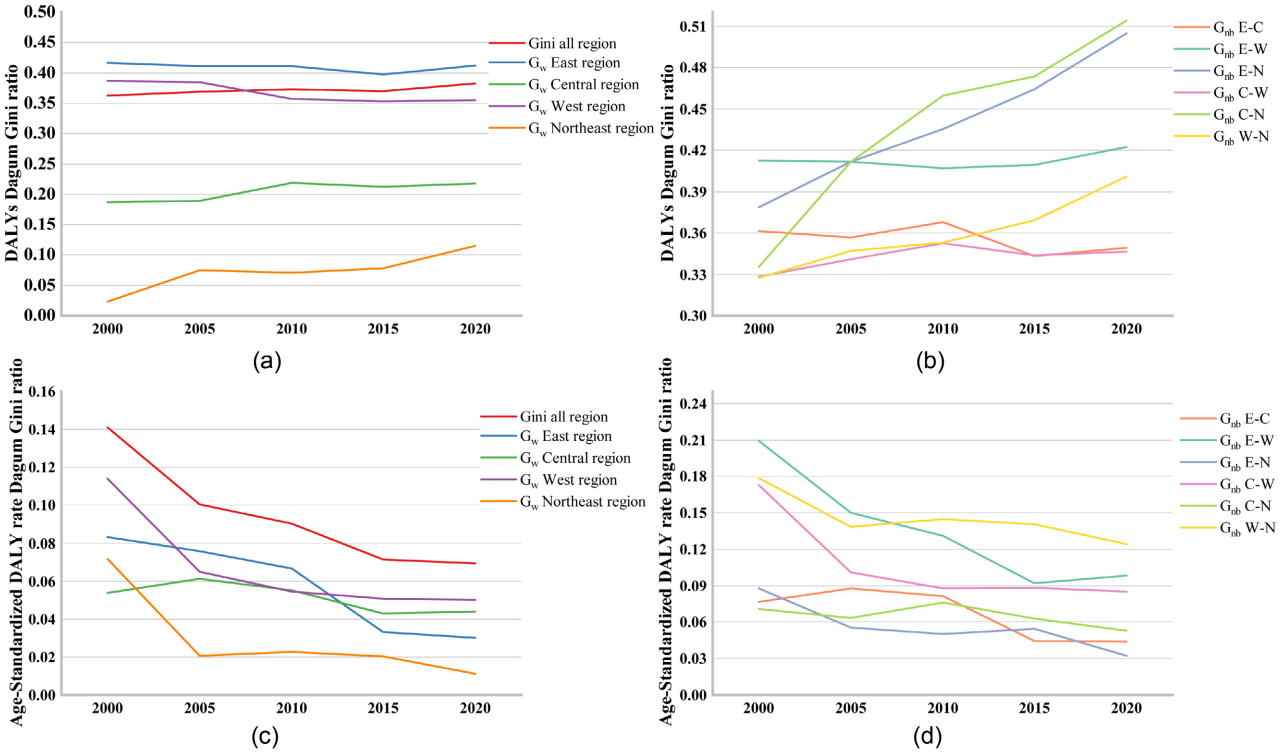


Figure 4. Dagum Gini ratio and its evolution of hidden hunger DALYs and age-standardized DALY rate. (a) The Gini ratio of the hidden hunger DALYs within four regions (G_w); (b) The Gini ratio of the hidden hunger DALYs between four regions (G_{nb}); (c) The Gini ratio of the hidden hunger age-standardized DALY rate within four regions (G_w); (d) The Gini ratio of the hidden hunger age-standardized DALY rate between four regions (G_{nb}). G_{nb} *E-C*, Gnb between east region and central region. G_{nb} *E-W*, G_{nb} between east region and west region. G_{nb} *E-N*, G_{nb} between east region and northeast region, G_{nb} *C-W*, Gnb between central region and west region. G_{nb} *C-N*, G_{nb} between central region and northeast region. G_{nb} *W-N*, G_{nb} between west region and northeast region.

The result of decomposition of differential contribution of hidden hunger in China. As shown in **Table 2**, the mean Dagum Gini ratio and relative contribution rate of regional discrepancy, interregional discrepancy and transvariation intensity of DALYs were 0.10% and 27.7%, 0.13% and 35.3%, 0.14% and 37.03%, respectively. The national discrepancy mainly derived from regional differences. Because the transvariation intensity is large, indicating that the cross-overlap of interregional samples had a great influence on the number of hidden hunger (Chen et al., 2020), which meant the population migration had a significant impact on the measurement of hidden hunger. And on the other hand, the incidence was also more affected by interregional discrepancy (**Table 3**). The average and contribution rates of regional differences, interregional differences and

transvariation intensity of age-standardized DALY rate were 0.0190% and 19.8%, 0.0662% and 70.2%, 0.0092% and 9.9%, respectively. Because the transvariation intensity was not large, meaning that the incidence of hidden hunger was mainly related to the local natural and social economy environment with regional characteristics.

Table 2. Decomposition of regional differential contribution of hidden hunger DALYs in China.

Year	Within regional disparity		Inter-regional disparity		Inter-regional transvariation intensity	
	G_w	Contribution	G_{nb}	Contribution	G_t	Contribution
2000	0.105	28.9%	0.099	27.4%	0.159	43.7%
2005	0.103	28.0%	0.115	31.2%	0.150	40.8%
2010	0.101	27.1%	0.141	37.7%	0.131	35.2%
2015	0.101	27.2%	0.147	39.6%	0.123	33.2%
2020	0.104	27.2%	0.155	40.5%	0.124	32.3%

Table 3. Decomposition of regional differential contribution of hidden hunger DALY rate in China.

Year	Within regional disparity		Inter-regional disparity		Inter-regional transvariation intensity	
	G_w	Contribution	G_{nb}	Contribution	G_t	Contribution
2000	0.031	21.7%	0.099	70.4%	0.011	7.9%
2005	0.020	20.4%	0.068	67.9%	0.012	11.7%
2010	0.018	19.6%	0.062	68.0%	0.011	12.4%
2015	0.013	18.8%	0.051	71.7%	0.007	9.6%
2020	0.013	18.7%	0.051	73.3%	0.006	8.0%

In Table 4 and Table 5, the diet quality had the largest impact on the hidden hunger of women of reproductive age and children in China, its mean contribution value and rate were 0.3 and 5.32, respectively. The followed driver is consumption structure, its mean contribution value is 0.18, rate is −3.96. Hidden hunger is less affected by urban-rural structure and benefiting level than diet quality and consumption. It is found that diet quality has an incremental driving effect on the incidence of hidden hunger in priority populations in China, and consumption structure, urban-rural structure and benefiting level have different degrees of reduction driving effect from 2000-2020 contribution values and rates. Over the past 20 years, the level of iron and zinc in Chinese food has not improved the hidden hunger level of priority population, especially in 2005-2010, and this situation was reversed in 2010-2015, but it still showed a weak positive effect overall. At the same time, we observe that the important role of consumption structure

in the improvement of hidden hunger became more prominent with time. Although urban-rural structures and benefiting level are relatively small, they also have a positive effect on improving the level of hidden hunger in China cannot be ignored.

Table 4. Contribution values of different drivers across time scales to the incidence of hidden hunger in priority populations in China.

Period	Diet quality $\Delta H'_d$	Consumption structure $\Delta H'_c$	Urban-rural structure $\Delta H'_u$	Benefiting level $\Delta H'_b$	Summation
2000-2005	0.20	−0.10	−0.06	−0.06	−0.02
2005-2010	1.01	−0.19	−0.06	−0.08	0.68
2010-2015	−0.21	−0.23	−0.01	0.06	−0.39
2015-2020	0.20	−0.20	−0.04	0.02	−0.02
Mean	0.30	−0.18	−0.04	−0.01	0.06
2000-2020	1.15	−0.68	−0.17	−0.06	0.25

Table 5. Contribution rates of different drivers across time to the incidence of hidden hunger in priority populations in China.

Period	Diet quality ρ_d	Consumption structure ρ_c	Urban-rural structure ρ_u	Benefiting level ρ_b	Summation
2000-2005	10.82	−5.40	−3.30	−3.12	−1
2005-2010	1.48	−0.28	−0.08	−0.12	1
2010-2015	−0.54	−0.58	−0.03	0.15	−1
2015-2020	9.53	−9.57	−1.86	0.90	−1
Mean	5.32	−3.96	−1.32	−0.55	−0.5
2000-2020	4.70	−2.77	−0.68	−0.25	1

4. Discussion

This study of iron-zinc deficiency hidden hunger of women of reproductive age and children in provinces of China revealed that the DALYs lost and DALY rate increased between 2000 to 2020, simultaneously, the hidden hunger in terms of DALYs inter-provincial disparity expanded slightly and the incidence of hidden hunger narrowed observably. By referring the calculation steps about the burden of chronic and hidden hunger of the Goedecke et al. (2018), we selected the DALYs data from the GBD2019 to compare with our results. We reasonably believed that the results of GBD may be more optimistic. Firstly, we were concerned with GBD in terms of population data and relative disease death data, which derived from credible official statistic. The second, the incidence and prevalence data of IDA and pneumonia we used were reliable as they come from authoritative and high cited researches. In GBD, the data they used might have been published

earlier, so results from Bayesian simulations with these data may be biased (Chen et al., 2022). Therefore, the problem of hidden hunger of women and children may still be serious in China and cannot be neglected. However, due to the lack of data on other micronutrient elements, only the most widely deficient iron and zinc were studied, this study highlights a need data for widely national survey of micronutrient deficiency in China.

For hidden hunger, on the one hand, local development determined the incidence, the other hand, the impact or population distribution and movement on the number of hidden hunger is significant. We analyzed that the reasons why eastern regions might be likely to become a hidden hunger highland have a certain relationship with its rapid urbanization accompanied by population migration. According to the census data from 2000 to 2020 and two 1% population sample surveys, the proportions of interprovincial labor migration were 76%, 79%, and 75% in the years 2000, 2005, and 2010, respectively. However, this proportion dropped to 52% in 2015 and further declined to 33% in 2020. Population movement from rural areas to urban areas has made urban areas a high ground for hidden hunger (Van de Poel et al., 2007). The proportion of DALYs lost and DALY rate in urban was higher over time. Urbanization doesn't always bring benefits to vulnerable groups, the incidence of poverty of rural-urban floating population is higher. Urbanization involves population migration, and a large number of migrants to cities have fallen into a situation where they are both separated from the rural services system, because the equalization of social and public services such as the household registration system has not yet been achieved. Women and children who follow the migration are greatly affected physically and mentally for various reasons, and become a high incidence group of hidden hunger in urban areas. In a considerable number of countries, the urban poor actually have higher rates of stunting and mortality than their rural counterparts (Van de Poel et al., 2007). The urban-rural gap is narrowing in a surprising way in China. On the one hand, urban populations is suffering from malnutrition among vulnerable populations and on the other enduring widespread obesity problems (Gao et al., 2020; Zonta et al., 2014).

With the acceleration of urbanization, China will have more large and even super, a large number of people will be concentrated in a few regions and cities. But the widening income gap, class solidification and social division with cities are bringing many challenges to the harmonious development of cities. However, the low position of the social structure network (Desmond & Gershenson, 2017), the lack of social capital caused by low social class and single solidification (Guzman et al., 2017), and the limited access to basic urban rights (Yao, 2020) are more critical factors. For example, the accessibility to fresh foods and diet diversity is unequal for people of different economic classes in a city (Wang & Li, 2022). Social inequality in the accessibility to supermarkets and to fruit stores is much greater than that of accessibility to vegetable markets and accessibility to nutritional, diverse and healthy food for children gets worse amid rapid urbanization at both

community and subdistrict levels (Hu et al., 2020). Low diet diversity and equality was associated with a high prevalence of micronutrient deficiency and vulnerable groups with low availability of healthy diets are more likely to suffer from hidden hunger (Lowe, 2021). Although the economic development brought about by urbanization have benefited vulnerable groups in terms of medical conditions and convenient transportation and so on, the direct impact of unfair nutritional intake on hidden hunger is more significant.

However, with the improvement of the household registration system and the maturation of China's urbanization policies, the possibility of settling down and establishing a career in large cities for interprovincial migrant workers has been realized, which ensures factors affecting hidden hunger, such as diet, health, and housing, are safeguarded (Harding et al., 2018). Chinese government tried to alleviate the severity of micronutrition deficiency and malnutrition for past decades. Such as the implementation of nutrition supplementation plans. Since 2011, in order to improve health status of rural students, Chinese government began to implement a nutrition improvement program for students in rural compulsory education. By 2020, 1762 counties in 29 provinces in China have implemented the nutrition improvement program, accounting for 84.12% of the total number of rural compulsory education schools and benefiting more than 40 million students. Especially, the marginal effect of the implementation of the program is more significant for children in western regions and children left behind and promote students' height and reduce the probability of growth retardation and excessive thinness (Liang et al., 2022). The reduction in the incidence and disparities of hidden hunger in western region is strongly related to the implementation of this policy. However, in some provinces, due to deviations in policy implementation and low awareness of the policy, the implementation effect of the nutrition improvement plan is limited, and the actual effect of nutritious meals is not obvious. This may be related to the hidden hunger in western region where is no widespread reduction in DALY rate (Zhao, 2015). Specific nutrition programs won't drive much impact probably in future. On a population level, nutrition supplementation to address hidden hunger is not practical because it is expensive and cannot solve the longer-term problem of a nutrient-poor diet (Lowe, 2021). A more sustainable and abroad approach to improving the nutrition of the population should be implemented, in terms of agricultural production, consumption structure, and dietary environment (Harding et al., 2018). Among them, the role of consumption structure in this study has emerged and many investigates has also been reported the contribution to nutritional improvement by changes in food consumption patterns in rural or urban areas.

5. Conclusion

This study uses Disability Age Life Years framework to measure iron and zinc deficiency of reproductive-aged women and children from 2000 to 2020 at provincial-level. The results provide a novel contribution to the hidden hunger in

China. Specifically, it contributes to understanding that the situation of hidden hunger in China is worse than estimated, and the discrepancy among regions still consists of the main discrepancy in the country. Special nutrition improvement programs may have limited impact and economic macro policies aimed at improving nutrition are likely to be a more effective for vulnerable population, even all groups. In all, the analysis results support managers or researches in their efforts to mitigate the negative health effects of hidden hunger.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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