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Study of the Spatial Pattern of Malnutrition (Stunting, Wasting and Overweight) in Countries in the World Using Geographic Information System

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Abstract

Background: Malnutrition is a great challenge for the public health system. Therefore, this study aimed to study the spatial pattern malnutrition using GIS in the world's countries.

Materials and Methods: In this cross-sectional study, secondary child malnutrition data analysis was conducted using World Health Organization data from 2005 to 2016. The data were analyzed by Arc/GIS 10.6 software. The prevalence rates of malnutrition were exported into Arc/GIS10.6 to visualize key estimations, and the excess risk of malnutrition of each country was calculated. In this regard, the spatial patterns of variables of the prevalence of stunting in children under 5 (%), prevalence of wasting in children under 5 (%), and prevalence of overweight in children under 5 (%) were evaluated by GIS.

Results: Our findings showed that the prevalence of stunting, wasting and overweight in children under 5 was not accidental and has emerged in the cluster form based on a regular occurrence in countries around the world. Furthermore, the results of our research indicated that the mean center and standard deviation of stunting and wasting included most of the African and Asian countries especially in the Middle East, but the mean center and standard deviation of overweight included more areas of the world. Overweight has included many parts of the world and its spatial distribution is more than stunting and wasting. Overweight was observed the African, Asian and European countries.

Conclusion:
The spatial pattern of malnutrition was clustered in the world. The results of this study could be the starting point for the development of appropriate malnutrition interventions and policies globally.

Key Words: Children, Geographic Information System, Spatial analysis, Malnutrition, World.

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1- INTRODUCTION

Each country in the world suffers from one or more forms of malnutrition. Fighting malnutrition in all its forms is one of the biggest global health challenges. Malnutrition is globally the main risk factor of sickness and death (1, 2). The medical, social, economic, and developmental effects of the global malnutrition burden are lasting and serious for individuals and their families, communities and countries. It is due to a complex and dynamic interaction between the environmental, economic, social, political, and other factors (3). In the year 2018, 1.9 billion adults were obese or overweight, while 462 million were underweight; 52 million children under 5 were wasted, 17 million were severely wasted and 155 million were stunted, while 41 million were obese or overweight. Approximately 45% of mortality among under 5 children have been related to under-nutrition. These usually take place in the low- and middle-income countries. At the same time, in these countries, the rates of childhood obesity and overweight were rising. Furthermore, malnutrition is one of the most acute health problems and the regional disease burden associated with the poor nutrition is growing (4-6).

The results of studies have shown that malnutrition is a great challenge for the public health system and is related to a significant increase in the risk of morbidity and mortality. It is due to a dynamic and complex interaction between the different factors, such as the environmental, political, socio-economic, health variables. In the developing countries, the prevalence of malnutrition in the form of under-nutrition is still high (7). Malnutrition, in all its forms, involves under-nutrition (wasting, stunting, overweight), inadequate minerals or vitamins, obesity, overweight and non-communicable diseases related to diet (4). The results of studies have shown that poverty amplifies the risk of and risks from malnutrition. The poor are more likely to be affected by the different forms of malnutrition. Furthermore, malnutrition increases the costs of healthcare, decreases productivity and slows the economic growth, which can perpetuate a cycle of poverty and illness (2, 8, 9). However, studies have shown that the increasing interest on the spatial-oriented research has been established in the health sciences (3, 10, 11). To this end, the geospatial analytical methods, including Geographic Information Systems (GIS) could be used, which allow spatiotemporally understanding the geographical patterns and identifying and analyzing the factors related to the health behaviors and the resulting outcomes (12). In this regard, as the spatial-oriented research has been established in the health sciences, the developments of GIS provide the useful tools to achieve an improved understanding of malnutrition (3). GIS is beneficial in identifying the most vulnerable parts of society in terms of malnutrition and living in poverty (3, 13).

Since malnutrition is a complex phenomenon, the combination and joint temporal and spatial analysis of the various data sources provide a new potential to achieve a better understanding (3). On the other hand, the results of studies have shown that a significant number of people live with food insecurity (7, 14, 15). This situation has caused human suffering, increased rates of disease and deaths, reduced labor productivity and even the backwardness of nations (8). Moreover, malnutrition has had a negative impact on the population's health in the short and long term (15). Malnutrition is well recognized as a widespread health problem with consequences that are both acute and, even more often, long-term. Both acute and underlying effects contribute to mortality, either directly or indirectly (through weakened defenses against other diseases such as malaria, respiratory, or diarrheal diseases). However, the long-term effects, especially from nutritional deficits early in life, on children who don't die, but have their development impaired, may exceed even the troubling mortality (16). The world is experiencing the unprecedented demographic and nutritional changes, with a related change in the burden of disease. While the problem of under-nutrition continues, diet-related chronic diseases caused by obesity and overweight are increasing. This nutritional transition has led to a double disease burden that has a negative impact on the world's health systems (16-18). On the other hand, the results of studies have indicated that the use of GIS and the spatial analysis methods are the useful tools for the better understanding of the spatial dimensions of malnutrition (3).

In this regard, according to our studies, most studies have examined the status of malnutrition at the local and regional level (3, 17, 19, 20). According to our search, no similar study was found on the spatial distribution of malnutrition worldwide using the indices of spatial statistics. Therefore, our study was the first attempt in this field to examine the global dimensions of malnutrition using the global spatial statistics. Hence, this study was conducted with the aim of examining the spatial pattern of malnutrition in countries around the world.

2- MATERIALS AND METHODS

2-1. Study Design and Population

In this cross-sectional study, secondary child malnutrition data analysis was conducted using World Health Organization (WHO) data from 2005 to 2016 (https://www.who.int/gho/publications/world_health_statistics/2017/whs2017_AnnexB.xlsx?ua=1). It should be noted that, the WHO's malnutrition data was published up to 2016. Data analysis was carried out using Arc/GIS version 10.6. The spatial patterns of variables of prevalence of stunting in children under 5 (%), prevalence of wasting in children under 5 (%) and prevalence of overweight in children under 5 (%) worldwide were evaluated by Arc/GIS software.

2-2. Determination of the spatial patterns

Due to inability to realize the types of patterns of the following data sets, the spatial autocorrelation coefficients are generally proper for studying the spatial patterns of data sets (21, 22). In the present research, the spatial patterns of the world were evaluated by Moran's I and Getis-Ord Gi* statistic. Moran's I compares the variable values at a single location with those at other locations (18, 22, 23). It is calculated as follows:

Equation 1 $$I = \frac{N \sum_i \sum_j W_{i.j} (X_i - \bar{X})(X_j - \bar{X})}{(\sum_i \sum_j W_{i.j}) \sum_i (X_i - \bar{X})(X_j - \bar{X})^2}$$

Where, N is the number of cases, X_i is the variable value at a certain location, X_j is the variable value at another location, X is the average variable, and W_{ij} is the weight used for the comparisons made between locations i and j. W_{ij} is a weighted matrix based on distance, and also is the reversed distance between locations i and j (11, 12, 23). The statistical equation for calculating Gi* is as follows:

Equation 2 $$G_i^*(d) = \frac{\sum_j W_{ij}(d) X_j - W^*_i \bar{X}^*}{S^* \{[(nS^*1i) - W_i^{*2}]/(n-1)\}^{1/2}}$$

Where, W_{ij} (d) is a spatial weight vector with values for all j cells within the distance of d from cell i; W*i is the total sum of the weights; S*1i is the square sum of the weights; S* is the standard deviation of data in the cells; and n is the number of cases (11, 12, 23). To identify the spatial deployment patterns, the following models were used:

A) Mean center: It is the mean latitude and longitude coordinates of all features within the study scope, and its calculation is proper for tracking both the changes that happened in the spatial distribution of features and their comparisons and is calculated as follows (11, 12, 23).

Equation 3 $$X = \sum_{i=1}^{N} \frac{Xi}{N} \quad Y = \sum_{i=1}^{N} \frac{Yi}{N}$$

Where, X_i and Y_i are the coordinates of the feature i, and N equals the total number of features and attributes.

B) Standard distance: It is a method for examining the level of concentration or dispersion of the geographic features around the mean center, which is calculated as follows (11, 12, 23):

Equation 4 $$SD = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n} + \frac{\sum(y_i - \bar{y})^2}{n}}$$

2-3. Geographically weighted regression (GWR)

GWR is one of several spatial regression techniques, which is increasingly used in geography and other disciplines. GWR provides a local model of the variable or process that one is trying to understand/predict by fitting a regression equation to every feature in the dataset. In this research, GWR was used to investigate the effect of income on nutrition (wasting, stunting, and overweight) (21, 24).

The formula for the geographically weighted regression model is as follows:

Equation 5 $$yi = \beta 0(ui, vi) + \sum \beta o(ui, vi) Xik + i€ \quad i = 1,2,...n$$

In this equation, (u_i, v_i) forms the coordinates of the ith point in space. β (u_i, v_i) is a continuous function of β, K (V, U) in each point of I. X_{i1}, ..., X_{ip}, the explanatory variables at point i and i€, are an error. For the given dataset of the regional parameters, βK (V, U) is estimated by the weighted least-squares process. The W_{ij} weights for i = 1, 2 ..., n at any position (v_i, u_i) are obtained as a continuous function of the intervals between points i and other data points (24).

2-4. Country income groups (World Bank Classification)

The World Bank Classification was used for country income groups. Economies were divided among the income groups according to the 2015 gross national income (GNI) per capita, which is calculated by the World Bank Atlas method.

The number of countries in each group:

- Low income - 31 countries
- Lower middle income- 51 countries
- Upper middle income- 53 countries
- High income: non-OECD-48 countries and
- High income: OECD- 32 countries.

For the current 2016 fiscal year, the low income economies are defined as those with a GNI per capita of $1,045 or less in 2014, which is calculated by the World Bank Atlas method. The middle income economies are those with a GNI per capita of more than $1,045, but less than $12,736. The high income economies are those with a GNI per capita of $12,736 or more. The lower middle income and upper middle income economies are separated with a GNI per capita of $4,125 (25). It should be noted that, Iran is an upper middle income country.

3- RESULTS

In this study, data were analyzed from 2005 to 2016 worldwide. In this regard, the findings showed that the prevalence of stunting in children under 5 and prevalence of wasting in children under 5 in countries characterized by red and orange colors were mostly found in African and Asian (especially the Middle East) countries, more than other areas, but the prevalence of overweight in children under 5 had a different pattern (**Figure 1**).

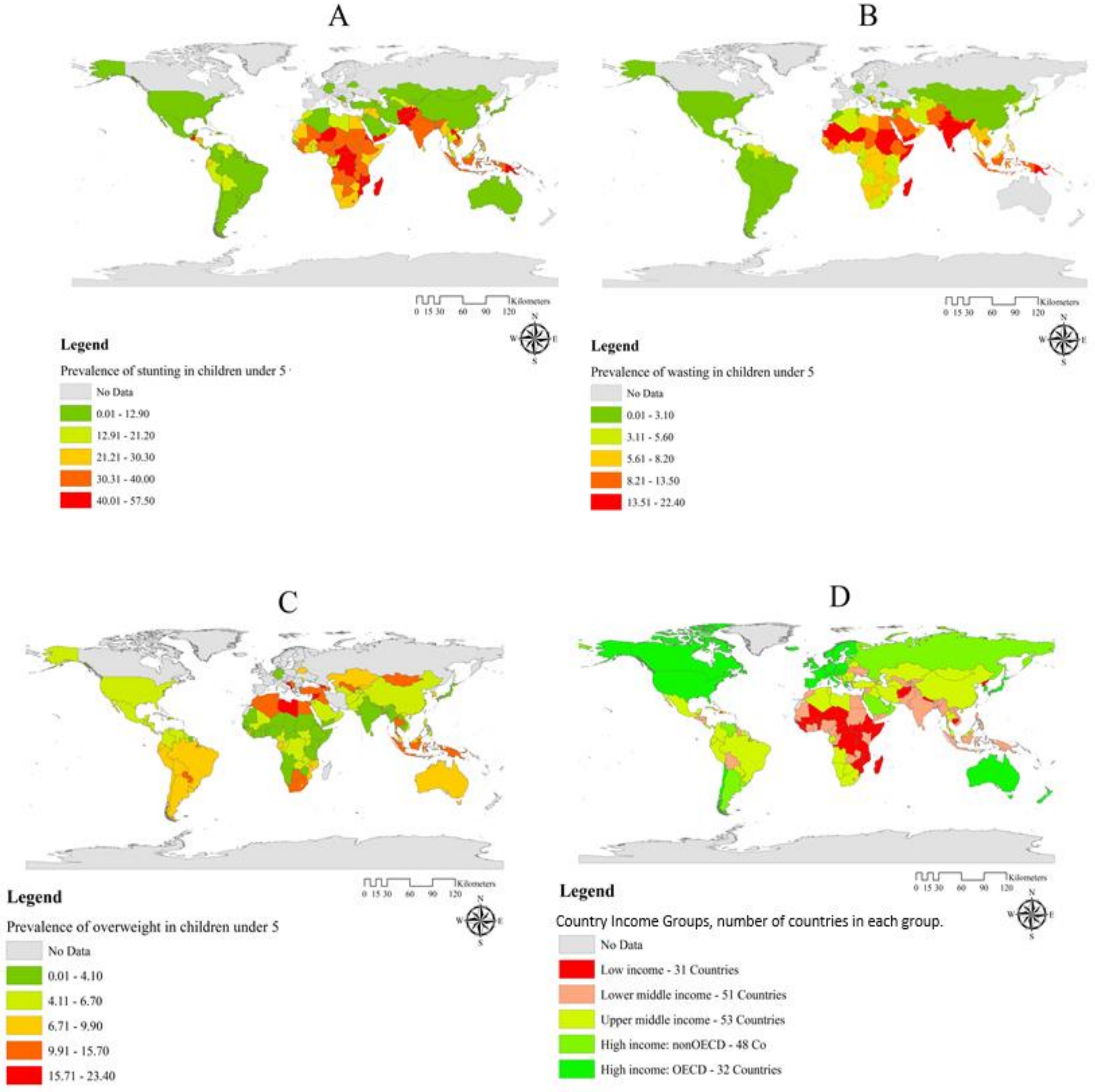


Fig.1: Prevalence of malnutrition in children under 5 (%) in the World, 2005 to 2016.

3-1. Spatial distribution of malnutrition

3-1-1. Prevalence of stunting in children

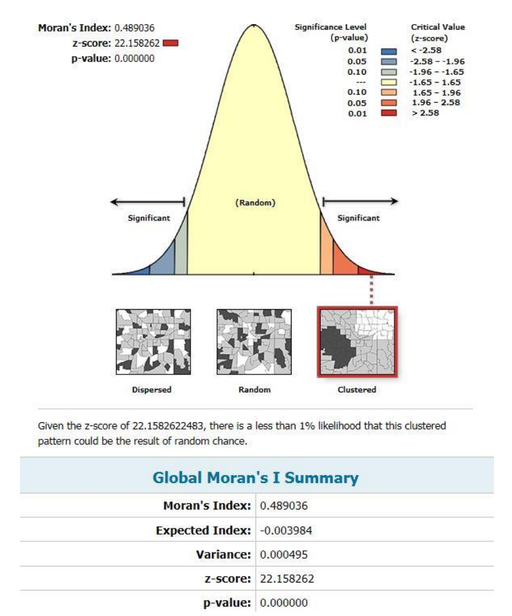
The calculated values for the prevalence of stunting in children under 5 in countries in the World for Moran's I showed the positive spatial autocorrelation. The value of Z-score = 22.15 at a confidence level of 0.01 was less than 2.58 (**Figure 2-A1**). Therefore, Moran's I was not a coincidence, but was based on a regular occurrence in countries in the world. The Getis-Ord General G was equal to 0.01, indicating the positive spatial autocorrelation. The Z-score value = 3.98 at a confidence level of 0.01 was less than 2.58. Therefore, the G ratio indicated the cluster prevalence of stunting in children under five at high concentration points (**Figure 2-A2**).

3-1-2. Prevalence of wasting in children

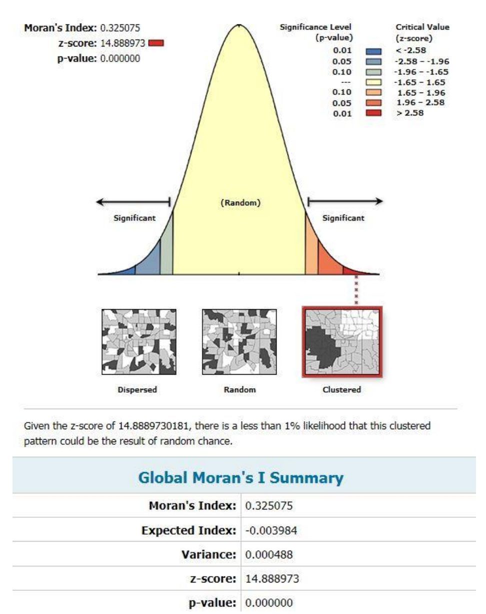
The calculated values for the prevalence of wasting in children under 5 for Moran's I was equal to 0.32, the value of Z-score = 14.88 at a confidence level of 0.01 was less than 2.58 and statistically significant (**Figure 2-B1**). According to the results of Moran's I, the prevalence of wasting in children under 5 in countries in the world was in the clustered form. Moreover, the results of the Getis-Ord General G test for the prevalence of wasting in children under 5 showed that Z-score = 3.29 at a confidence level of 0.01 was less than 2.58 and statistically significant. Thus, the calculated G ratio was as the high-concentration cluster and was not a result of random variations (**Figure 2-B2**).

3-1-3. Prevalence of overweight in children

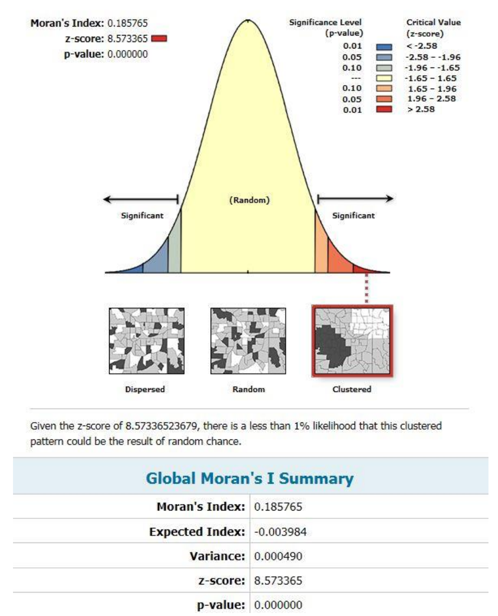
The calculated values for the prevalence of overweight in children under 5 in countries in the world for Moran's I showed the positive spatial autocorrelation. The value of Z-score = 8.57 at a confidence level of 0.01 was less than 2.58 (**Figure 2-C1**). Therefore, Moran's I was not a coincidence, but was based on a regular occurrence in the world's countries. The Getis-Ord General G ratio also showed the positive spatial autocorrelation. The value of Z-score = 2.89 at a confidence level of 0.01 was less than 2.58. Therefore, the G ratio indicated the cluster prevalence of overweight in children under 5 with high concentration points (**Figure 2-C2**).



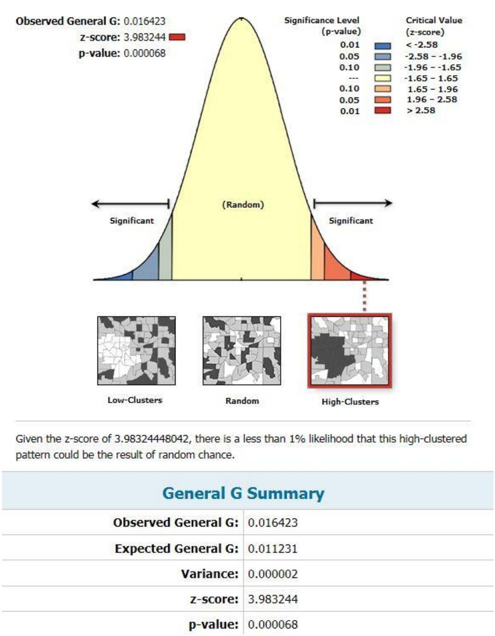
A1. Classification of the prevalence of stunting in children under 5 worldwide based on Moran's I



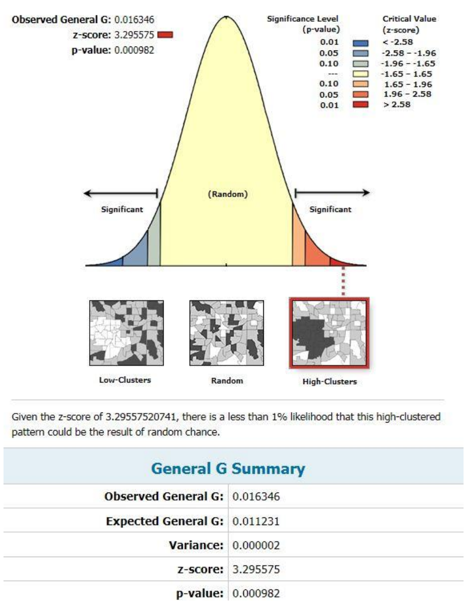
B1. Classification of the prevalence of wasting in children under 5 worldwide based on Moran's I



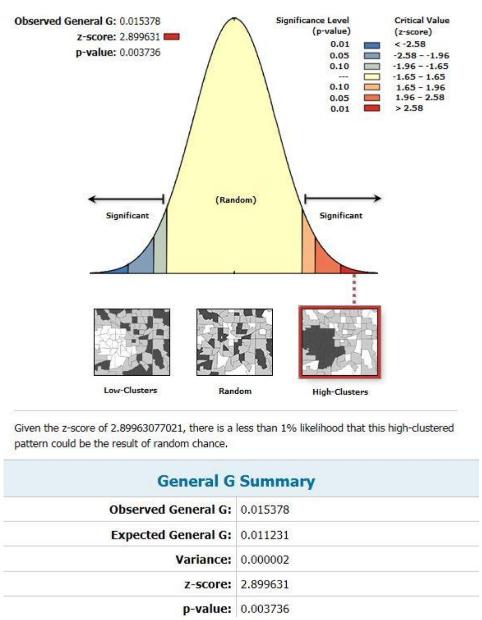
C1. Classification of the prevalence of overweight in children under 5 worldwide based on Moran's I



A2. Classification of the prevalence of stunting in children under 5 worldwide based on the Getis-Ord General G ratio



B2. Classification of the prevalence of wasting in children under 5 worldwide based on the Getis-Ord General G ratio



C2. Classification of the prevalence of overweight in children under 5 worldwide based on the Getis-Ord General G ratio

Fig.2: Predictable values, variance and Z-score based on malnutrition variables in the world, 2005 to 2016.

3-2. Mean center and standard distance

In **Figure.3**, the mean center for the prevalence of stunting in children under 5, prevalence of wasting in children under 5 and prevalence of overweight in children under 5 has been calculated. The results showed that the mean center of the prevalence of stunting in children under 5 was in Ethiopia, and the standard distance covered most African and Middle East Asian countries. The mean center of the prevalence of wasting in children under 5 was also in Yemen, and the standard distance was found mostly in the Middle East and African countries. Moreover, the mean center of the prevalence of overweight in children under 5 was in Chad, which, in addition to the African and Asian countries, also covered a wider range.

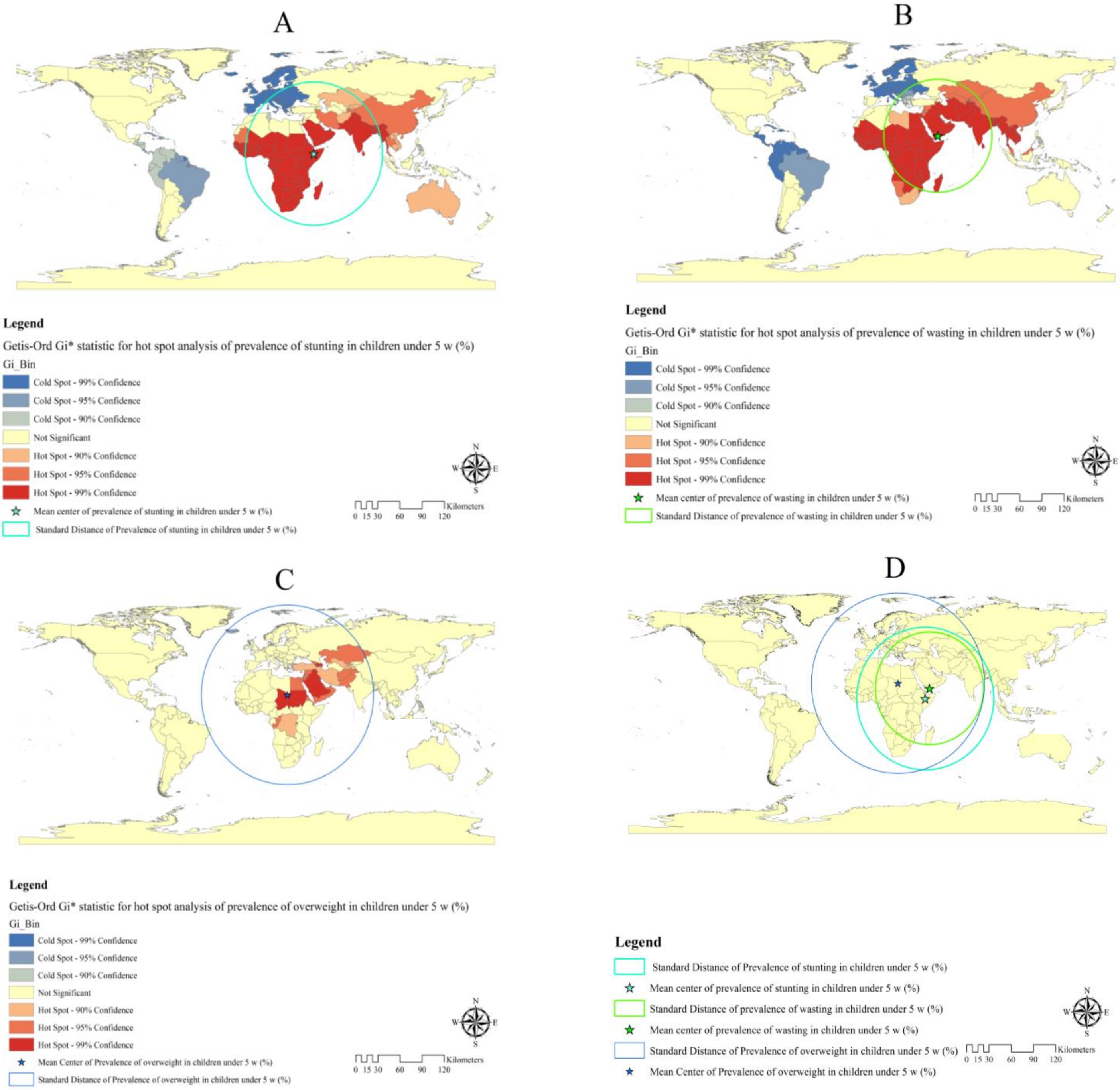


Fig.3: Spatial dimension of malnutrition analyses in the world, 2005 to 2016.

3-3. Geographically weighted regression (GWR)

The findings from the GWR model for assessing the impact of the income of countries on malnutrition (wasting, stunting, and overweight) showed that income affected stunting (49.72%), wasting (39.67%), and overweight (21.34%). The highest value of R^2 was for the prevalence of stunting in children under 5 (**Figure.4**). **Figure.4** shows the effect of the income index on malnutrition (wasting, stunting, overweight). The findings showed that the impact of income was different in various countries. Regression coefficients suggested that rising income levels in countries shown in red and orange can help eliminate the problems caused by malnutrition, but in countries with a negative regression coefficient, rising income would not have an effect on malnutrition. The results showed that malnutrition in the African and Middle Eastern countries was more influenced by the income situation of the countries.

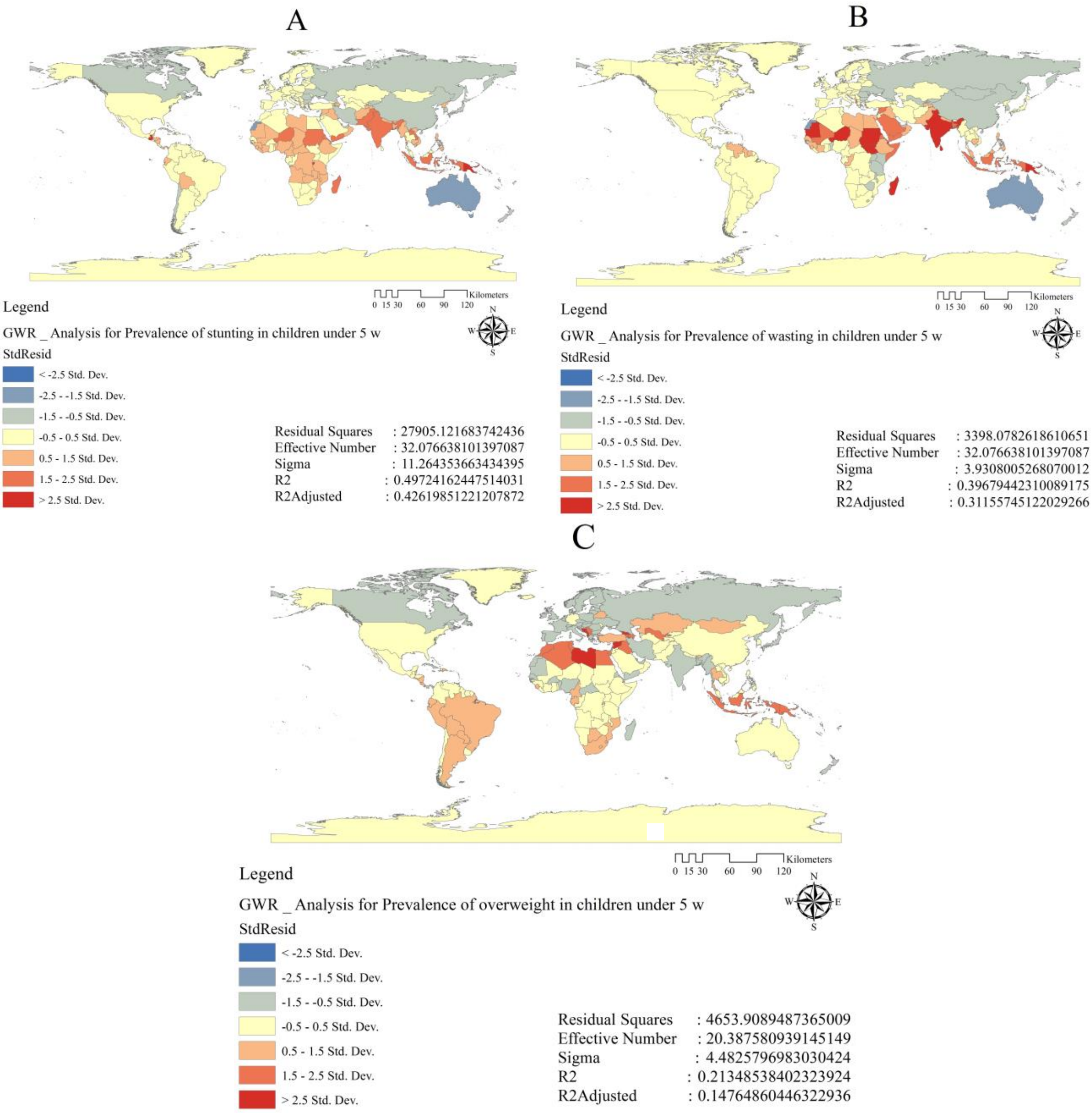


Fig.4: Spatial distribution of GWR in the world, 2005 to 2016.

4- DISCUSSION

Nutrition has the profound effects on health throughout the human life course and is inextricably linked with the cognitive and social development, especially in early childhood (9). Therefore, this research aimed to study the spatial pattern of malnutrition using GIS in countries in the world. In this regard, we reported an analysis of malnutrition clustering (wasting, stunting, and overweight) of under 5 children. We also identified the locations of the clusters in the world. Our findings showed that the prevalence of wasting in children under 5 and prevalence of stunting in children under 5 were clustered in countries in the world (Figure 2, A-B). The results of studies by Hasan et al. (2018) in Bangladesh (26), and Gebreyesus et al. (2016) in Ethiopia (27) were also in line with those of our study. Their study results indicated that children identified in a cluster were at risk (stunted and wasted children) more than four times the ones outside the cluster (27), but the results of studies by Varghese et al. (2019) in India showed that there was no evidence of cluster formation (28).

In this regard, the findings of other studies have shown that child illnesses, food diversification and food security have not been effective in the cluster formations of stunted and wasted children but the geographic location has affected this area (27). Cluster formation, as shown in the results of other studies, was probably influenced by climatic conditions (29). Aoun et al. (2015) also considered geographical access to healthcare to be effective (19). The results of our study showed that the prevalence of overweight in children under 5 was not accidental and has been occurred in the cluster form based on a regular occurrence in countries around the world (Figure 2-C). The results of studies by Turi et al. (2013) in Uganda (30), and Torres-Roman et al. (2018) in Peru were similar to ours (31), but the results of studies by Varghese et al. (2019) in India showed that there was no evidence of an overweight cluster (28). Other studies have suggested that the increasing global prevalence of overweight in early childhood results from changes in both patterns of nutrition and physical activity (32). The prevention of overweight in children is very important; for example, overweight at this age can significantly increase the risk of adult obesity (33), and obesity-related diseases such as high blood pressure, diabetes and some types of cancers (9). The results of our study showed that the mean center and standard deviation of stunting and wasting is greater in the African and Asian countries (Figure.3).

This situation is likely to be affected by lifestyle, cultural beliefs and access to health care (19) in these countries. Chronic and prolonged food poverty will lead to stunting, as well as complications such as mental retardation and acute food poverty will lead to wasting (34). This situation can have many problems for the inhabitants of these areas of the world, which is a threat to the future of these societies. On the other hand, as children in all countries, especially in the backward and developing countries are considered as a vulnerable stratum, maintaining their promotion and providing their health is a global priority.

Therefore, it is imperative that global and local policymakers give priority to reducing and eliminating the problems of these areas of the world. The mean center and standard deviation of overweight included more areas of the world, which was a far more significant threat than stunting and wasting (Figure.3). Other studies have shown that economic development, industrialization, and rapid urbanization in the developing countries have led to the adoption of the unhealthy physical, dietary, and lifestyle behaviors, which have, in turn, increased the prevalence of obesity in children (31, 32, 35). This situation can be a serious threat to the world's people in the future, leading to the outbreak of diseases such as diabetes, high blood pressure and high cholesterol, and in childhood, it can cause depression and low self-confidence (33). The findings of this study indicated that malnutrition in the African and Middle East countries was more affected by the income status of countries (Figure.4).

Similar results have been observed in other studies (7, 9, 17). Given the differences between the different regions of countries in the world, which is somehow due to differences in the level of development of these regions (25, 31, 36, 37), the necessity of designing and implementing targeted solutions for different regions is necessary from the global organizations. On the other hand, given that the factors affecting malnutrition in children are known (1, 2, 14, 16, 29, 33), in addition to reducing malnutrition, measurements should be taken to improve the health, social and economic indicators in the African and Middle Eastern countries, by designing and implementing interventions in the field of factors such as household income, improving access to food, promoting nutrition literacy, access to health services and disease control.

4-1. Study Limitations

In this study, our data were cross-sectional and we were unable to review malnutrition changes periodically and annually. We were also unable to investigate potential risk factors, such as parental work or health literacy, due to lack of access to the data. In addition, we failed to assess the prevalence of malnutrition based on gender and religion. Besides, we were unable to analyze data of malnutrition for 2017 to 2019, because the data have not been made available in the WHO website.

5- CONCLUSION

GIS was used for the spatial clustering of malnutrition worldwide. Cluster analysis can identify the vulnerable areas in the world. The vulnerable areas (stunting and wasting) were found mostly in the African and Asian countries, especially in the Middle East, while overweight included more areas of the world, a threat that is far more important than stunting and wasting. The results of this study could be the starting point for the development of appropriate malnutrition interventions and policies in the world, because it showed the spatial differences and spatial pattern of malnutrition in the world.

6- CONFLICT OF INTEREST: None.

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