

Trend Analysis and Prediction of Protein-Energy Malnutrition Incidence in China, 1990-2019: A Postprint

Authors: Wang Hongxin, Fan Wenlong, Yang Xiaoyu, Chen Dongyu, Huang Qiao, Pan Suyue, Wang Pu, Hu Min, He Yuqing

Date: 2022-08-01T00:00:00+00:00

Abstract

Background Protein-energy malnutrition (PEM) is one of the common nutritional deficiency diseases. With changes in lifestyle and dietary habits, there has been increasing attention to nutritional health issues, and this disease can have varying degrees of impact on the health of different age groups. In recent years, the incidence trend, the incidence status across different ages, and related predictions require analysis and investigation. Objective To analyze the incidence and changing trends of PEM in China from 1990 to 2019, understand the incidence status of PEM across different ages, and predict future trends until 2029, providing evidence for PEM prevention. Methods Based on data from the Global Burden of Disease 2019 (GBD 2019) study, log-linear models were fitted to the age-specific incidence rates and age-standardized incidence rates of PEM from 1990 to 2019 using Joinpoint software to analyze their changing trends. Annual percentage change (APC) and average annual percentage change (AAPC) with 95% confidence intervals (CI) were used to describe the trends of each indicator. The ARIMA model was used to predict the incidence trend of PEM in China from 2020 to 2029. Results In 2019, the age-standardized incidence rate of PEM in the entire Chinese population was 1996.5/100,000, higher in males than in females. The incidence rate of PEM was highest in the under-5 age group (4402.5/100,000), followed by the 80-84 age group. After age 5, the incidence rate increased with age in both males and females. The results of China's PEM age-standardized incidence rate demonstrated: the age-standardized incidence rate of PEM in China showed a decreasing trend during 1990-1995 and 2010-2014. The results of China's PEM age-specific incidence rate demonstrated: from 1990 to 2019, the under-5 age group decreased at an average annual rate of change of 2.1%, while the average annual change in other age groups demonstrated an overall stable increasing trend. The prediction results from the ARIMA model demonstrated that by 2029, the incidence rate of

PEM in China will reach 7280.06/100,000. Conclusion Since 1990, the incidence rate of PEM in China has demonstrated a steadily increasing trend. Moreover, the incidence rate in mainland China will continue to rise until 2029. This study will provide references for policy formulation and evidence for PEM prevention.

Full Text

Preamble

Trend Analysis and Forecast of Protein-Energy Malnutrition Incidence in China from 1990-2019

WANG Hongxin¹, FAN Wenlong¹, YANG Xiaoyu¹, CHEN Dongyu¹, HUANG Qiao¹, PAN Suyue¹, WANG Pu¹, HU Min¹, HE Yuqing^{1, 2*}

¹Department of Epidemiology and Medical Statistics, Institute of Medical Systems Biology, Guangdong Medical University, Dongguan, Guangdong 523808, China;

²Dermatological Department, Liaobu Hospital, Dongguan, Guangdong 523400, China

Corresponding author: HE Yuqing, Researcher, Doctoral supervisor; Email: dr.hyq@hotmail.com

Abstract

Background: Protein-energy malnutrition (PEM) is one of the common nutritional deficiencies. With changes in lifestyle and dietary habits, people are increasingly concerned about nutritional health issues, and this disease can affect the health of different age groups to varying degrees. Recent trends in morbidity, age-specific morbidity status, and related predictions require analysis and study.

Objective: By analyzing the incidence and changing trends of PEM in China from 1990 to 2019, we aimed to understand the age-specific incidence of PEM and predict future trends until 2029, providing a basis for PEM prevention.

Methods: Based on data from the Global Burden of Disease 2019 (GBD 2019) study, we used Joinpoint software to fit log-linear models to PEM incidence rates by age group and age-standardized incidence rates from 1990 to 2019, analyzing their changing trends. Annual percentage change (APC) and average annual percentage change (AAPC) with 95% confidence intervals (CI) were used to describe trends for each indicator. The ARIMA model was used to predict PEM incidence trends in China from 2020 to 2029.

Results: In 2019, the age-standardized incidence rate of PEM in China's total population was 1996.5/100,000, higher in males than females. The incidence was highest in children under 5 years (4402.5/100,000), followed by the 80-84 age group. After age 5, incidence increased with age in both sexes. The

age-standardized incidence showed declining trends during 1990-1995 and 2010-2014. Age-specific incidence rates showed that the under-5 group declined at an average annual rate of 2.1% from 1990-2019, while other age groups showed overall stable upward trends. ARIMA model predictions indicated that China's PEM incidence rate will reach 7280.06/100,000 by 2029.

Conclusion: Since 1990, PEM incidence in China has shown a steady upward trend and will continue to rise through 2029. This study provides a reference for policy development and a basis for PEM prevention.

Keywords: Protein-energy malnutrition; Morbidity; Trends; Joinpoint regression model; ARIMA model

Introduction

The World Health Organization defines malnutrition as “the cellular imbalance between the supply of nutrients and energy and the body's demand for them to maintain growth, and specific functions.” Malnutrition adversely affects developing countries and represents a global risk factor for disease and mortality. Protein-energy malnutrition (PEM) is one of the common nutritional deficiencies, typically affecting infants aged 1-5 years. Due to poor brain and neurological development, these effects can persist into adulthood. Chronic insufficient energy and nutrient supply further increases infection risk and can lead to death. PEM patients face higher risks of hypoglycemia, hypothermia, severe infection, and electrolyte disturbances. PEM can also cause prematurity, infectious diseases, and parasitic diseases. Anthropometric indicators such as height, weight, skinfold thickness, and arm circumference are considered important markers for PEM. This study utilizes Global Burden of Disease 2019 (GBD) data to analyze the current status of PEM in China in 2019, estimate incidence trends from 1990-2019, and predict future trends through 2029. This research will provide references for policy formulation and a basis for PEM prevention.

1. Materials and Methods

1.1 Data Sources

Data for this study were obtained from the Global Burden of Disease 2019 (GBD 2019) study, which provides data from 1990 to 2019 for 204 countries and territories on years lived with disability (YLD), years of life lost (YLL), and disability-adjusted life years (DALY) for 369 diseases and injuries, and 87 risk factors and combinations thereof. All rates are age-standardized using the world standard population. From this database, we extracted PEM incidence and mortality indicators for different age groups in China from 1990 to 2019.

1.2 Disease Definition and Coding

Protein-energy malnutrition (PEM) includes moderate and severe acute malnutrition, commonly referred to as “wasting,” and is defined by weight-for-height

Z-score (WHZ) based on the WHO 2006 Child Growth Standards. The burden of non-fatal PEM is quantified into four mutually exclusive and collectively exhaustive categories reflecting different severity levels: moderate wasting without edema (WHZ $<-2SD$ to $-3SD$), moderate wasting with edema (WHZ $<-2SD$ to $-3SD$), severe wasting without edema (WHZ $<-3SD$), and severe wasting with edema (WHZ $<-3SD$). The sum of categories including edema is generally termed kwashiorkor, while severe wasting is equivalent to marasmus. ICD-10 codes for PEM are E40-E46.9, E64.0, and ICD-9 codes are 260-263.9. Incidence data were divided into 18 age groups (<5 years, 5-9 years, and so on up to 80-84 years and 85+ years).

1.3.1 Joinpoint Regression Model

Using Joinpoint Regression Program 4.9.0.0 software, we conducted trend analysis on PEM incidence rates by age group and age-standardized incidence rates from 1990 to 2019 based on GBD 2019 data. Trends were described using Annual Percentage Change (APC) and Average Annual Percentage Change (AAPC) with 95% confidence intervals (CI). $APC > 0$ indicates increasing incidence, $APC < 0$ indicates decreasing incidence. If $APC = AAPC$, the trend curve has no joinpoints, indicating a monotonic trend. With data spanning 30 years, the maximum number of joinpoints was set at 5. To fit the log-linear model, the permutation test α value was set at 0.05 with 4,499 permutations. APC and AAPC with 95% CI were calculated for each segment. $P < 0.05$ indicated statistically significant differences.

1.3.2 ARIMA Model

The Autoregressive Integrated Moving Average (ARIMA) model is a time series forecasting method widely used for its good accuracy and effectiveness. It predicts future trends by fitting data characteristics. The three parameters of ARIMA(p,d,q) are: p for autoregressive (AR) order, q for moving average (MA) order, and d for the number of differencing operations required to make the data stationary. ARIMA modeling mainly involves stationarity testing, parameter determination, model validation, and forecasting.

1.4 Statistical Analysis

GraphPad Prism 8.0.2 was used to describe the incidence status of PEM in 2019. Joinpoint Regression Program 4.9.0 was used for trend analysis of PEM incidence rates by age group and age-standardized incidence rates from 1990-2019. SPSS 14.0 was used to predict PEM incidence rates in China from 2020-2029.

2. Results

In 2019, the age-standardized incidence rate of PEM in China's total population was 1996.5/100,000, higher in males (2444.7/100,000) than females

(1536.0/100,000). This rate was lower than the global average (2099.4/100,000), though male PEM incidence exceeded the global rate (2304.0/100,000). The highest incidence occurred in children under 5 years (4402.5/100,000), followed by the 80-84 age group (2417.7/100,000). After age 5, incidence increased with age in both sexes, with rates remaining higher in males than females. [Figure 1: see original paper]

2.1 Joinpoint Regression Analysis of Age-Standardized PEM Incidence Trends in China (1990-2019)

The age-standardized incidence rate showed six inflection points in 1995, 2006, 2010, 2014, 2017, and 2019. The rate declined during 1990-1995 and 2010-2014, with APC values of -1.3% and -2.3%, respectively. Between 1995-2010 and 2006-2010, the rate showed upward trends with APC values of 0.9% and 2.5%. The most significant increase occurred during 2017-2019, with an APC of 8.9%. The APC for 2014-2017 showed no statistical significance, indicating no significant change during this period. The AAPC was 0.7%, indicating that China's age-standardized PEM incidence rate increased at an average annual rate of 0.7% from 1990-2019. [Figure 2: see original paper]

2.2 Joinpoint Regression Analysis of Age-Specific PEM Incidence Rates in China (1990-2019)

Age-specific incidence rates showed that the under-5 group declined at an average annual rate of 2.1% from 1990-2019, while other age groups showed overall stable upward trends. All age groups had their highest APC values during 2017-2019, all positive and indicating yearly increases. Among ages 5-29, five age groups showed declining incidence during 2010-2014, with APC values of -6.0%, -5.2%, -3.5%, -2.6%, and -2.4%. For ages 30-34, 35-39, and 40-44, incidence also declined during 2010-2017, 2010-2014, and 2010-2016, respectively, with APC values of -1.1%, -1.5%, and -0.7% (all statistically significant). For five age groups between 45-69, incidence declined during 2010-2014 but without statistical significance. For three age groups between 70-84, PEM incidence showed upward trends in all time intervals from 1990-2019.

2.3 Prediction of PEM Incidence in China (2020-2029)

Using data from 1990-2019, we established an ARIMA(1,2,0) model to predict age-standardized PEM incidence for 2020-2029. Model residuals passed white noise testing (Ljung-Box Q test, $P = 0.830 > 0.05$), confirming model appropriateness. The R^2 value was 0.974, indicating good model fit. Predictions show PEM incidence will continue rising over the next decade, reaching 7280.06/100,000 by 2029.

3. Discussion

China's economic development has accelerated urbanization, and changes in lifestyle and dietary habits have increased public concern about nutritional health. Research shows PEM incidence is higher in developing than developed countries and is more prevalent among low-income and less-educated populations. Assessing PEM trend changes in China is important for guiding prevention and treatment policy development. This study analyzed the current incidence status of PEM in China in 2019 and trends from 1990-2019.

We found that children under 5 had the highest PEM incidence in 2019. During childhood growth and development, PEM's effects may be long-term and irreversible. Particularly during critical periods of brain development, malnutrition affects brain structure and function, causing growth retardation, delayed myelination, and other damage. Long-term changes in brain function are also associated with malnutrition-related cognitive impairment. From a trend perspective, the under-5 group showed gradual decline from 1990-2019, indicating that China's efforts for child nutrition have been effective over the past 30 years. Continued strengthening of nutrition education and timely complementary feeding for infants is necessary to provide essential material foundations for child growth and development.

PEM is mostly secondary, caused by insufficient nutrient intake/increased loss or decreased protein synthesis/increased catabolism. In China's poorer rural areas, children with nutritional problems due to insufficient intake or elderly with excessive consumption due to underlying diseases may be the main affected groups. Our study showed that the second-highest incidence group in 2019 was ages 80-84, and after age 5, incidence increased with age in both sexes. Research indicates malnutrition risk increases with age, primarily due to insufficient nutritional intake, a problem common among elderly living alone. Food intake often decreases with aging due to disease and appetite changes, further contributing to malnutrition. PEM manifests as muscle loss and weight reduction. Muscle mass accounts for 40% of body weight, and protein is essential for muscle. After age 50, muscle mass decreases by about 1-2% annually, particularly in men, seriously affecting mobility and quality of life. We found that ages 70-84 showed upward PEM incidence trends across all time intervals from 1990-2019, indicating that elderly nutrition remains a major challenge. Some PEM occurs in hospitalized patients; since most hospitalized elderly have one or more diseases, chronic conditions increase PEM risk, and the two factors mutually reinforce each other. PEM can also occur in critically ill patients with significant inflammatory responses, such as sepsis. PEM not only increases sepsis likelihood but also shows less mortality improvement in sepsis patients over the years, making early and regular nutritional screening crucial for hospitalized sepsis patients. Additionally, causal relationships exist between poor nutritional status and post-stroke functional performance, with PEM potentially affecting post-stroke recovery through multiple mechanisms and systems. High incidence and mortality of diseases such as chronic kidney disease (CKD) and

heart failure (HF) are also associated with PEM. Therefore, personalized care and timely nutritional services for hospitalized patients are essential to facilitate comprehensive recovery. Among the elderly, nutritional knowledge deficits exist regarding protein requirements and the relationship between diet and health, making dietary pattern improvement necessary. Finally, our predictions show PEM incidence will continue rising over the next decade. With China's aging population, the number of elderly with PEM may increase, potentially driving overall PEM incidence upward.

PEM occurrence and severity are related to socioeconomic development. Analysis of PEM incidence trends reflects the economic burden on the healthcare system. Our results highlight the importance of nutrition policy development and provide a basis for PEM prevention.

Author Contributions: WANG Hongxin, FAN Wenlong, and YANG Xiaoyu conceived the research ideas, objectives, methods, and study title. WANG Hongxin drafted and wrote the manuscript. WANG Hongxin, FAN Wenlong, and YANG Xiaoyu collected and organized data. CHEN Dongyu, HUANG Qiao, PAN Suyue, WANG Pu, and HU Min carefully reviewed the data analysis process and analyzed and interpreted the results. All authors participated in manuscript revision and proofreading. WANG Hongxin and HE Yuqing were responsible for final version revision and overall manuscript responsibility.

Conflict of Interest: The authors declare no conflict of interest.

References

- [1] GULERIA P, KUMAR V, GULERIA S. Genetic Engineering: A Possible Strategy for Protein-Energy Malnutrition Regulation[J]. *Molecular Biotechnology*, 2017;59(11-12):499-517. DOI:10.1007/s12033-017-0033-8.
- [2] BATOOL R, BUTT MS, SULTAN MT, et al. Protein-energy malnutrition: a risk factor for various ailments[J]. *Critical Reviews in Food Science and Nutrition*, 2015;55(2):242-253. DOI:10.1080/10408398.2011.651543.
- [3] DEREJE N. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019[J]. *The Lancet*, 2020, 396(10258):1204-1222. DOI:10.1016/S0140-6736(20)30925-9.
- [4] XIAO Y, ZHONG CH, WEI FH, et al. Joinpoint regression analysis of the epidemiological trend of schistosomiasis in the population of Hubei Province from 2004-2018[J]. *Chinese Journal of Schistosomiasis Control*, 2022,34(02):122-127. DOI:10.16250/j.32.1374.2022011.
- [5] GAO H, CHEN XX, JIANG Y, et al. Analysis of injury trends among primary and secondary school students in Changning District, Shanghai based on Joinpoint regression model from 2010-2017[J]. *Public Health and Preventive Medicine*, 2021,32(05):24-27. DOI: 10.3969/j.issn.1006-2483.2021.05.006.

- [6] LI ZC, LIU S. Comparison of forecasting based on ARIMA model, gray model and regression model[J]. *Statistics and Decision Making*, 2019,35(23):38-41. DOI: 10.13546/j.cnki.tjyc.2019.23.007.
- [7] XU JR, CHEN L, WANG M, et al. Trend analysis and prediction of ovarian cancer incidence in Chinese women from 1990-2019[J]. *Modern preventive medicine*, 2021,48(19):3457-3460+3470.
- [8] ZHAO CY, YUAN KJ, YANG Y, et al. A study on predicting the burden of chronic obstructive pulmonary disease in China based on ARIMA and NNAR models[J]. *China General Medicine*, 2022,25(16):1942-1949. DOI: 10.12114/j.issn.1007-9572.2022.0045.
- [9] YUE YQ, SHEN J, GU YF, et al. Analysis of the current situation of malnutrition in infants and young children aged 0-24 months in a community in Shanghai[J]. *Journal of Community Medicine*, 2018,16(18):1382-1384+1388. DOI: CNKI:SUN:SQYX.0.2018-18-003.
- [10] ZHANG FX, HU Y, SONG YN, et al. Investigation of protein-energy malnutrition in rural left-behind children under 1 year old in Zunyi area and analysis of influencing factors[J]. *Chinese General Medicine*, 2021,24(11):1406-1409. DOI: 10.12114/j.issn.1007-9572.2021.00.137.
- [11] FAN JZ, WEI H, WANG YW, et al. Advances in study of protein-energy consumption in adult maintenance hemodialysis patients[J]. *Nursing Research*, 2019,33(02):302-305. DOI: 10.12102/j.issn.1009-6493.2019.02.028.
- [12] DWYER JT, GAHCHE JJ, WEILER M, et al. Screening Community-Living Older Adults for Protein Energy Malnutrition and Frailty: Update and Next Steps[J]. *Journal of community health*, 2020;45(3):640-660. DOI:10.1007/s10900-019-00739-1.
- [13] KAIPAINEN T, HARTIKAINEN S, TIIHONEN M, et al. Effect of individually tailored nutritional counselling on protein and energy intake among older people receiving home care at risk of or having malnutrition: a non-randomised intervention study[J]. *BMC Geriatr*. 2022;22(1):391. DOI:10.1186/s12877-022-03088-2.
- [14] SIEBER CC. Malnutrition and sarcopenia[J]. *Aging Clinical and Experimental Research*, 2019;31(6):793-798. DOI:10.1007/s40520-019-01170-1.
- [15] MATHEWSON SL, AZEVEDO PS, GORDON AL, et al. Overcoming protein-energy malnutrition in older adults in the residential care setting: A narrative review of causes and interventions[J]. *Ageing Research Reviews*, 2021;70:101401. DOI:10.1016/j.arr.2021.101401.
- [16] LEIJ-HALFWERK S, VERWIJS MH, VAN HOUDT S, et al. Prevalence of protein-energy malnutrition risk in European older adults in community, residential and hospital settings, according to 22 malnutrition screening tools validated for use in adults ≥ 65 years: A systematic review and meta-analysis[J]. *Maturitas*, 2019;126:80-89. DOI:10.1016/j.maturitas.2019.05.006.

- [17] ADEJUMO AC, AKANBI O, PANI L. Protein Energy Malnutrition Is Associated with Worse Outcomes in Sepsis-A Nationwide Analysis[J]. Journal of the Academy of Nutrition and Dietetics, 2019;119(12):2069-2084. DOI:10.1016/j.jand.2019.04.019.
- [18] MATWEE LK, ALAVERDASHVILI M, MUIR GD, et al. Preventing protein-energy malnutrition after cortical stroke enhances recovery of symmetry in forelimb use during spontaneous exploration[J]. Applied Physiology, Nutrition, and Metabolism, 2020;45(9):1015-1021. DOI:10.1139/apnm-2019-0865.
- [19] ALAVERDASHVILI M, CAINE S, LI X, et al. Protein-Energy Malnutrition Exacerbates Stroke-Induced Forelimb Abnormalities and Dampens Neuroinflammation[J]. Translational Stroke Research, 2018;9(6):622-630. DOI:10.1007/s12975-018-0613-3.
- [20] OLIVEIRA EA, ZHENG R, CARTER CE, et al. Cachexia/Protein energy wasting syndrome in CKD: Causation and treatment[J]. Seminars in Dialysis, 2019;32(6):493-499. DOI:10.1111/sdi.12832.
- [21] ADEJUMO AC, ADEJUMO KL, ADEGBALA OM, et al. Protein-Energy Malnutrition and Outcomes of Hospitalizations for Heart Failure in the USA[J]. American Journal of Cardiology, 2019;123(6):929-935. DOI:10.1016/j.amjcard.2018.12.014.
- [22] SCHOLES G. Protein-energy malnutrition in older Australians: A narrative review of the prevalence, causes and consequences of malnutrition, and strategies for prevention[J]. Health Promotion Journal of Australia, 2022;33(1):187-193. DOI:10.1002/hpja.489

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv – Machine translation. Verify with original.