Iran J Public Health, Vol. 53, No.3, Mar 2024, pp.634-643

Original Article

Trends in Undernutrition among Macao Children and Adolescents Aged 7~18 Years: An Analysis from Four Successive Macau Government Surveys from 2005 to 2020

#Chunjing Tu [1], #Xiaolong Chen [2], Yibo Gao [3], Qi Pan [2], Lupei Jiang [3], Yuyu Li [2], *Yanfeng Zhang [3]

1. *School of Teacher (Physical) Education, Taizhou University, Taizhou, China*
2. *School of Physical Education, Hangzhou Normal University, Hangzhou, China*
3. *China Institute of Sport Science, Beijing, China*

#Chunjing Tu and Xiaolong Chen are equally contributed to this work

***Corresponding Author:** Email: zhangyanfeng0310@126.com

(Received 10 Sep 2023; accepted 18 Nov 2023)

Abstract

Background: We aimed to explore the epidemiological trends and characteristics of undernutrition among children and adolescents aged 7~18 years in Macao from 2005 to 2020 to provide insights into the improvement of nutritional status among the youth in Macao, China.

Methods: Based on the data collected from the Citizen Physical Fitness surveillance sessions in Macao in 2005, 2010, 2015, and 2020, the prevalence of undernutrition among children and adolescents aged 7~18 years in Macao was calculated.

Result: In 2020, the prevalence of undernutrition among children and adolescents aged 7~18 years in Macao was 12.11%. Among them, the rates of stunting, moderate or severe wasting, and mild wasting were 0.63%, 5.25%, and 6.23%, respectively. The prevalence of undernutrition among boys (13.81%) was higher than that among girls (10.06%). Mild wasting was the main form of undernutrition among students. From 2005 to 2020, the prevalence of malnutrition showed a decreasing trend ($P<0.05$), but there was a rebound in 2020 from 2015, mainly because it may be caused by the COVID-19 pandemic in 2020. The prevalence of undernutrition among children and adolescents in Macao was lower than that in Mainland China ($P<0.01$).

Conclusion: The detection rates of undernutrition showed a decreasing trend from 2005 to 2020. In the post-pandemic era, Macao should undertake more effective measures in areas such as promoting balanced nutritional intake, increasing physical activity levels, enhancing school physical education, and incorporating mental health education. These efforts are essential for further reducing the prevalence of undernutrition among children and adolescents.

Keywords: Undernutrition; Children and adolescents; China; Trends

Introduction

The nutritional status of children not only serves as a crucial indicator for assessing their current health levels but also plays an important role in predicting, to some extent, their likelihood of

developing certain diseases in the future (1). However, while the issue of childhood nutritional excess is becoming increasingly apparent, the situation of undernutrition has not yet been effectively addressed. The WHO survey in 2020 found that 149 million children under 5 were estimated to be stunted, 45 million were estimated to be wasted and 38.9 million were overweight or obese (2). More than 40% of deaths in children under 5 were associated with malnutrition (3). The burden of undernutrition imposes severe and persistent impacts on individuals, their families, communities, and the development, economy, society, and healthcare systems of nations.

Date from the 2019 China National Physical Fitness Surveillance (CNPFS) indicated that the prevalence of undernutrition among Han Chinese students aged 7 to 18 in China is 8.64%. This includes rates of 0.50% for stunting, 3.25% for moderate to severe wasting, and 4.89% for mild wasting. Notably, urban and the eastern region, showed undernutrition rates of 7.98% and 8.14%, respectively. Guangdong Province, one of the economically developed areas in China, unexpectedly topped the provinces with a malnutrition rate of 16.89% (4). This suggests that economically developed regions also maintain relatively high levels of undernutrition. Research suggests that 9.5% of adults in Macao are in a state of undernutrition.

Childhood and adolescence represent one of the most crucial periods in life, and undernutrition not only has adverse effects on the health of children and adolescents, such as delaying physical growth and brain development (5) but also poses a threat to economic growth and national development. The Chinese government places significant importance on the health of children and adolescents. The "Outline of the Healthy China 2030 Plan," issued in 2016, outlines the goal of "establishing a health promotion system for children and adolescents and gradually addressing the coexistence of insufficient and excess nutrition among residents" (6). Macao is in the southern part of China, surrounded by the sea on three sides, and is a Special Administrative Region of China. Before its return to the mainland in 1999, Macao was ruled by the Portuguese for over 400 years. This unique geographical position has facilitated the convergence of Eastern and Western cultures, and since its return to China, there has been increased communication between Mainland China and Macao. The unique historical and physical setting has shaped Macao's unique living conditions, educational methods, behavioral habits, etc. As a result, the growth and development levels, as well as the nutritional status of children and adolescents in Macao, are likely to have their characteristics. However, there is a scarcity of research on the nutritional trends among children and adolescents in Macao.

From the above, it is essential to research the nutritional status and trends among children and adolescents in the economically developed Macao. Therefore, based on data obtained from various Macao citizens' Physical Fitness and Health Survey over the years, we analyzed the current situation of undernutrition among children and adolescents in Macao in 2020. Additionally, we conducted a longitudinal analysis of undernutrition among children and adolescents in Macao from 2005 to 2020 to explore the trends and characteristics of undernutrition. The goal was to provide a scientific reference for improving the nutritional status of children and adolescents in Macao.

Materials and Methods

Research subjects

We focused on the physical indicators, including height, weight, and BMI, of children and adolescents aged 7 to 18 years in Macao from 2005 to 2020. Data were collected in the years 2005, 2010, 2015, and 2020. Stratified random cluster sampling principles were applied for sample selection.

The sampling process was outlined as follows: Firstly, based on various schools in Macao, schools were categorized into three regions based on the location of the school's main campus: North Region, Central Region, and South Region, including the Outlying Islands Region. Sub-

sequently, 2 to 3 schools were randomly selected from each region, and then sampling was performed at the class level. Samples were divided by gender into male and female, with each age group representing a one-year interval one-year interval between each age group. In total, there were 24 age groups and 55 participants were sampled for each gender, region, and age group in each round.

Measurement Method

All testing locations, sampling methods, and testing methods were consistent, using the same brand of testing equipment (Jianmin II, Beijing) and the same testing methods. All investigators and researchers have undergone standardized training on data collection protocols and instrument usage. Quality control was conducted by supervisors, with 5% of the participants randomly selected for retesting. Data were entered using a double-entry method and underwent comparison, verification, and correction. Height was measured using a calibrated height gauge accurate to 0.1cm. Weight was measured with a corrected weight measurement instrument, accurate to 0.1 kg. BMI = weight/ (height × height) (kg/m^2). Screening for undernutrition is conducted based on the "Screening standard for malnutrition of school-aged children and adolescents" (WS/T456-2014) (7). Initially, individuals with a height below or equal to the corresponding threshold for their gender and age were classified as having stunted growth (chronic undernutrition). After excluding individuals with stunting, individuals with wasting were categorized according to the BMI threshold range (acute undernutrition), and those with a BMI below or equal to the threshold were further classified as "moderate to severe wasting" and "mild wasting". Finally, the three categories of "stunting," "moderate to severe wasting," and "mild wasting" are combined into "undernutrition."

Statistic

Data entry was conducted using the dedicated survey input software for Macao citizens' physical fitness, and statistical analysis was performed using SPSS 26.0 (IBM Corp., Armonk, NY, USA), with GraphPad Prism 9.0 used for plotting. ANOVA was used to compare the differences in age, height, weight, and BMI among the four surveys; the Chi-square test was used for the differential test of multiple percentages; the Chi-square trend test was utilized to analyze the differences in the prevalence of undernutrition, stunting, moderate-to-severe underweight, and mild underweight in Macao from 2005 to 2020. The ratio Z-test was used to analyze the differences in the prevalence of undernutrition, stunting, moderate-to-severe underweight, and mild underweight between Mainland China in 2019 and Macao in 2020.

Results

Sample characteristics

We included 16,732 participants (4,190 in 2005, 4,132 in 2010, 4,125 in 2015, and 4,285 in 2020) with complete records on age, sex, height, and weight in the final analyses. There were more boys than girls in the survey ($P<0.001$). From 2005 to 2020, the height, weight, and BMI of both males and females showed an increasing trend with time ($P<0.01$). There were significant differences in height, weight, and BMI indicators among the four surveys ($P<0.01$).

Trends in the Prevalence of undernutrition in children and adolescents aged 7~18 years in Macao from 2005 to 2020

To begin with, from 2005 to 2020, the overall prevalence of undernutrition among children and adolescents aged 7~18 years in Macao exhibited a decreasing trend, and the difference is statistically significant ($P<0.001$). However, the overall prevalence of undernutrition increased from 9.6% in 2015 to 12.11% in 2020. During this period, the prevalence for males increased from 12.31% to 13.81%, and for females, it increased from 6.36% to 10.06%. Both boys and girls showed a significant rebound in detection rates ($P<0.001$) (Table 1).

Table 1: Basic characteristics of children and adolescents from 2005 to 2020

Variable	*2005*	*2010*	*2015*	*2020*	χ^2/F	*P*
Participants	4190	4132	4125	4285		
Sex					23.83	<0.001
Boys	2201 (52.53%)	2119 (51.28%)	2316 (56.15%)	2346 (54.75%)		
Girls	1989 (47.47%)	2013 (48.72%)	1809 (43.85%)	1939 (45.25%)		
Age groups (yr)					14.34	0.111
7~9	1091 (26.04%)	1035 (25.05%)	1103 (26.74%)	1172 (27.35%)		
10~12	1035 (24.70%)	991 (23.98%)	969 (23.49%)	1065 (24.85%)		
13~15	1052 (25.11%)	1039 (25.15%)	990 (24.00%)	1013 (23.64%)		
16~18	1012 (24.15%)	1067 (25.82) %	1063 (25.77%)	1035 (24.15%)		
Age (yr)						
Boys	12.25±3.47	12.34±3.44	12.38±3.51	12.13±3.48	2.21	0.085
Girls	12.60±3.44	12.80±3.48	12.56±3.57	12.56±3.49	2.15	0.092
Height (cm)						
Boys	151.71±18.43	152.98±18.04	153.91±18.27	153.27±18.65	5.67	0.001
Girls	147.89±13.58	149.76±13.40	149.26±14.15	150.14±13.91	10.08	<0.001
Weight (kg)						
Boys	44.14±15.74	45.70±16.28	47.79±18.27	47.81±18.49	24.50	<0.001
Girls	41.02±12.07	43.50±12.89	44.08±13.87	43.59±13.39	21.68	<0.001
BMI (kg/cm²)						
Boys	18.53±3.55	18.88±3.78	19.45±4.09	19.57±4.30	34.80	<0.001
Girls	18.33±3.26	18.96±3.54	19.26±3.75	18.85±3.60	23.52	<0.001

Secondly, when looking at gender differences, the prevalence of severe wasting, mild wasting, and undernutrition among boys showed a significant decreasing trend, with statistical significance (P<0.05). The prevalence of stunting, mild wasting, and undernutrition among girls also showed a decreasing trend, with statistical significance (P<0.05).

Thirdly, in the longitudinal comparison by age group, the overall prevalence of undernutrition showed a "U"-shaped distribution, with lower rates in the middle and higher rates at both ends. This pattern was particularly evident for wasting. The prevalence of mild wasting in children and adolescents aged 11-13 was the lowest. In 2020, the prevalence of severe wasting was highest in 18-year-old males and 16-year-old girls.The lowest prevalence was among 10-year-old boys and 13-year-old girls. The prevalence of mild wasting was highest in 16-year-old boys and 8-year-old girls, respectively. The lowest prevalence was in 9-year-old boys and 12-year-old girls. The prevalence of undernutrition was highest in 16-year-old boys and girls, while the lowest prevalence was in 9-year-old boys and 13-year-old girls (Table 2, Fig. 1).

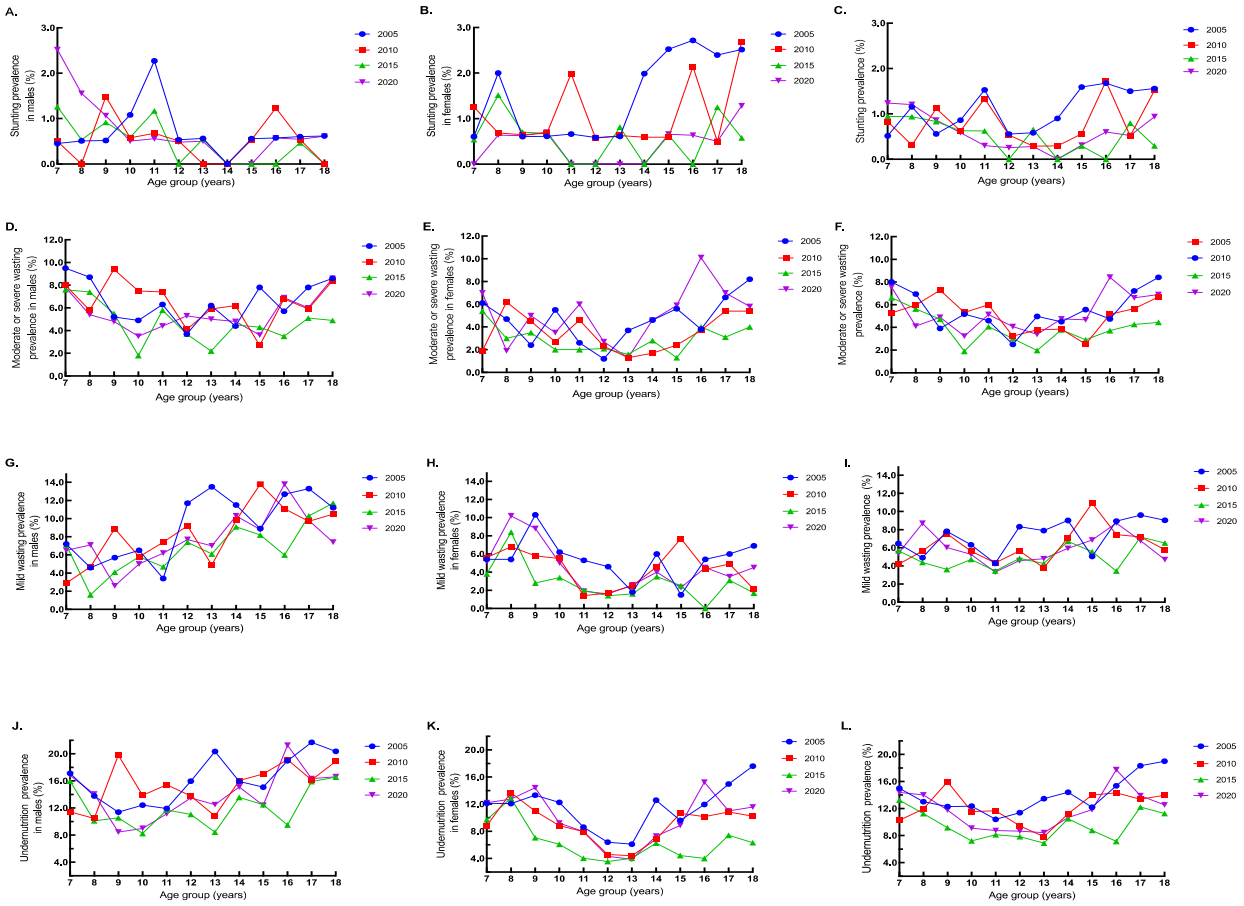

Fig. 1: The prevalence of stunting, moderate or severe wasting, mild wasting, and undernutrition in children and adolescents of different ages from 2005 to 2020 [stunting in boys (A), and girls (B), and overall (C), moderate or severe wasting in boys (D), and girls (E), and overall (F), mild wasting in boys (G), and girls (H), and overall (I), undernutrition in boys (J), and girls (K), and overall (L)]

Table 2: The prevalence of stunting, moderate or severe wasting, mild wasting, and undernutrition in children and adolescents from 2005 to 2020

Variable	*2005*	*2010*	*2015*	*2020*	χ^2_{trend}	P_{trend}
Stunting						
Boys	0.68	0.52	0.52	0.81	0.28	0.595
Girls	1.51	1.09	0.55	0.41	15.96	<0.001
Total	1.07	0.80	0.53	0.63	7.07	0.008
Moderate or severe wasting						
Boys	6.41	6.47	4.79	5.37	4.70	0.030
Girls	4.58	3.53	2.99	5.11	0.30	0.584
Total	5.54	5.03	4.00	5.25	1.52	0.218
Mild wasting						
Boys	9.04	8.16	6.82	7.63	4.73	0.030
Girls	5.33	4.37	2.82	4.54	3.57	0.058
Total	7.28	6.32	5.07	6.23	6.81	0.009
Undernutrition						
Boys	16.13	15.15	12.31	13.81	8.99	0.003
Girls	11.41	8.99	6.36	10.06	5.07	0.024
Total	13.89	12.15	9.60	12.11	12.11	<0.001

Comparison of Malnutrition Detection Rates between Macao in 2020 and Mainland China in 2019

In 2020, The undernutrition prevalence in Macao was 3.47% higher than that in Mainland China (P<0.001)(4). When comparing with provinces in Mainland China, the top 5 provinces with the highest malnutrition rates were Guangdong (16.89%), Yunnan (14.26%), and Guangxi (12.08%)(4). Macao ranked between the second and third position among the provinces in Mainland China. When analyzed by age groups, the prevalence of undernutrition in children and adolescents in Macao in 2020 was generally higher. Differences between Macao and Mainland China were statistically significant for the 7-9 years, 13-15 years, and 16-18 years age groups (P<0.01). 1) stunting, except for the 7-9 years age group, the prevalence of stunting in Macao in 2020 was lower than those in Mainland China in 2019 for all age groups. 2) Concerning moderate to severe wasting, the prevalence in Macao for all age groups in 2020 was higher than that in Mainland China in 2019. 3) For mild wasting, except for the 10-12 years age group, the prevalence in Macao for all age groups in 2020 was higher than those in Mainland China in 2019 (Fig. 2).

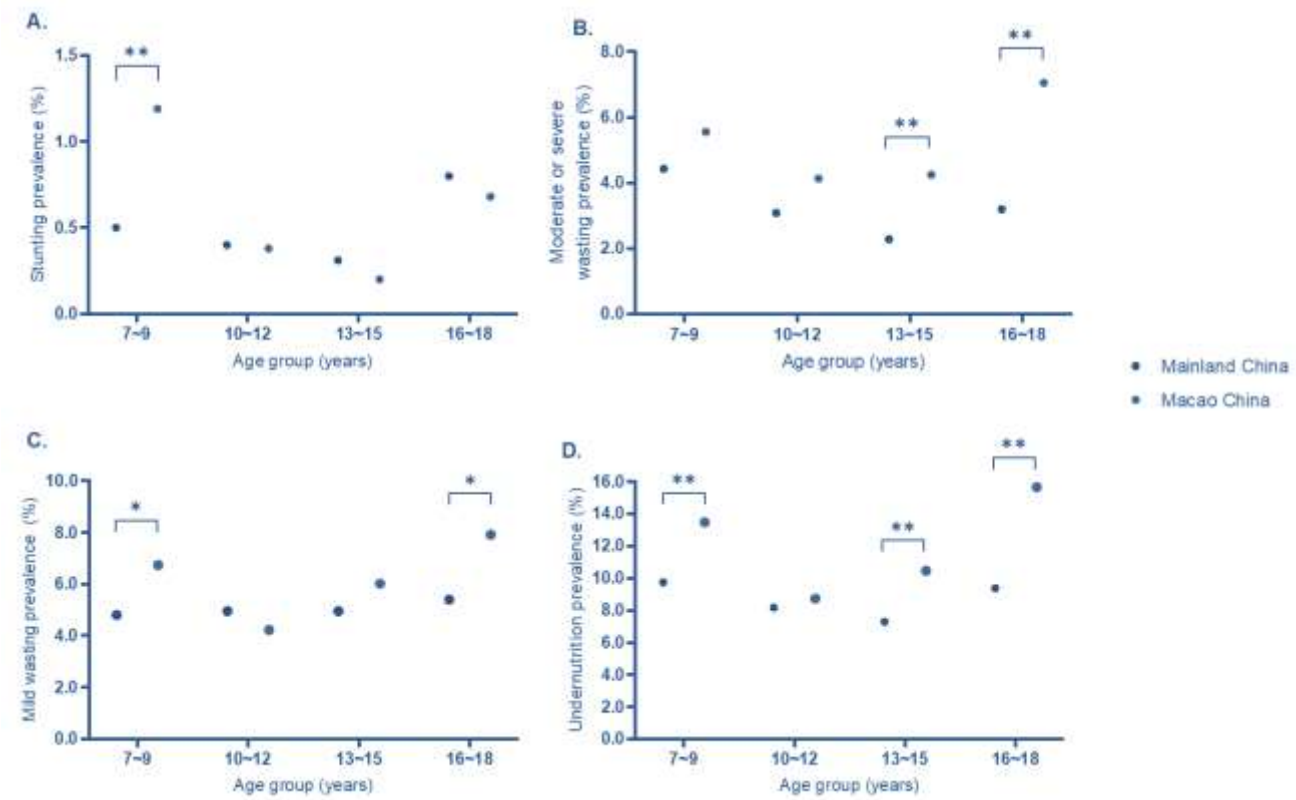

Fig. 2: Comparison of the prevalence of stunting, moderate or severe wasting, mild wasting, and undernutrition among children and adolescents in different age grounds between Mainland China in 2019 and Macao in 2020 [stunting (A), and moderate or severe wasting (B), and mild wasting (C), and undernutrition (D)]

Discussion

We analyzed the changing trend in undernutrition prevalence from 2005 to 2020. We also conducted a comparative analysis of the differences in undernutrition detection rates among children and adolescents in Macao in 2020 and Mainland

China in 2019. Now, the research results are further analyzed.

Trends and causes of malnutrition among children and adolescents in Macao from 2005 to 2020

From 2005 to 2020, the overall undernutrition prevalence among children and adolescents in Macao showed a decreasing trend, which is consistent with research results in Mainland China (8, 9) and some developed countries (10, 11). The decline in undernutrition prevalence is closely associated with improvements in nutritional and sanitary conditions brought about by economic development (12-14). From 1999 to 2018, Macao's total economic volume increased from 6.43 billion USD to 55.19 billion USD, and the per capita GDP rose from 14,895 USDto83,169 USD, a 5.5-fold increase. The median monthly income of Macao residents also increased from 610 USD in 1999 to 1986 USD in 2018, a 2.25-fold increase (15). Several studies have reported a negative correlation between economic growth and malnutrition (16, 17). As the level of regional economic development increases, the accessibility and diversity of food gradually increase. There is a strong association between dietary patterns and childhood malnutrition. The Western dietary pattern, which emphasizes high-quality proteins, can reduce the risk of childhood undernutrition (18). Since 2008, the Macao Special Administrative Region government has implemented a milk program, providing free milk to students, thereby increasing the intake of dairy products in student diets (19). This change in dietary structure is beneficial for reducing the risk of undernutrition.

In comparison to 2015, there was a notable rebound in the undernutrition detection rate among children and adolescents in 2020, potentially linked to COVID-19. Since December 2019, COVID-19 has spread globally and caused a pandemic. Wessely et al has observed a significant increase in malnutrition among children under the influence of COVID-19 compared to the period before the outbreak (20). The Macao Student Physical Fitness Test was conducted from September to November 2020, about 10 months after the widespread impact of COVID-19 on society.

During the COVID-19 pandemic, the Macao government implemented extremely strict measures to combat the disease and prevent infection. These measures included maintaining social distancing, home isolation, and various other preventive strategies. In response to the issue of students returning to school, the Macao government introduced a series of epidemic prevention measures, requiring the delayed opening of primary and secondary schools, preschool education, and special education institutions, while supporting students in engaging in home-based learning. Although these restrictive measures effectively slowed the spread of the virus and contained the disease, they also had impacts on people's physical activity (21), sleep quality (22), and mental health (24). Regarding physical activity, there was a significant reduction in students' daily exercise and outdoor activities during the epidemic (21). Reduced physical activity is closely associated with malnutrition in children and adolescents (23-25). In terms of mental health, epidemic prevention measures have also led to an increase in students' anxiety disorders, depressive symptoms, and psychological stress. Relevant studies indicate that during the COVID-19 outbreak, the clinical depression prevalence among children and adolescents was 22.8%, significantly higher than the estimated 13.2% during normal times in China and 2%-6% in Western countries (26). There is a dose-response relationship between adolescent depressive symptoms and dietary intake, with adolescents showing more pronounced depressive symptoms having lower food intake (24). This may lead to weight loss, subsequently causing undernutrition. Therefore, in the post-pandemic era, we should emphasize the relevant factors leading to the increased undernutrition prevalence caused by the pandemic. This includes increasing the time, frequency, and intensity of physical activity, enhancing the mental health levels of children and adolescents, consuming a balanced intake of various nutrients, aiming to reduce malnutrition, and improving overall physical development.

Causes of malnutrition difference between children and adolescents in Macau and Mainland China

In 2020, a comparison between Macao and Mainland China in 2019 revealed that the prevalence of undernutrition in Macao was 3.47 percentage points higher than in Mainland China. Macao ranked between the 2nd and 3rd positions among the provinces in Mainland China. In 2010 and 2015, the malnutrition rates among children and adolescents in Macao were 12.15% and 9.60%, respectively, higher than those in the eastern cities of Mainland China in 2010 and 2014 by 1.25 and 0.66 percentage points. The reasons for these differences are analyzed as follows.

For nutrient intake, a 2021 survey in Macao on dietary structure found that students' daily intake of vitamin A, calcium, and iodine was significantly inadequate, markedly lower than the recommended nutrient intake in China mainland (18). The supplementation of vitamins and minerals is crucial for the growth and development of children and adolescents. The "Child Development Outline of China (2011-2020)" released by the Chinese government in 2011 identified malnutrition as one of the key health issues to focus on in the development of children in the coming decade (27). The formulation and implementation of these policies have significantly improved the issue of malnutrition among Chinese children and adolescents, leading to a substantial decrease in stunting and wasting rates. Therefore, the Macao Region should strengthen policies to improve the nutritional status of children and adolescents, especially in the supplementation of vitamins and minerals, to promote their healthy development.

In terms of physical activity environment factors, Macao has a small land area, ranking first in population density among major economies worldwide, with the per capita living area approximately half that of cities in Mainland China. The high population density results in a severe shortage of sports facilities in schools. Some schools cannot even conduct regular physical education classes on campus, which may impact the intensity of physical activity among Macao children and adolescents, thereby affecting their levels of growth and development.

In terms of physical education factors, each type of school lacks a unified physical education teaching objective and assessment standards, which results in a wake sense of responsibility among many schools and physical education teachers. In contrast, domestic primary and secondary schools have a comprehensive physical education curriculum standard system and physical education scores are included in the overall scores for the secondary school entrance examination. This has a significant impact on promoting the growth and development of students. Additionally, geographical and climatic factors such as humidity and solar radiation also influence the growth and development of children in Macao, located in the southern coastal region of China.

Conclusion

The malnutrition rate of children and adolescents aged 7-18 years in Macao showed a downward trend from 2005 to 2020. The pandemic caused the rebound of malnutrition rate in 2020, and the malnutrition rate in Macao was higher than that in Mainland China. Thus, in the post-epidemic era, the Macao government should promote balanced nutrition intake, increase physical activity, enhance school physical education, and provide mental health education. This will further reduce the prevalence of malnutrition among children and adolescents.

Journalism Ethics considerations

Ethical issues (including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy) were observed by the authors.

Acknowledgements

A joint project of the Sports Bureau of Macao SAR Government and China Institute of Sports

Science (b2117). We are grateful to the China National Physique Surveillance Center and the test participants for their assistance in collecting data for our study.

Conflict of interest

We declare no competing interest.

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