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World Breastfeeding Week

August 1–7, 2025

Invest in breastfeeding, invest in the future

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Cover Image: adapted from the World Health Organization, https://www.who.int/campaigns/world-breastfeeding-week/ 2025.

Why We All Need to Work Together to Prioritize Breastfeeding

Amakobe Sande[1,#]

ABSTRACT

The first week of August marks World Breastfeeding Week. It provides a valuable opportunity to review progress in breastfeeding initiatives, analyze the enabling environment for breastfeeding support, and propose targeted actions to protect, promote, and support breastfeeding practices.

As of April 2025, 48% of infants under six months are exclusively breastfed worldwide, approaching the World Health Assembly's target of 50% by 2025. However, reaching the more ambitious global target of 60% by 2030 will require sustained investment in evidence-based programs and policies, strong political commitment, robust accountability mechanisms, and strengthened health systems to protect, promote, and support breastfeeding practices.

China has undertaken measures to promote breastfeeding nationwide. In 2021, fifteen government ministries issued the National Action Plan for Promoting Breastfeeding (2021–2025). Concurrently, China has implemented concrete national-level actions, including nationwide promotion of infant and young child feeding counseling services, improvements in family-friendly workplace policies, and strengthening of Baby-Friendly Hospital Initiatives.

Achieving breastfeeding targets requires sustained, multisectoral efforts across all levels of society. Key recommendations for action include enacting and enforcing a legally binding Code of Marketing of Breastmilk Substitutes, implementing comprehensive family-friendly workplace policies, strengthening community support networks, integrating breastfeeding counseling and support into routine maternal and child health services, implementing the Ten Steps to Successful Breastfeeding in all maternity facilities, and establishing routine monitoring and evaluation systems. Through these coordinated measures, mothers will receive the comprehensive support they need to breastfeed exclusively, providing their babies with the healthiest possible foundation for life.

Breastfeeding extends far beyond nutrition — it establishes the foundation for lifelong health. Rather than simply providing essential nutrients, breast milk is a living, complex fluid rich in antibodies, enzymes, and hormones that protect infants and young children from infections such as diarrhea and respiratory illnesses while reducing the risk of chronic diseases later in life, including obesity and diabetes. Breastfeeding also fosters emotional security and strengthens the maternal-infant bond. For mothers, breastfeeding provides protection against certain cancers and facilitates postpartum recovery. In China, these benefits are particularly significant for advancing national health objectives. National strategies, including the Healthy China Initiative (2019–2030), National Nutrition Plan (2017–2030), and the China Children Development Plan (2012–2030), have established a target of achieving exclusive breastfeeding for at least 50% of children under six months of age.

The first week of August marks World Breastfeeding Week, providing a valuable opportunity to assess progress in breastfeeding initiatives, evaluate the enabling environment for breastfeeding support, and propose strategic actions to protect, promote, and support breastfeeding practices. World Breastfeeding Week (WBW) was established in 1992 by the World Alliance for Breastfeeding Action, with support from the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), calling for global commitment to breastfeeding promotion. Each year, WBW mobilizes stakeholders around specific themes, including healthcare integration, women in the workforce, marketing restrictions, and community engagement (1). This year's theme, "Prioritize Breastfeeding: Create Sustainable Support Systems," emphasizes the critical need for robust policy and workplace support for breastfeeding — a key demand of the 2025 WBW — while highlighting breastfeeding's minimal carbon footprint and contribution to climate resilience.

As of April 2025, 48% of infants under six months worldwide are exclusively breastfed, representing an increase from 38% a decade ago and approaching the World Health Assembly's target of 50% by 2025.

However, achieving the more ambitious global target of 60% by 2030 (*2*) will require sustained investment in evidence-based programs and policies, continued political commitment, strengthened accountability mechanisms, and enhanced health systems to effectively protect, promote, and support breastfeeding.

To track progress and drive evidence-based policy action, the Global Breastfeeding Collective, led by the WHO and UNICEF, launched the Global Breastfeeding Scorecard in 2017. This comprehensive monitoring tool evaluates a country's performance across critical domains including maternity protection, health system support, implementation of the International Code of Marketing of Breastmilk Substitutes, and community engagement. The Scorecard has emerged as a cornerstone accountability mechanism for countries to benchmark their progress and prioritize strategic interventions (*3*). The 2024 Global Breastfeeding Scorecard reveals that only 30% of countries have successfully implemented all four of the Collective's recommended policy actions, highlighting the urgent need for accelerated implementation of maternity protection, Code enforcement, Baby Friendly Hospital Initiative (BFHI) coverage, and community support (*4*).

A comprehensive Lancet Breastfeeding series from 2023 demonstrated that the marketing of Breastmilk Substitutes profoundly influences societal beliefs, values, and practices surrounding infant feeding, creating an ecosystem that systematically undermines breastfeeding (*5*). Furthermore, mothers' decisions to breastfeed are shaped by multiple interconnected factors — biological, cultural, social, and commercial — and must be supported through coordinated actions across households, communities, workplaces, health systems, and national regulatory frameworks.

China has implemented measures to promote breastfeeding nationwide. In 2021, fifteen government ministries jointly issued the National Action Plan for Promoting Breastfeeding (2021–2025), establishing a comprehensive breastfeeding promotion mechanism led by the government, coordinated across departments, and supported by society as a whole to advance breastfeeding practices (*6*). While more recent estimates are not yet available, UNICEF anticipates that these measures will result in substantial national progress in exclusive breastfeeding rates, which according to the most recent National Nutrition and Health Surveillance of 2017 stood at 34% (*7*).

China has implemented concrete national-level actions to promote breastfeeding practices. Since 2019,

the National Health Commission and UNICEF have jointly implemented the Infant and Young Child Feeding (IYCF) program, training more than 290,000 health workers from townships and villages across 1,212 counties in all thirty-one provincial-level administrative divisions to deliver skilled IYCF counseling as part of routine primary health care (*8*). Progress in family-friendly workplace policies is also evident, with institutional support for breastfeeding, parental leave, childcare services, and flexible work arrangements (*9*). Additionally, China's Baby-Friendly Hospital Initiative has expanded substantially: 7,036 hospitals had achieved "Baby-Friendly" accreditation by 2015, representing the highest number globally (*10*).

Achieving breastfeeding targets demands sustained, multi-sectoral commitment and coordinated implementation efforts. The following evidence-based recommendations provide a framework for creating sustainable support systems that prioritize breastfeeding (*4*):

1) Enact and enforce a legally binding Code of Marketing of Breastmilk Substitutes to protect breastfeeding from aggressive marketing practices of breast milk substitutes.

2) Enforce family-friendly workplace policies by ensuring employers fully implement maternity leave and lactation break legislation while providing safe, designated breastfeeding spaces in workplace environments.

3) Strengthen community support networks by providing both emotional and practical assistance throughout mothers' breastfeeding journeys.

4) Integrate breastfeeding counseling and support into routine maternal and child health services, encompassing antenatal, delivery, and postnatal care. This integration should ensure systematic assessment of breastfeeding practices and provision of individualized counseling tailored to each mother's needs.

5) Implement the Ten Steps to Successful Breastfeeding across all maternity facilities to establish comprehensive support systems that motivate healthcare providers delivering maternity and newborn services (*11*).

6) Establish robust monitoring and evaluation systems to systematically assess breastfeeding outcomes and policy implementation effectiveness. These systems should utilize standardized questionnaires and the global breastfeeding scorecard framework to guide evidence-based nationwide interventions.

Through implementing these comprehensive

measures, mothers will receive the essential support necessary for successful exclusive breastfeeding, thereby providing their infants with the optimal foundation for lifelong health and development.

Corresponding author: Amakobe Sande, asande@unicef.org.

1 UNICEF Representative to China, United Nations Children's Fund (UNICEF) Office for China, Beijing, China.

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Amakobe Sande
UNICEF Representative to China

Preplanned Studies

Association Between Family Upbringing Environment and Mobile Phone Dependence Syndrome in Middle School Students — Guangzhou City, Guangdong Province, China, 2023

Runquan Zhang[1]; Haiyuan Zhu[1]; Qiqi Wu[1]; Rong Lin[2]; Hui Liu[2]; Minying Sun[2]; Weiquan Lin[2]; Wenhao Li[3]; Bing Huang[4]; Jierong Zhao[4]; Yingyu Yang[5]; Ying Li[5]; Xiaomei Dong[1,#]; Chang Wang[2,#]

Summary

What is already known about this topic?

Smartphones have consistently served as the primary device for internet access among younger populations. Recent research demonstrates that more than 25% of Chinese adolescents experience smartphone addiction. This study aims to examine the association between family upbringing environment and Mobile Phone Dependence Syndrome (MPDS) among middle school students in Guangzhou.

What is added by this report?

This study demonstrates that middle school students whose fathers had educational attainment levels of junior high school [odds ratio (*OR*)=0.39, 95% confidence interval (95% *CI*): 0.17–0.90], senior high school, junior college, technical secondary school, or vocational university (*OR*=0.28, 95% *CI*: 0.12–0.67), or a bachelor's degree and above (*OR*=0.34, 95% *CI*: 0.12–0.92) may function as a protective factor against MPDS among adolescents. Additionally, students whose fathers employed an authoritarian parenting style (*OR*=1.98, 95% *CI*: 1.22–3.21) are also associated with middle school students' MPDS.

What are the implications for public health practice?

These findings indicate that democratic parenting approaches and higher educational attainment among fathers play essential roles in mitigating adolescent MPDS, providing valuable guidance for developing evidence-based strategies and interventions aimed at promoting adolescent physical and mental health.

ABSTRACT

Introduction: With the widespread adoption of smartphones, Mobile Phone Dependence Syndrome (MPDS) has emerged as a significant public health concern. However, the relationship between family upbringing environment and MPDS among middle school students remains unclear.

Methods: The study employed a multi-stage cluster random sampling method to conduct questionnaire and scale assessments among 1,928 students from eight middle schools in Guangzhou during April and May 2023. Propensity score matching was performed to control for confounding variables, including sex, grade, boarding status, and place of residence. used Multivariate logistic regression models were used to examine the associations between parental educational attainment, parenting styles, care levels, family economic conditions, and middle school students' MPDS.

Results: After adjusting for covariates, this study revealed that middle school students whose fathers had educational attainment levels of junior high school [odds ratio (*OR*)=0.39, 95% confidence interval (95% *CI*): 0.17–0.90], senior high school, junior college, technical secondary school, or vocational university (*OR*=0.28, 95% *CI*: 0.12–0.67), or a bachelor's degree and above (*OR*=0.34, 95% *CI*: 0.12–0.92) demonstrated significantly lower odds of MPDS compared to those whose fathers had only an elementary school education or below. Additionally, students whose fathers employed an authoritarian parenting style (*OR*=1.98, 95% *CI*: 1.22–3.21) showed significantly higher odds of MPDS compared to those whose fathers embraced a democratic parenting approach.

Conclusion: Promoting democratic parenting styles among fathers and enhancing fathers' educational levels may be beneficial in reducing adolescents' MPDS risk. This study provides valuable insights for developing scientifically informed strategies aimed at promoting adolescents' physical and mental well-being.

In recent years, the rapid advancement of China's industrial and information technology infrastructure has led to widespread smartphone adoption. However, excessive smartphone use, termed MPDS, can result in subjective distress, psychological symptoms, health complications, and social disruptions. Research indicates that more than 25% of Chinese adolescents experience smartphone addiction (1). The emergence of excessive smartphone use during adolescence correlates significantly with increased risks of depression, anxiety, loneliness, and sleep disorders. Therefore, addressing excessive smartphone use among teenagers represents a critical public health priority.

Adolescent MPDS is influenced by individual, school, and family factors, with the family upbringing environment playing a particularly crucial role. The family upbringing environment is shaped by parental educational attainment and the quality of care they provide. Building upon Baumrind's foundational parenting style theory, Maccoby and Martin further categorized parenting styles into four distinct types — democratic, authoritarian, indulgent, and spoiling — based on the dimensions of demandingness and responsiveness (2). Within China's sociocultural context, traditional Chinese parenting has been characterized by strict parental authority and child obedience. However, as China has experienced significant social and economic transformation during the past four decades, Chinese parents have become more educated and enjoy improved living standards, leading many to adopt more democratic parenting styles. This study aims to examine the association between family upbringing environment and MPDS occurrence among middle school students in Guangzhou City, thereby providing evidence-based strategies and measures for promoting adolescent physical and mental health development.

Data were collected from 1,928 students across 8 middle schools in Liwan and Nansha districts of Guangzhou City, Guangdong Province, China, between April and May 2023. Participants were selected using a multistage cluster random sampling method. Liwan District and Nansha District were selected to represent the central urban area and rural administrative region, respectively. 1 key middle school, 1 key high school, 1 ordinary middle school, and 1 ordinary high school were selected from each district (if there is no distinction, then randomly select). 1 ordinary class and 1 key class were selected from grades 7 to 12 from each district (if there is no distinction, then randomly select). All students in the selected classes were included in the investigation.

Based on an existing study (3), the prevalence of MPDS among middle school students was estimated at 15.0%. The α value was set at 0.05, while the d value was set at 0.15 p. To account for the multistage cluster sampling design, we increased this estimate by 50%. Assuming a 90% response rate, the final minimum required sample size was 1,613 students.

$$n = \frac{Z_{\alpha}^2 p \left(1 - p\right)}{d^2}$$

Participants were excluded if any of the following conditions occurred: 1) the middle school student MPDS scale was not completed, or contained 1 or more missing questions (n=14); 2) the questionnaire contained logical errors (n=31). Finally, 1,883 eligible participants were included in the final analysis.

The Mobile Phone Dependence Scale, developed by Wang Xiaohui (4), was employed to assess MPDS severity among middle school students. Scores exceeding 48 indicated MPDS. Parental parenting styles were categorized into four types: authoritarian, democratic, indulgent, and spoiling. The questionnaire provided explicit definitions for each parenting style, and students identified the approaches adopted by their respective parents. Due to the absence of self-reported household income data in the questionnaire, we used students' boarding status and monthly allowance as substitute variables to reflect their family economic status. A monthly allowance of less than 500 Chinese Yuan (CNY) for boarding students indicates low family economic status. A monthly allowance between 500 and 1,500 CNY for boarding students, or between 500 and 1,000 CNY for non-boarding students, is classified as average family economic status. When the monthly allowance exceeds 1,500 CNY for boarding students or 1,000 CNY for non-boarding students, the family is classified as having high economic status.

This study utilized propensity score matching (PSM) to control for potential confounding factors. Four baseline characteristics were matched: sex, grade, boarding status, and place of residence. We employed 1:3 nearest-neighbor matching with a caliper width of 0.02. Following matching, 747 participants were included in two groups. A standardized mean difference (SMD) below 0.10 was considered acceptable for balance assessment.

Qualitative data are presented as frequencies and percentages (n, %), while quantitative data following

TABLE 1. Characteristics of participants (*N*=1,883).

Characteristics	*n*	*%*
Sex		
Male	1,035	54.97
Female	848	45.03
Grade		
Grade 7	290	15.40
Grade 8	285	15.14
Grade 9	295	15.67
Grade 10	353	18.75
Grade 11	318	16.89
Grade 12	342	18.16
Household registration		
Guangzhou	1,030	54.70
Other areas in China	853	45.30
Boarding status		
Yes	612	32.50
No	1,271	67.50
Only child		
Yes	1,373	72.92
No	510	27.08
Monthly allowances (CNY)		
<500	1,435	76.21
500–999	276	14.66
1,000–1,499	107	5.68
≥1,500	65	3.45
Personality trait		
Introverted	500	26.55
Extroverted	680	36.11
Neutral	703	37.33
Peer interaction		
Very easy	754	40.04
Average	1,008	53.53
Not easy	121	6.43
Peer social frequency		
Frequently	996	52.89
Occasionally	827	43.92
Rarely	60	3.19
Academic performance		
Top 25% in grade	603	32.02
26%–50% in grade	593	31.49
51%–75% in grade	484	25.70
76%–100% in grade	203	10.78
Place of residence		
Rural	722	38.34

Continued

Characteristics	n	%
Urban	1,161	61.66
Father's educational attainment		
Elementary school and below	100	5.31
Junior high school	670	35.58
Senior high school/Junior college/Technical secondary school/Vocational university	868	46.10
Bachelor's degree and above	245	13.01
Mother's educational attainment		
Elementary school and below	205	10.89
Junior high school	724	38.45
Senior high school/Junior college/Technical secondary school/Vocational university	753	39.99
Bachelor's degree and above	201	10.67
Father's parenting style		
Democratic	1,023	54.33
Authoritarian	396	21.03
Indulgent	447	23.74
Spoiling	17	0.90
Mother's parenting style		
Democratic	1,081	57.41
Authoritarian	374	19.86
Indulgent	405	21.51
Spoiling	23	1.22
Father's caring level		
Very caring	935	49.66
Average	807	42.86
Not caring	141	7.49
Mother's caring level		
Very caring	1,273	67.61
Average	541	28.73
Not caring	69	3.66
Family economic condition		
Low	1,435	76.21
Average	320	16.99
High	128	6.77
	Mean	SD
Age (year)	15.33	1.71
MPDS scores	35.74	10.61

Abbreviation: MPDS=mobile phone dependence syndrome; CNY=Chinese Yuan.

normal distribution are expressed as means and standard deviations. Univariate analyses were conducted on matched data to compare individual and family characteristics between MPDS and non-MPDS participants. Multivariate logistic regression models examined the association between family upbringing environment and middle school students' MPDS. Model 1 remained unadjusted; Model 2 adjusted for sex and grade; Model 3 incorporated all covariates. Database construction utilized Epidata software (version 3.1, Epidata Association, Odense, Denmark). Statistical analyses were performed using R software

TABLE 2. Matched variables of MPDS and non-MPDS groups before and after matching (N_1=1,883, N_2=747).

Variables	Unmatched population				Matched population			
	Non-MPDS (n=1,694)	MPDS (n=189)	SMD	P	Non-MPDS (n=558)	MPDS (n=189)	SMD	P
Sex			0.223	0.004*			0.017	0.608
Male	950 (56.08)	85 (44.97)			239 (42.83)	85 (44.97)		
Female	744 (43.92)	104 (55.03)			319 (57.17)	104 (55.03)		
Grade			0.304	0.005*			0.003	0.995
Grade 7	271 (16.0)	19 (10.05)			57 (10.22)	19 (10.05)		
Grade 8	263 (15.53)	22 (11.64)			63 (11.29)	22 (11.64)		
Grade 9	274 (16.17)	21 (11.11)			63 (11.29)	21 (11.11)		
Grade 10	314 (18.54)	39 (20.63)			125 (22.40)	39 (20.63)		
Grade 11	275 (16.23)	43 (22.75)			127 (22.76)	43 (22.75)		
Grade 12	297 (17.53)	45 (23.81)			123 (22.04)	45 (23.81)		
Boarding status			0.103	0.160			0.015	0.651
Yes	542 (32.00)	70 (37.03)			217 (38.89)	70 (37.04)		
No	1,152 (68.00)	119 (62.97)			341 (61.11)	119 (62.96)		
Place of residence			0.066	0.383			0.004	0.819
Rural	644 (38.02)	78 (41.27)			225 (40.32)	78 (41.27)		
Urban	1,050 (61.98)	111 (58.73)			333 (59.68)	111 (58.73)		

Abbreviation: MPDS=mobile phone dependence syndrome; SMD=standardized mean difference; N_1=number of unmatched population; N_2=number of matched population.
* $P<0.01$.

(version 4.3.1, R Foundation for Statistical Computing, Vienna, Austria) and SPSS software (version 26.0, IBM Corp., Armonk, NY, USA). Statistical significance was set at $P<0.05$, with all tests being two-tailed.

Among the 1,883 enrolled middle school students, 1,035 were male (54.97%) and 848 were female (45.03%). The mean MPDS scale score was 35.74±10.61, with 189 students (10.04%) classified as having MPDS (Table 1). Following propensity score matching, the analysis included 558 students (74.70%) in the non-MPDS group and 189 students (25.30%) in the MPDS group. The PSM procedure successfully balanced the distributions of sex, grade, boarding status, and place of residence across groups ($P>0.05$) (Table 2).

Univariate logistic regression analysis demonstrated that personality traits ($P=0.026$) and academic performance ($P=0.007$) among middle school students were significantly associated with MPDS variations. Within family upbringing environment factors, fathers' educational attainment ($P=0.010$), fathers' parenting style ($P<0.001$), and fathers' caring level ($P=0.003$) showed significant associations with MPDS among middle school students (Table 3).

After controlling for all relevant confounding factors

in Model 3, fathers' educational attainment and parenting style remained significantly associated with MPDS scores among middle school students. Compared with students whose fathers had completed only elementary school or below, those whose fathers had completed junior high school [odds ratio (OR)=0.39, 95% confidence interval (95% CI): 0.17–0.90], senior high school/junior college/technical secondary school/vocational university (OR=0.28, 95% CI: 0.12–0.67), and bachelor's degree or above (OR=0.34, 95% CI: 0.12–0.92) demonstrated protective effects against MPDS. Students with authoritarian fathers showed a 98% higher odds of MPDS compared to those with democratic fathers (OR=1.98, 95% CI: 1.22–3.21) (Table 4). We also found that mothers with senior high school, junior college, technical secondary school, or vocational university degrees were associated with increased odds of middle school students' MPDS. However, this association did not attain statistical significance in the crude model. The parenting style of the mother, the caring level of the father, the caring level of the mother, and the family's economic condition were not statistically correlated with MPDS among middle school students.

TABLE 3. Baseline characteristics of MPDS and non-MPDS groups after matching (*N*=747).

Variables	Non-MPDS (*n*=558)	MPDS (*n*=189)	P
Household registration			0.773
Guangzhou	324 (58.06)	112 (59.26)	
Other areas in China	234 (41.94)	77 (40.74)	
Only child			0.689
Yes	150 (26.88)	48 (25.40)	
No	408 (73.12)	141 (74.60)	
Monthly allowances (CNY)			0.334
<500	424 (75.99)	132 (69.84)	
500–999	89 (15.95)	37 (19.58)	
1,000–1,499	31 (5.56)	12 ((6.35)	
≥1,500	14 (2.51)	8 (4.23)	
Personality trait			0.026*
Introverted	218 (39.07)	66 (34.92)	
Extroverted	196 (35.13)	55 (29.10)	
Neutral	144 (25.81)	68 (36.08)	
Peer interaction			0.103
Very easy	214 (38.35)	64 (33.86)	
Average	314 (56.27)	107 (56.61)	
Not easy	30 (5.38)	18 (9.52)	
Peer social frequency			0.065
Frequently	280 (50.18)	93 (49.21)	
Occasionally	263 (47.13)	84 (44.44)	
Rarely	15 (2.69)	12 (6.35)	
Academic performance			0.007**
Top 25% in grade	175 (31.36)	58 (30.69)	
26%–50% in grade	197 (35.30)	47 (24.87)	
51%–75% in grade	128 (22.94)	50 (26.46)	
76%–100% in grade	58 (10.39)	34 (17.99)	
Father's educational attainment			0.010*
Elementary school and below	17 (3.05)	16 (8.47)	
Junior high school	193 (34.59)	71 (37.56)	
Senior high school/Junior college/Technical secondary school/Vocational university	269 (48.21)	79 (41.80)	
Bachelor's degree and above	79 (14.16)	23 (12.17)	
Mother's educational attainment			0.342
Elementary school and below	63 (11.29)	19 (10.05)	
Junior high school	199 (35.67)	70 (37.04)	
Senior high school/Junior college/Technical secondary school/Vocational university	234 (41.94)	87 (46.03)	
Bachelor's degree and above	62 (11.11)	13 (6.88)	
Father's parenting style			<0.001**
Democratic	326 (58.42)	76 (40.21)	
Authoritarian	101 (18.10)	57 (30.16)	
Indulgent	125 (22.40)	54 (28.57)	

Continued

Variables	Non-MPDS (*n*=558)	MPDS (*n*=189)	*P*
Spoiling	6 (1.08)	2 (1.06)	
Mother's parenting style			0.109
Democratic	331 (59.32)	94 (49.74)	
Authoritarian	108 (19.35)	43 (22.75)	
Indulgent	115 (20.61)	49 (25.93)	
Spoiling	4 (0.72)	3 (1.59)	
Father's caring level			0.003**
Very caring	287 (51.43)	71 (37.57)	
Average	234 (41.94)	99 (52.38)	
Not caring	37 (6.63)	19 (10.05)	
Mother's caring level			0.279
Very caring	389 (69.71)	120 (63.49)	
Average	153 (27.42)	63 (33.33)	
Not caring	16 (2.87)	6 (3.17)	
Family economic condition			0.188
Low	424 (75.99)	132 (69.84)	
Average	105 (18.82)	42 (22.22)	
High	29 (5.20)	15 (7.94)	

Abbreviation: CNY=Chinese Yuan; MPDS=mobile phone dependence syndrome.
* *P*<0.05;
** *P*<0.01.

DISCUSSION

This study establishes a clear relationship between family upbringing environment and MPDS prevalence among middle school students. After controlling for covariates, we consistently identified authoritarian paternal parenting styles and lower paternal educational attainment as robust predictors of MPDS development in adolescents.

The study revealed a significant positive correlation between fathers' authoritarian parenting styles and MPDS. A similar conclusion was drawn from an Indonesian study that demonstrated authoritarian parenting styles were associated with increased likelihood of offspring developing MPDS (*5*). One study has shown that parenting styles serve as mediators in the relationship between family socioeconomic status and digital addiction in young children (*6*). Families provide essential emotional warmth and social support for adolescents. However, authoritarian parenting — characterized by high demands and low responsiveness — may elevate stress levels in children, prompting them to seek comfort through mobile phone use. The emotional bond between mothers and adolescents develops earlier in

life. Although mothers may adopt authoritarian approaches in child-rearing, they frequently display positive and supportive attitudes that mitigate the potential negative effects of strict parenting (*7*). Consequently, children may demonstrate greater tolerance toward their mothers. In contrast, fathers typically focus on establishing rules and exercising behavioral control, often directly intervening in their children's autonomy and behavioral boundaries. Authoritarian fathers assume a dominant role in parent-child relationships. They strictly regulate their children's mobile phone usage while simultaneously suppressing their children's need for autonomy. This authoritarian approach may contribute to elevated stress levels in children, leading them to seek solace through mobile phone use. Adolescents often avoid communicating with their fathers to prevent potential conflicts, viewing mobile phones as relaxation tools and engaging more frequently in online activities for comfort (*8*). Support from fathers may facilitate more effective stress-coping strategies to meet everyday and long-term demands in ways that reduce addictive behaviors. Consequently, a democratic parenting style is recommended for fathers.

Notably, fathers' educational attainment

TABLE 4. Logistic regression analysis results after PSM (*N*=747).

Variables	Model 1[†]		Model 2[††]		Model 3[†††]	
	OR (95% CI)	*P*	*OR (95% CI)*	*P*	*OR (95% CI)*	*P*
Father's educational attainment						
Elementary school and below (reference)						
Junior high school	0.38 (0.17, 0.86)	0.020*	0.37 (0.17, 0.85)	0.018*	0.39 (0.17, 0.90)	0.026*
Senior high school/Junior college/Technical secondary school/Vocational university	0.27 (0.12, 0.63)	0.002**	0.27 (0.12, 0.62)	0.002**	0.28 (0.12, 0.67)	0.004**
Bachelor's degree and above	0.33 (0.13, 0.87)	0.025*	0.33 (0.12, 0.87)	0.025*	0.34 (0.12, 0.92)	0.034*
Mother's educational attainment						
Elementary school and below (reference)						
Junior high school	1.43 (0.75, 2.72)	0.273	1.48 (0.77, 2.85)	0.235	1.61 (0.82, 3.15)	0.169
Senior high school/Junior college/Technical secondary school/Vocational university	1.92 (0.99, 3.71)	0.053	1.97 (1.01, 3.83)	0.046*	2.06 (1.03, 4.15)	0.042*
Bachelor's degree and above	1.03 (0.42, 2.57)	0.947	1.04 (0.42, 2.62)	0.927	1.02 (0.39, 2.66)	0.967
Father's parenting style						
Democratic (reference)						
Authoritarian	1.90 (1.19, 3.04)	0.007**	1.90 (1.19, 3.03)	0.007**	1.98 (1.22, 3.21)	0.006**
Indulgent	1.46 (0.93, 2.29)	0.104	1.47 (0.93, 2.31)	0.096	1.49 (0.94, 2.38)	0.091
Spoiling	1.48 (0.28, 7.96)	0.648	1.43 (0.26, 7.88)	0.679	1.38 (0.24, 8.01)	0.719
Mother's parenting style						
Democratic (reference)						
Authoritarian	1.01 (0.63, 1.61)	0.964	1.04 (0.65, 1.67)	0.870	0.93 (0.58, 1.51)	0.776
Indulgent	1.24 (0.79, 1.93)	0.349	1.25 (0.80, 1.96)	0.323	1.19 (0.75, 1.89)	0.461
Spoiling	1.61 (0.31, 8.25)	0.571	1.56 (0.31, 7.98)	0.591	1.40 (0.25, 7.81)	0.701
Father's caring level						
Very caring (reference)						
Average	1.51 (0.98, 2.32)	0.062	1.52 (0.99, 2.35)	0.057	1.42 (0.91, 2.23)	0.125
Not caring	1.71 (0.83, 3.49)	0.144	1.72 (0.84, 3.53)	0.142	1.54 (0.73, 3.24)	0.259
Mother's caring level						
Very caring (reference)						
Average	0.94 (0.61, 1.45)	0.776	0.95 (0.61, 1.47)	0.803	1.00 (0.63, 1.57)	0.987
Not caring	0.72 (0.24, 2.18)	0.563	0.72 (0.23, 2.19)	0.556	0.70 (0.22, 2.25)	0.551
Family economic condition						
Low (reference)						
Average	1.28 (0.83, 1.96)	0.259	1.27 (0.82, 1.96)	0.279	0.98 (0.16, 5.92)	0.984
High	1.66 (0.84, 3.27)	0.143	1.64 (0.83, 3.26)	0.155	1.63 (0.61, 4.37)	0.333

Abbreviation: *OR*=odds ratio; *CI*=confidence interval; PSM=propensity score matching.
[†] Model 1 unadjusted;
[††] Model 2 adjusted for sex and grade;
[†††] Model 3 adjusted for sex, grade, boarding status, place of residence, household registration, only child status, monthly allowances, personality trait, peer interaction, peer social frequency, and academic performance.
* *P*<0.05;
** *P*<0.01.

demonstrated a significant negative correlation with MPDS occurrence among middle school students. Previous research has shown that children from families with lower parental educational levels and reduced income tend to engage in more extensive mobile phone use compared to peers from higher socioeconomic backgrounds (*9*). The relationship between fathers' limited educational attainment and

adolescent addictive behaviors operates through inadequate supervision and the absence of clear household guidelines (*10*). Fathers with restricted education may lack essential skills to recognize and effectively address their children's addictive behaviors. Furthermore, implementing restrictive rules alone proves insufficient for managing addictive behaviors. In contrast, fathers with higher educational levels are more likely to proactively guide their children toward developing balanced and informed approaches to mobile phone use from an early age. Well-educated fathers typically employ more effective educational strategies and supervision techniques rather than relying solely on rigid time restrictions, fostering healthier usage patterns in their children. Conversely, fathers with limited educational backgrounds are more prone to excessive mobile phone use themselves, creating negative behavioral models for their children. In summary, low education among fathers may hinder effective parenting practices, weaken the quality of parent-child attachment, and reduce emotional support, which are critical protective factors against the development of MPDS.

Public health policies must expand beyond traditional individual-level interventions to address MPDS among middle school students. The family system should be recognized as a fundamental component within comprehensive frameworks for managing adolescent behavioral health and developing robust prevention and control systems. This study recommended that the prevention of MPDS among middle school students be integrated into existing public health prevention systems. This integration should include developing monitoring systems for MPDS that specifically assess family upbringing environment as key risk factors.

This study has several limitations that warrant consideration. First, because the research was conducted in only eight middle schools within Guangzhou City, the generalizability of the findings to regions with different cultural backgrounds or socioeconomic environments may be limited. Second, the cross-sectional design precludes the establishing longitudinal trends or causal relationships between family parenting styles and MPDS development among middle school students. Third, the reliance on self-reported data for assessing family parenting styles may introduce response bias, potentially compromising the accuracy and consistency of the findings.

These findings underscore the critical importance of fathers' democratic parenting approaches and higher educational attainment in mitigating adolescent MPDS. The family upbringing environment, particularly paternal influence on adolescent MPDS, represents a significant factor in promoting comprehensive physical and mental health development among students.

Ethical statement: Approved by the Ethics Committee of the Guangzhou Center for Disease Control and Prevention with the ethics approval number GZCDC-ECHR-2021P0063. All the participants provided written informed consent.

Conflicts of interest: No conflicts of interest.

Corresponding authors: Xiaomei Dong, tdongxm@jnu.edu.cn; Chang Wang, gzcdc_wangc@gz.gov.cn.

1 Department of Public Health and Preventive Medicine, School of Medicine, Jinan University, Guangzhou City, Guangdong Province, China; 2 Guangzhou Center for Disease Control and Prevention (Guangzhou Health Supervision Institute), Guangzhou City, Guangdong Province, China; 3 The Affiliated Guangdong Second Provincial General Hospital of Jinan University, Guangzhou City, Guangdong Province, China; 4 Guangzhou Liwan District Center for Disease Control and Prevention, Guangzhou City, Guangdong Province, China; 5 Guangzhou Nansha District Center for Disease Control and Prevention, Guangzhou City, Guangdong Province, China.

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Preplanned Studies

Association Between Early-life Malnutrition and Lifestyle Behaviors in Later Life Among Rural Elderly with Hypertension — Jia County, Pingdingshan City, Henan Province, China, 2023

Jian Wu[1]; Saiyi Wang[1]; Yudong Miao[1]; Zichen Zhou[1]; Yifei Feng[1]; Lipei Zhao[1]; Weijia Zhao[1]; Clifford Silver[1]; Yaru Duan[2]; Ronghai Bie[1,#]

Summary

What is already known about this topic?

Early-life malnutrition influences lifestyle behaviors and health outcomes, particularly in vulnerable populations, such as elderly hypertensive populations.

What is added by this report?

This study revealed that malnutrition among infant and toddler exposed, preschool exposed, school-aged child exposed, and adolescent exposed groups was associated with increased smoking and drinking behaviors and a lower likelihood of maintaining a healthy weight and avoiding central obesity.

What are the implications for public health practice?

Public health interventions should target elderly individuals exposed to early-life malnutrition to address long-term risks and mitigate the health impacts of food scarcity and natural disasters.

ABSTRACT

Introduction: Early-life malnutrition plays a critical role in human development; however, its long-term impact on lifestyle behaviors remains poorly understood. This study investigated the association between early-life malnutrition and lifestyle behaviors among elderly hypertensive populations.

Methods: A total of 17,871 elderly hypertensive populations were surveyed from July 11 to August 31, 2023, in Jia County, Pingdingshan City, Henan Province, China. Early-life malnutrition exposure was defined based on natural disasters occurring between 1959 and 1961, with participants categorized by age at exposure as follows: infant and toddler exposed group (1956–1958), preschooler exposed group (1953–1955), school-aged exposed group (1947–1952), adolescent exposed group (1942–1946), and adult exposed group (before 1942). Outcome measures included four lifestyle behaviors: smoking, alcohol consumption, healthy body mass index (BMI), and healthy waist circumference (WC). Multivariable logistic regression models were used to evaluate associations with sex-stratified subgroups, and sensitivity analyses were performed to ensure robustness.

Results: The mean age of the participants was 73.4 years, and 57.9% were women. Compared to the adult exposed group, individuals exposed to malnutrition during infancy, preschool, school-aged, and adolescence had significantly higher risks of smoking and alcohol consumption. Additionally, those with early-life malnutrition exposure showed a lower likelihood of maintaining healthy BMI and WC, with odds ratios (ORs) demonstrating significant trends as age at exposure increased ($P_{\text{for trend}}<0.001$). Subgroup analysis revealed that these associations were significant in males, whereas no statistically significant associations were observed between smoking and alcohol consumption in females. Sensitivity analyses, excluding individuals with diabetes or coronary heart disease, confirmed the robustness of the findings.

Conclusions: Early-life malnutrition, particularly during infancy, childhood, and adolescence, was significantly associated with unhealthy lifestyle behaviors, including increased smoking, alcohol consumption, and obesity among elderly individuals with hypertension. These findings provide valuable insights for countries and regions facing natural disasters. Furthermore, they can help public health professionals design targeted interventions for vulnerable populations.

The developmental origins of health and disease hypothesis posits that early life experiences play a

pivotal role in individual development, influencing later health status and predisposing individuals to disease (*1*). Between 1959 and 1961, China experienced severe natural disasters that significantly affected its population and economy (*2*). Although previous studies have established links between early malnutrition and increased risks of hypertension, diabetes, and cardiovascular disease (*3*), little is known about the impact of malnutrition on lifestyle behaviors later in life, particularly among hypertensive populations. This study aimed to investigate whether malnutrition experienced during critical developmental stages is associated with adverse lifestyle behaviors, including smoking, alcohol consumption, body mass index (BMI), and waist circumference (WC), later in life among elderly hypertensive populations.

METHODS

Data were collected from July 11 to August 31, 2023, in Jia County, Pingdingshan City, Henan Province. This large-scale cross-sectional survey employed a cluster sampling method, with data collected through face-to-face interviews. This study included hypertensive populations born before 1959 who resided in Jia County and were enrolled in a local basic public health service program, ensuring that the sample was representative of the hypertensive population in Jia County. The exclusion criteria included populations with mental illnesses, those who refused to participate, and those who were unable to provide informed consent. Participants diagnosed at secondary- or higher-level medical institutions completed questionnaires on demographics, disease history, and lifestyle behaviors. For participants with low literacy levels, trained staff assisted them in reading and completing the questionnaire during face-to-face interviews. After excluding 679 populations with missing or incomplete information, 17,871 hypertensive populations were included.

Early malnutrition was defined as exposure to natural disasters between 1959 and 1961 that led to widespread food scarcity and malnutrition (*4*). Participants born before 1942 were categorized into the adult exposed group, which served as the reference group. Others were classified based on their age during the early malnutrition period: infancy and toddler exposed group (born 1956–1958), preschooler exposed group (born 1953–1955), school-aged child exposed group (born 1947–1952), and adolescent exposed group (born 1942–1946) (*5*). Lifestyle outcomes included smoking status, alcohol consumption, BMI, and WC. Smoking status and alcohol consumption were assessed using structured questionnaires. The participants were asked whether they smoked (former smoker, current smoker, or never smoked) or consumed alcohol (yes or no). Former and current smokers were classified as smokers. A healthy weight was defined as a BMI between 18.5 and 24.9 kg/m^2. Healthy WC was defined as less than 90 cm for men and less than 85 cm for women. The covariates included age, sex, residence, education, marital status, diabetes, coronary heart disease, stroke, and duration of hypertension. Diabetes and coronary heart disease (CHD) were defined based on the physician's diagnosis, as recorded in the participants' public health records or self-reported history confirmed by medical documentation from secondary or tertiary hospitals. Analysis of variance (ANOVA), Kruskal-Wallis H test, and binary logistic regression were used to analyze the data after adjusting for covariates. The Cochran-Armitage trend test was used to explore whether there was a decreasing trend in risky behaviors with increasing age at exposure. Sensitivity analyses excluded participants with diabetes or coronary heart disease. Statistical analyses were conducted using SPSS Statistics (version 20.0; IBM Corp., Armonk, NY, USA), with significance set at $P<0.05$. Graphs were created using GraphPad Prism 8.0 (GraphPad Software, San Diego, CA, USA).

The characteristics of the 17,871 hypertensive populations are presented in Table 1. The majority of the participants were female (n=10,351, 57.9%), with a mean age of 73.4 years (range: 65–104 years). Among the study population, 2,740 (15.3%) were exposed to early malnutrition during infancy and toddlerhood, 3,720 (20.8%) during preschool age, 6,490 (36.3%) during school age, 3,191 (17.9%) during adolescence, and 1,730 (9.7%) during adulthood. Significant differences were observed in the distribution of educational status, marital status, smoking, alcohol consumption, diabetes, coronary heart disease, stroke, duration of hypertension, BMI, WC, sleep duration, and physical activity duration among the five exposure groups (Table 1, $P_{\text{for trend}}<0.05$).

RESULTS

The prevalence of lifestyle behaviors varied significantly across the early malnutrition exposure groups (Figure 1). Compared to the adult exposed

TABLE 1. Demographic characteristics and early malnutrition exposure of hypertensive participants in the study conducted in Jia County, Pingdingshan City, Henan Province, China, 2023.

Variable	Infant and toddler exposed (n=2,740)	Preschooler exposed (n=3,720)	School-aged exposed (n=6,490)	Adolescent exposed (n=3,191)	Adult exposed (n=1,730)	Overall (n=17,871)	$P_{for\ trend}$
Birth cohort	1956–1958	1953–1955	1947–1952	1942–1946	Before 1942	17,871 (100.0)	−
Number, [n (%)]	2,740 (15.3)	3,720 (20.8)	6,490 (36.3)	3,191 (17.9)	1,730 (9.7)	17,871 (100.0)	−
Gender (male), [n (%)]	1,114 (40.7)	1,568 (42.2)	2,773 (42.7)	1,379 (43.2)	686 (39.7)	7,520 (42.1)	0.721
Educational status (illiterate), [n (%)]	1,020 (37.2)	1,606 (43.2)	3,183 (49.0)	1,363 (42.7)	1,003 (58.0)	8,175 (45.7)	<0.001
Marriage (married), [n (%)]	2,278 (83.1)	2,957 (79.5)	4,845 (74.7)	1,943 (60.9)	732 (42.3)	12,755 (71.4)	<0.001
Current smoker (yes), [n (%)]	714 (26.1)	971 (26.1)	1,638 (25.2)	775 (24.3)	288 (16.6)	4,386 (24.5)	<0.001
Current drinker (yes), [n (%)]	387 (14.1)	444 (11.9)	695 (10.7)	322 (10.1)	116 (6.7)	1,964 (11.0)	<0.001
Diabetes (yes), [n (%)]	768 (28.0)	946 (25.4)	1,578 (24.3)	663 (20.8)	287 (16.6)	4,242 (23.7)	<0.001
Coronary heart disease (yes), [n (%)]	346 (12.6)	500 (13.4)	1,006 (15.5)	511 (16.0)	278 (16.1)	2,641 (14.8)	<0.001
Duration of hypertension (15 years or above), [n (%)]	572 (21.1)	791 (21.5)	1,454 (22.8)	758 (24.2)	426 (25.4)	4,001 (22.4)	<0.001
BMI (kg/m²)	25.47±4.09	25.18±3.73	25.01±3.99	24.29±3.77	23.40±4.38	24.83±3.99	<0.001
WC (cm)	89.42±0.89	89.01±10.82	88.73±12.41	87.96±15.40	85.57±14.89	88.45±12.78	<0.001

Note: "−" means no data.
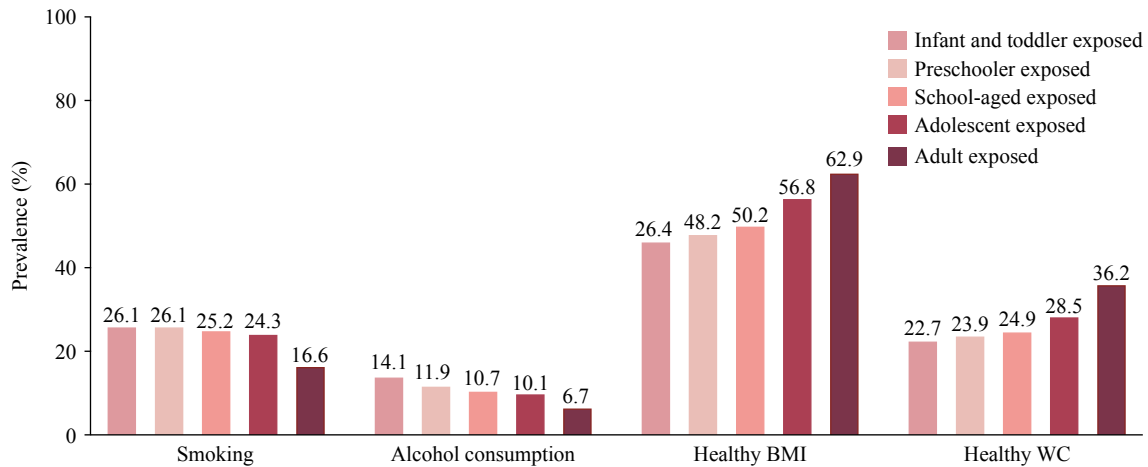Abbreviation: BMI=body mass index; WC=waist circumference.

FIGURE 1. Prevalence of healthy lifestyle behaviors among hypertensive populations with different early malnutrition exposures in Jia County, Pingdingshan City, Henan Province, China, 2023 (n=17,871).
Abbreviation: BMI=body mass index; WC=waist circumference.

group, the risk of smoking was significantly higher in the infant and toddler [odds ratio (OR)=2.17, 95% confidence interval (CI): 1.79, 2.64], preschooler (OR=2.03, 95% CI: 1.69, 2.44), school-aged (OR=1.89, 95% CI: 1.59, 2.24), and adolescent (OR=1.68, 95% CI: 1.40, 2.02) exposed groups. Similarly, alcohol consumption risk was elevated in the infant and toddler (OR=2.06, 95% CI: 1.62, 2.62), preschooler (OR=1.65, 95% CI: 1.31, 2.08), school-aged (OR=1.56, 95% CI: 1.25, 1.94), and adolescent (OR=1.40, 95% CI: 1.11, 1.78) exposed groups compared to the adult exposed group (all P<0.05).

Furthermore, the odds of maintaining a healthy weight were significantly lower in the infant and toddler (OR=0.52, 95% CI: 0.46, 0.59), preschooler (OR=0.55, 95% CI: 0.49, 0.62), school-aged (OR=0.59, 95% CI: 0.53, 0.66), and adolescent (OR=0.76, 95% CI: 0.67, 0.86) exposed groups compared to the adult exposed group, with similar patterns observed for healthy WC. All OR values showed a significant decreasing trend with increasing age at exposure ($P_{for\ trend}$ <0.001) (Table 2).

Subgroup analysis revealed that compared with the adult exposed group, males in the infant and toddler

TABLE 2. Association between early malnutrition exposure and healthy behaviors in hypertensive populations from Jia County, Pingdingshan City, Henan Province, China, 2023.

Variable	Adult exposed	Infant and toddler exposed		Preschooler exposed		School-aged exposed		Adolescent exposed		$P_{for\ trend}$
		Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P	Adjusted OR (95% CI)	P	
Smoking	1.00	2.17 (1.79, 2.64)	<0.001	2.03 (1.69, 2.44)	<0.001	1.89 (1.59, 2.24)	<0.001	1.68 (1.40, 2.02)	<0.001	<0.001
Alcohol consumption	1.00	2.06 (1.62, 2.62)	<0.001	1.65 (1.31, 2.08)	<0.001	1.56 (1.25, 1.94)	<0.001	1.40 (1.11, 1.78)	<0.001	<0.001
Healthy BMI	1.00	0.52 (0.46, 0.59)	<0.001	0.55 (0.49, 0.62)	<0.001	0.59 (0.53, 0.66)	<0.001	0.76 (0.67, 0.86)	<0.001	<0.001
Healthy WC	1.00	0.56 (0.49, 0.65)	<0.001	0.59 (0.51, 0.67)	<0.001	0.61 (0.54, 0.69)	<0.001	0.71 (0.62, 0.81)	<0.001	<0.001

Note: Adjusted OR (95% CI): adjusted for gender, educational status, marriage, diabetes, coronary heart disease and duration of hypertension.
Abbreviation: BMI=body mass index; WC=waist circumference; OR=odds ratio; CI=confidence interval.

(OR=2.32, 95% CI: 1.90, 2.84), preschooler (OR=2.14, 95% CI: 1.77, 2.58), school-aged (OR=1.96, 95% CI: 1.65, 2.33), and adolescent (OR=1.96, 95% CI: 1.65, 2.33) exposed groups had significantly increased risks of smoking and alcohol consumption (all P<0.05). No statistically significant associations were observed between female subgroups. Among males, the probability of maintaining a healthy weight was significantly lower in the infant and toddler exposed (OR=0.73, 95% CI: 0.60, 0.89), preschooler exposed (OR=0.68, 95% CI: 0.56, 0.82), and school-aged exposed (OR=0.69, 95% CI: 0.57, 0.82) groups (all P<0.05). Similarly, the probability of maintaining a healthy WC was significantly lower in the infant and toddler (OR=0.63, 95% CI: 0.51, 0.77), preschooler (OR=0.61, 95% CI: 0.51, 0.74), school-aged (OR=0.63, 95% CI: 0.53, 0.74), and adolescent (OR=0.71, 95% CI: 0.59, 0.86) exposed groups (all P<0.05). In females, the probability of maintaining a healthy weight was similarly lower in the infant and toddler (OR=0.40, 95% CI: 0.34, 0.48), preschooler (OR=0.47, 95% CI: 0.40, 0.55), school-aged (OR=0.53, 95% CI: 0.46, 0.61), and adolescent (OR=0.71, 95% CI: 0.61, 0.84) exposed groups (all P<0.05). The probability of maintaining a healthy WC was also significantly lower in the infant and toddler (OR=0.49, 95% CI: 0.40, 0.60), preschooler (OR=0.55, 95% CI: 0.46, 0.66), school-aged (OR=0.58, 95% CI: 0.49, 0.68), and adolescent (OR=0.70, 95% CI: 0.59, 0.84) exposed groups (all P<0.05), as shown in Figure 2.

The sensitivity analysis conducted after excluding populations with diabetes and coronary heart disease yielded results consistent with those of the main analysis, as presented in Figure 3.

DISCUSSION

The findings of this study indicate that infant and toddler exposure, preschooler exposure, school-aged exposure, and adolescent exposure to malnutrition are associated with an increased risk of smoking and alcohol consumption in later life. Additionally, individuals exposed to malnutrition during infancy exhibited the highest risk behaviors compared to other age groups, with this risk demonstrating a clear decreasing trend as age at exposure increased.

The infant and toddler exposed group showed the strongest associations, supporting the concept that experiences during this critical developmental stage have profound long-term effects on individual behavior (6). One explanation for this pattern is that individuals who experienced malnutrition as infants and toddlers may develop lasting physiological stress responses, potentially serving as a trigger for smoking and alcohol consumption later in life. Research has indicated that malnutrition during fetal and early childhood development could adversely affect brain development and neural function, thereby influencing adult behavior and increasing sensitivity to addictive substances, such as nicotine and alcohol (7). This neurobiological mechanism may explain the observed results for smoking and drinking behaviors.

Our findings further indicate that individuals who experienced infant and toddler exposure, preschool exposure, school-aged exposure, and adolescent exposure to malnutrition were more prone to obesity compared to those who experienced malnutrition during adulthood. Infants and toddlers who experienced malnutrition may face the risk of overfeeding when food becomes available, thereby increasing the likelihood of obesity later in life. Exposure to malnutrition during infancy may alter neuroendocrine function, leading to excessive secretion of glucocorticoids and subsequent fat accumulation in later life (8). Furthermore, during periods of malnutrition, the body may enter a state of energy
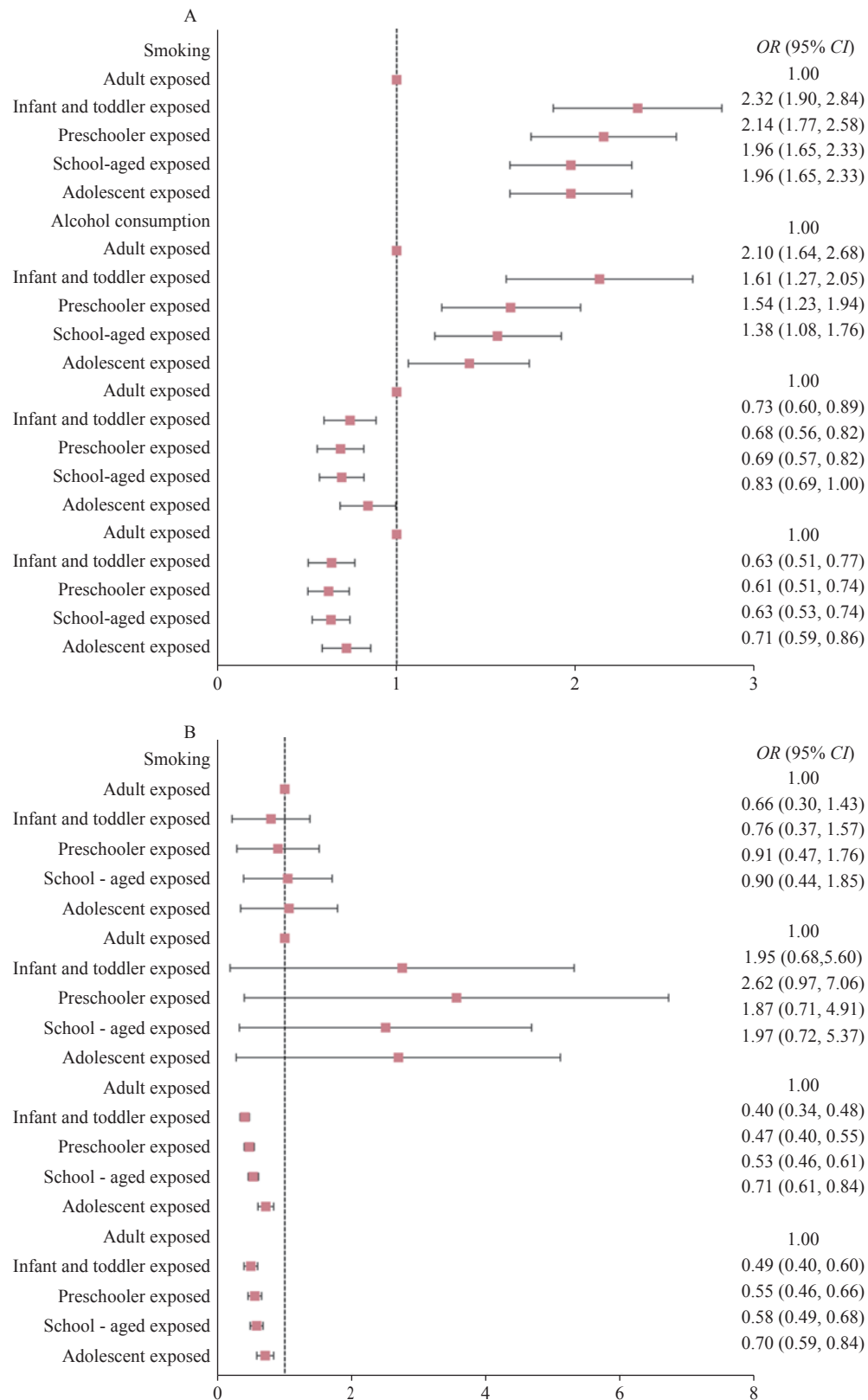
A

	OR (95% CI)
Smoking	
Adult exposed	1.00
Infant and toddler exposed	2.32 (1.90, 2.84)
Preschooler exposed	2.14 (1.77, 2.58)
School-aged exposed	1.96 (1.65, 2.33)
Adolescent exposed	1.96 (1.65, 2.33)
Alcohol consumption	
Adult exposed	1.00
Infant and toddler exposed	2.10 (1.64, 2.68)
Preschooler exposed	1.61 (1.27, 2.05)
School-aged exposed	1.54 (1.23, 1.94)
Adolescent exposed	1.38 (1.08, 1.76)
Adult exposed	1.00
Infant and toddler exposed	0.73 (0.60, 0.89)
Preschooler exposed	0.68 (0.56, 0.82)
School-aged exposed	0.69 (0.57, 0.82)
Adolescent exposed	0.83 (0.69, 1.00)
Adult exposed	1.00
Infant and toddler exposed	0.63 (0.51, 0.77)
Preschooler exposed	0.61 (0.51, 0.74)
School-aged exposed	0.63 (0.53, 0.74)
Adolescent exposed	0.71 (0.59, 0.86)

B

	OR (95% CI)
Smoking	
Adult exposed	1.00
Infant and toddler exposed	0.66 (0.30, 1.43)
Preschooler exposed	0.76 (0.37, 1.57)
School - aged exposed	0.91 (0.47, 1.76)
Adolescent exposed	0.90 (0.44, 1.85)
Adult exposed	1.00
Infant and toddler exposed	1.95 (0.68, 5.60)
Preschooler exposed	2.62 (0.97, 7.06)
School - aged exposed	1.87 (0.71, 4.91)
Adolescent exposed	1.97 (0.72, 5.37)
Adult exposed	1.00
Infant and toddler exposed	0.40 (0.34, 0.48)
Preschooler exposed	0.47 (0.40, 0.55)
School - aged exposed	0.53 (0.46, 0.61)
Adolescent exposed	0.71 (0.61, 0.84)
Adult exposed	1.00
Infant and toddler exposed	0.49 (0.40, 0.60)
Preschooler exposed	0.55 (0.46, 0.66)
School - aged exposed	0.58 (0.49, 0.68)
Adolescent exposed	0.70 (0.59, 0.84)

FIGURE 2. Adjusted *OR*s and 95% *CI*s for healthy behaviors in hypertensive populations with different early malnutrition exposures, stratified by gender, in Jia County, Pingdingshan City, Henan Province, China, 2023. (A) Male; (B) Female. Abbreviation: BMI=body mass index; WC=waist circumference; *OR*=odds ratio; *CI*=confidence interval.
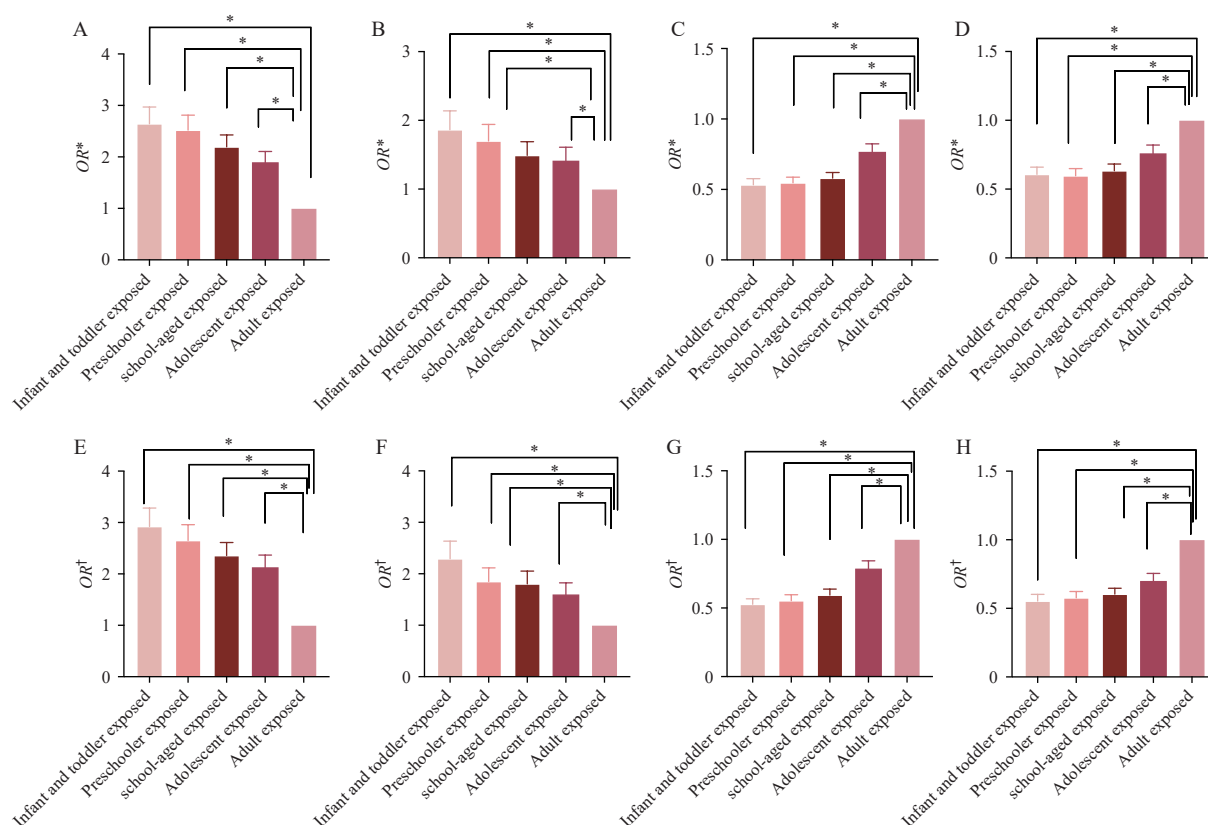
FIGURE 3. Sensitivity analysis of the association between early malnutrition exposure and healthy behaviors in hypertensive populations in Jia County, Pingdingshan City, Henan Province, 2023. (A) The association between different exposure groups and the risk of smoking after excluding participants with diabetes; (B) The association between different exposure groups and the risk of alcohlol consumption after excluding participants with diabetes; (C) The association between different exposure groups and the risk of healthy BMI after excluding participants with diabetes; (D) The association between different exposure groups and the risk of healthy WC after excluding participants with diabetes; (E) The association between different exposure groups and the risk of smoking after excluding participants with coronary heart disease; (F) The association between different exposure groups and the risk of alcohlol consumption after excluding participants with coronary heart disease; (G) The association between different exposure groups and the risk of healthy BMI after excluding participants with coronary heart disease; (H) The association between different exposure groups and the risk of healthy WC after excluding participants with coronary heart disease.

Abbreviation: BMI=body mass index; WC=waist circumference; OR=odds ratio; CI=confidence interval.

* Indicates excluding participants with diabetes.

† Indicates excluding participants with coronary heart disease.

conservation to adapt to food shortages. However, once these periods end, this lowered metabolic rate may persist, increasing the likelihood of fat accumulation and contributing to obesity in later life (9).

The present study has several strengths. This comprehensive investigation involved hypertensive populations across an entire county, lending considerable rigor to the conclusions. Additionally, this study simultaneously measured and analyzed multiple healthy lifestyle factors, providing a more holistic understanding of the associations between lifestyle and health outcomes.

However, there are also several limitations. First, the

respondents in this study were generally older, which might have introduced a survivor bias. To address this, we included age as a covariate in the regression analysis to minimize its impact on the study outcomes and mitigate potential differences between age groups. We also performed sensitivity analyses to confirm the robustness of our findings; the results consistently supported the study's main conclusions. Although survivor bias remains a possibility, we implemented multiple measures to control and account for its effects, ensuring the reliability of our results. Second, lifestyle behaviors were self-reported, potentially introducing recall bias. Third, this study did not account for the potential influence of local climate,

cultural dietary practices, or regional birth rates on early malnutrition. These factors may play important roles in childhood nutritional status and warrant further investigation. Future research should explore their impact to provide a more comprehensive understanding of the determinants of early malnutrition and offer deeper insights into the long-term effects of early-life malnutrition on health and behavior. This study focused on selected lifestyle behaviors, including smoking, alcohol consumption, BMI, and waist circumference. Other relevant behavioral factors, such as diet, physical activity, and sleep, were not assessed. Future research should include these variables to provide a more holistic understanding of the long-term impact of early-life malnutrition.

In conclusion, malnutrition at various developmental stages can lead to an increased risk of unhealthy lifestyle habits, including smoking, alcohol consumption, and obesity, in later years. Targeted health policies that provide nutritional support and behavioral monitoring for those exposed to early-life malnutrition may be effective in mitigating the elevated risk of smoking, drinking, and obesity in old age.

[#] Corresponding author: Ronghai Bie, brongh@zzu.edu.cn.

[1] Department of Health Management, College of Public Health, Zhengzhou University, Zhengzhou City, Henan Province, China; [2] Henan University of Chinese Medicine, Zhengzhou City, Henan Province, China.

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Preplanned Studies

Estimating Hospitalization Expenditures Associated with Chronic Diseases and Multimorbidity for Older Adults — Guangzhou City, Guangdong Province, China, 2017–2019

Fei Zhao[1]; Yang Li[1]; Xuyan Lou[1]; Molin Li[1]; Chao Ma[2]; Wei Xu[3]; Yangdong Fan[4]; Yang Jiao[5]; Yihan Wu[2]; Zhuo Chen[1,6,#]

Summary

What is already known about this topic?

Chronic diseases and multimorbidity impose substantial burdens on healthcare systems globally, particularly in aging populations, resulting in elevated healthcare utilization rates and increased expenditures.

What is added by this report?

This study validates previous research findings using an extensive administrative database from a major city in South China. Additionally, it provides comprehensive estimates of annual hospitalization expenditures per patient associated with chronic diseases and multimorbidity patterns among older adults, elucidating the economic burden and cost variations across specific diseases and multimorbidity combinations. Cancer, cerebrovascular disease (CVD), and heart disease — whether occurring individually or in conjunction with other chronic conditions, particularly within complex multimorbidity patterns — were associated with substantial annual hospitalization expenditures and significant healthcare resource utilization.

What are the implications for public health practice?

Disease burden studies provide critical evidence for prioritizing public health policies and targeted interventions. Policymakers should implement comprehensive prevention strategies, evidence-based interventions, appropriate reimbursement policies, and integrated management approaches to control disease progression and reduce healthcare expenditures.

ABSTRACT

Introduction: Chronic diseases and multimorbidity are increasingly prevalent among older adults in China, contributing substantially to hospitalization burden. However, real-world evidence on their direct medical expenditures remains limited.

Methods: This study employed a retrospective analysis by using hospital discharge data from Guangzhou during 2017–2019, and adopted generalized linear models (GLMs) to estimate hospitalization expenditures across chronic disease and multimorbidity patterns.

Results: Older patients with multimorbidity incurred nearly double the median annual hospitalization expenditures (3,708 USD vs. 1,844 USD) and 45% higher costs per additional condition compared to single diseases. Hospitalization cost varied by specific diseases and multimorbidity patterns. Schizophrenia (7,421.3 USD) has the highest annual total hospitalization expenditure (THE) among single chronic diseases while the combination of cancer + CVD + heart disease (10,698.8 USD for THE, 4,024.6 USD for out-of-pocket expenditure) ranked the top expenditures among multimorbidity patterns. Approximately 57.1% of disease combinations exhibited super-additive spending.

Conclusion: This study provides robust evidence of the substantial economic burden of chronic diseases and multimorbidity. The findings underscore the need for an integrated care model, evidence-based strategies to optimize healthcare resource allocation and health outcomes in aging populations.

Chronic diseases have emerged as major public health challenges in China, with their prevalence and incidence rates increasing rapidly over the past two decades. Multimorbidity, defined as the co-occurrence of two or more chronic diseases, results in poorer health-related quality of life and higher health service utilization and expenditures compared to single

conditions (*1–3*). In China, multimorbidity prevalence exhibits a marked age gradient, ranging from 30.2% (aged 50–54 years) to 57.5% (aged 80–84 years), with corresponding mortality rates of 15.92–24.80 per 1,000 person-years among those ≥65 years (*1–2*). Multimorbid patients constitute 72.7% of outpatient and 77.3% of inpatient services among adults aged ≥50 years, with their annual hospitalization costs varying between physical [3,703.2 Chinese Yuan (CNY)] and physical-mental (5,969.5 CNY) multimorbidity patterns, underscoring their substantial healthcare burden (*3*). Understanding expenditures related to chronic multimorbidity among older adults is therefore crucial for informed decision-making. This study examines the impact of specific chronic diseases and multimorbidity patterns on hospitalization spending by comparing sociodemographic characteristics, annual hospitalization healthcare resource utilizations (HCRUs), and costs between older patients with single chronic conditions and those with multimorbidity using real-world hospital discharge data. Key findings reveal that schizophrenia imposes a substantial economic burden on both payers and families. Cancer, cerebrovascular disease (CVD), and heart disease — whether occurring alone or within complex multimorbidity patterns — are also associated with high annual hospitalization expenditures and significant resource utilization. This knowledge is essential for guiding resource allocation, designing cost-effective prevention and intervention strategies, and ultimately reducing socioeconomic burden while improving quality of life and enhancing population health outcomes.

Despite numerous studies exploring the association between multimorbidity and healthcare costs, a significant gap remains in understanding the economic burden of multimorbidity in China. Existing research typically focuses on a limited range of chronic conditions, employs overly simplistic definitions of multimorbidity, and frequently relies on self-reported data, resulting in biased and inconsistent estimates. This study adopts a comprehensive approach to accurately assess this burden, providing robust evidence for public policy and practice. It employed a retrospective cohort design using a de-identified hospital discharge database from 273 public hospitals and medical institutions in Guangzhou (2017–2019). Patients aged 50 years or older with 1 or more of 40 predefined chronic conditions (Supplementary Table S1, available at https://weekly.chinacdc.cn/)

were categorized into single disease or multimorbidity cohorts based on the number of unique chronic conditions for which they were hospitalized as the primary diagnosis. This study then excluded hospitalization records for non-targeted conditions to maintain data accuracy and relevance. Descriptive analyses were conducted to characterize patient demographics, HCRUs, and expenditures across cohorts and by specific chronic diseases and multimorbidity patterns. This study also used generalized linear models (GLMs) with gamma distribution and log-link function to examine the correlation between multimorbidity and annual hospitalization spending, as well as to estimate the impact on annual total hospitalization expenditures (THE) and annual hospitalization out-of-pocket expenditures (OOPE) associated with specific chronic diseases and multimorbidity patterns. GLM accounts for the skewed distribution of cost data. All analyses were conducted in SAS (version 9.4, SAS Institute Inc., Cary, NC, USA).

After applying sample inclusion and exclusion criteria (Supplementary Figure S1, available at https://weekly.chinacdc.cn/), the overall cohort comprised 273,452 patients, with 159,847 (58.5%) having a single chronic condition and 113,605 (41.5%) experiencing multimorbidity. The mean age was 68.9 years, with multimorbidity patients being older (mean age 70.1 years) compared to those with a single chronic condition (mean age 68.1 years). Patients aged 65 or above and women demonstrated significantly higher rates of multimorbidity than their younger and male counterparts, respectively ($P<0.0001$). Multimorbidity patients averaged 2.03 (±1.83) inpatient visits and experienced longer hospital stays (mean 20.2±31.2 days) compared to those with a single chronic condition. The crude median annual THE and OOPE in the multimorbidity cohort were [3,708.1 United States Dollars (USD)] and 1,844.6 USD, respectively — nearly double those observed in patients with a single chronic condition. Overall, traditional Chinese medicine (TCM) expenditures accounted for approximately 15.8% of total medication expenses (Table 1).

The most prevalent chronic diseases among hospitalized patients were heart disease (9.7%), CVD (9.5%), and cancer (6.8%). Annual hospitalization duration varied substantially across conditions, ranging from 2.1 (±1.7) days for senile cataracts to 19.4 (±40.9) days for CVD. The most common multimorbidity patterns included CVD + heart disease

TABLE 1. Patient demographics, crude annual healthcare resource utilization, and costs of elderly hospitalized patients.

Variables	Overall (N=273,452)	Single condition (N=159,847)	Multimorbidity (N=113,605)	P
Age (at initial inpatient admission) [mean (SD)]	68.97 (11.34)	68.14 (11.70)	70.13 (10.71)	<0.0001
Age category (n, %)				
50–64	106,765 (39.04)	67,985 (42.53)	38,780 (34.14)	<0.0001
65–79	108,904 (39.83)	59,786 (37.40)	49,118 (43.24)	
≥80	57,783 (21.13)	32,076 (20.07)	25,707 (22.63)	
Gender (n, %)				
Male	128,536 (47.00)	77,148 (48.26)	51,388 (45.23)	<0.0001
Female	144,916 (53.00)	82,699 (51.74)	62,217 (54.77)	
Insurance type (n, %)				
UEBMI	179,635 (65.69)	107,869 (67.48)	71,766 (63.17)	<0.0001
URRBMI	93,817 (34.31)	51,978 (32.52)	41,839 (36.83)	
Follow-up period (n, %)				
1 year	107,613 (39.35)	94,470 (59.10)	13,143 (11.57)	<0.0001
2 years	95,803 (35.03)	48,757 (30.50)	47,046 (41.41)	
3 years	70,036 (25.61)	16,620 (10.40)	53,416 (47.02)	
Number of chronic conditions [mean (SD)]	1.23 (1.11)	1.00 (0)	2.64 (0.96)	<0.0001
Number of chronic conditions (category, n, %)				
2			67,245 (59.19)	
3			28,512 (25.10)	
≥4			17,848 (15.71)	
Inpatient healthcare utilization (PPPY)				
Inpatient visits [mean (SD)]	1.55 (1.57)	1.21 (1.26)	2.03 (1.83)	<0.0001
Days of hospitalization [mean (SD)]	16.05 (32.26)	13.10 (32.66)	20.21 (31.21)	<0.0001
Number of surgeries (n, %)				
No surgeries	171,487 (62.71)	114,139 (71.41)	57,348 (50.48)	<0.0001
1 surgery	51,360 (18.78)	21,175 (13.25)	30,185 (26.57)	
2 surgeries	23,506 (8.60)	10,638 (6.66)	12,868 (11.33)	
≥3 surgeries	27,099 (9.91)	13,895 (8.69)	13,204 (11.62)	
Inpatient cost (PPPY)				
Total hospitalization expenditures (median, IQR)	2,491.6 (4,323.1)	1,844.6 (3,003.4)	3,708.1 (5,324.4)	<0.0001
Cost=0 (n, %)	0 (0)	0 (0)	0 (0)	
Total medication expenditures (median, IQR)	632.7 (1,127.5)	436.3 (840.3)	951.7 (1,369.6)	<0.0001
Cost=0 (n, %)	398 (0.15)	398 (0.25)	0 (0)	
Total traditional Chinese medicine expenditures (median, IQR)	100.5 (250.8)	54.5 (187.7)	172.4 (297.3)	<0.0001
Cost=0 (n, %)	42,470 (15.53)	38,479 (24.07)	3,991 (3.51)	
Total hospitalization out-of-pocket expenditures (median, IQR)	675.1 (1,124.3)	529.1 (831.2)	947.8 (1,395.5)	<0.0001
Cost=0 (n, %)	39 (0.01)	37 (0.02)	2 (0)	
Total cost covered by basic medical insurance (median, IQR)	1,554.7 (2,702.5)	1,151.0 (1,946.2)	2,266.9 (3,386.4)	<0.0001
Cost=0 (n, %)	193 (0.07)	193 (0.12)	0 (0)	

Note: Age refers to the patient's age at their first inpatient visit during 2017–2019; Follow-up years are defined as the number of unique calendar years in which patients received at least one hospitalization for any reason in a given year; PPPY: Per person per year is calculated by dividing each patient's total inpatient health utilizations/costs from 2017 to 2019 by their follow-up years, then averaging these totals by the number of patients; All costs were adjusted for inflation to the year 2019 CNY using the national CPI and converted to 2019 USD at an exchange rate of 1 CNY=0.1449 USD. "Cost=0" in this table indicates the No. of patients with zero expenditures.
Abbreviation: SD=standard deviation; IQR=interquartile range; PPPY=per patient per year; CNY=Chinese yuan; USD=United States dollar; CPI=Consumer price index; UEBMI=Urban employee basic medical insurance; URRBMI=Urban resident basic medical insurance.
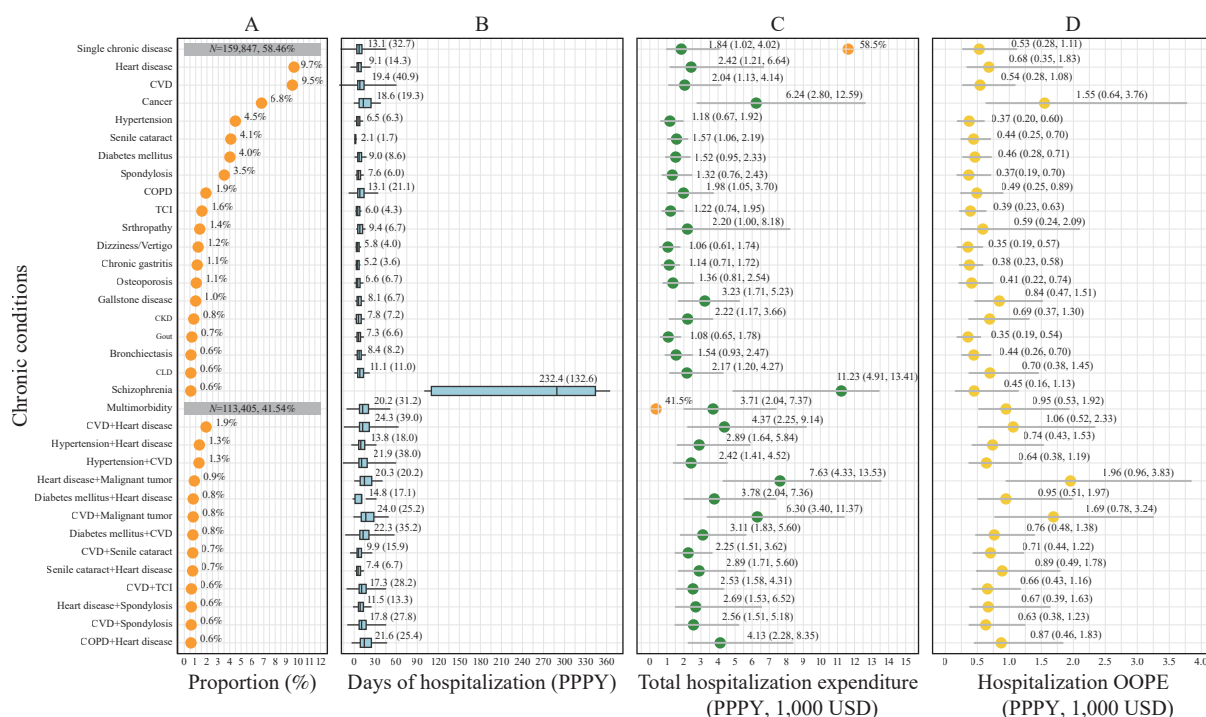
FIGURE 1. Descriptive statistics (PPPY) by specific diseases and multimorbidity patterns (ordered by proportion of hospitalized patient). (A) Proportion of patients hospitalized due to diseases; (B) Annual days of hospitalization; (C) Annua Total hospitalization expenditure (Crude); (D) Annual hospitalization Out-of-Pocket expenditure (Crude).

Note: Only chronic diseases and multimorbidity patterns with a patient proportion hospitalized during 2017–2019 greater than 500 per 100,000 are presented. Mean (SD) is shown for annual days of hospitalization; median (Q1, Q3) is shown for annual total hospitalization expenditure and annual hospitalization OOPE.

Abbreviation: PPPY=per patient per year; OOPE=out-of-pocket expenditure; SD=standard deviation; CVD=cerebrovascular disease; COPD=chronic obstructive pulmonary disease; TCI=transient cerebral ischemia; USD=United States dollar.

(1.9%), hypertension + heart disease (1.3%), and hypertension + CVD (1.3%), with cancer-based multimorbidity combinations resulting in the longest hospital stays and highest associated costs (Figure 1).

GLM analyses revealed that each additional chronic condition increased annual THE and OOPE by approximately 20%. Patients with two conditions experienced a 29% increase in THE and 28% increase in OOPE; those with three conditions showed a 54% increase in THE and 52% increase in OOPE; patients with four or more conditions demonstrated a 97% increase in THE and 87% increase in OOPE. Overall, multimorbidity was associated with 45% higher THE and 43% higher OOPE compared to single chronic conditions (Table 2).

Among single chronic diseases, schizophrenia demonstrated the highest estimated annual THE at 7,421.3 USD per patient per year (PPPY), followed by cancer at 5,751.6 USD, spleen disease at 4,405.8 USD, and arthropathy at 4,216.2 USD. For multimorbidity patterns, the combination of CVD + heart disease + cancer resulted in the most substantial costs, with an

estimated annual THE of 10,698.8 USD and OOPE of 4,024.6 USD per patient. Other high-cost multimorbidity patterns included cancer-based dyads combined with arthropathy, chronic liver disease, anemia, heart disease, chronic obstructive pulmonary disease (COPD), and spondylosis, which generated annual THE ranging from 5,000 USD to 7,000 USD PPPY (Supplementary Figure S2, available at https://weekly.chinacdc.cn/).

The analysis revealed significant cost variations across different chronic diseases and multimorbidity patterns. Approximately 57.1% of disease combinations exhibited super-additive spending effects (where combined costs exceeded the sum of individual disease costs), 10% demonstrated additive spending patterns (where combined costs approximated the sum of individual diseases), and 32.9% showed sub-additive spending effects (where combined costs fell below the sum of individual diseases). Notably, the three largest super-additive effects in annual THE occurred in combinations of CVD + dementia (+1,496.6 USD), CVD + heart disease + cancer (+1,013.2 USD), and heart

TABLE 2. The association of multimorbidity and hospitalization expenditures among older adults.

Cohort	Estimated total hospitalization costs (PPPY)				Estimated annual hospitalization OOPE (PPPY)			
	Exp. (coefficient)	Stderr	95% *CI* lower	95% *CI* upper	Exp. (coefficient)	Stderr	95% *CI* lower	95% *CI* upper
Model 1								
Intercept* (USD)	2,611.3	0.0045	2,588.4	2,634.4	673.1	0.0045	667.2	679.1
No. of chronic conditions (range from 1-11)	1.22	0.0016	1.22	1.23	1.21	0.0016	1.20	1.21
Model 2								
Intercept† (USD)	3,143.4	0.0039	3,119.2	3,167.8	797.7	0.0039	791.6	803.9
One condition (reference)	1.00		1.00	1.00	1.00		1.00	1.00
Multimorbidity	1.45	0.0032	1.44	1.46	1.43	0.0033	1.42	1.44
Model 3								
Intercept† (USD)	3,157.8	0.0048	3,133.7	3,182.1	800.5	0.0039	794.4	806.6
One condition (reference)	1.00		1.00	1.00	1.00		1.00	1.00
Two conditions	1.29	0.0038	1.28	1.29	1.28	0.0038	1.27	1.29
Three conditions	1.54	0.0053	1.53	1.56	1.52	0.0053	1.51	1.54
Four or more conditions	1.97	0.0066	1.95	2.00	1.87	0.0065	1.84	1.89

Abbreviation: PPPY=per patient per year; OOPE=out-of-pocket expenditure; No.=number; UEBMI=urban employee basic medical insurance; *CI*=confidence interval.
* Age=50, sex=female, insurance type=UEBMI.
† Age=50, sex=female, insurance type=UEBMI, with single chronic condition.

disease + diabetes mellitus (+980.3 USD). Conversely, cancer + heart disease (–2,394.2 USD), cancer + arthropathy (–2,323.3 USD), and cancer + CVD (–1,435.4 USD) demonstrated the most pronounced sub-additive effects on expenditures (Supplementary Figure S2).

DISCUSSION

This study provides a comprehensive analysis of hospitalization expenditures associated with chronic diseases and multimorbidity patterns among older adults in Guangzhou City, Guangdong Province, China. Its findings align with previous research demonstrating that elderly patients and women are more likely to develop multimorbidity. A US epidemiologic review showed that 67% of Medicare beneficiaries had multimorbidity, with higher prevalence in older age groups and among women. This pattern reflects the "male-female health-survival paradox," where women experience higher rates of chronic diseases but tend to live longer, while men are more prone to severe conditions such as cancer and ischemic heart disease (*4*). This study confirms the increased healthcare resource utilization and costs associated with multimorbidity, consistent with existing literature (*3*). Schizophrenia costs 7,421.3 USD PPPY in our study, similar to Zhong et al.'s

estimate of 8,061 USD for long-action injectable and 6,822 USD for orally treated schizophrenia patients (*5*). While Chen et al. observed a 3.4-fold cost increase for multimorbid patients in Beijing, higher than our study's estimates (*6*). Zhao et al. reported lower annual per-capita inpatient costs attributable to heart disease, chronic lung disease, and stroke or cardiovascular disease (*7*). These discrepancies likely reflect methodological variations in population sampling, diseases, and cost definitions.

This study observes significant heterogeneity in hospitalization costs across different multimorbidity patterns, primarily driven by variations in physiological functions and corresponding treatment approaches. Our findings demonstrate that organ-related multimorbidity, particularly involving cancer, CVD, and heart disease, incurs substantially higher hospitalization expenditures compared to sensory-related conditions. These complex diseases require intensive, specialized medical resources and prolonged inpatient care, making them less amenable to outpatient or community-based management. In contrast, foundational chronic conditions like hypertension and diabetes show relatively lower hospitalization costs, reflecting the successful implementation of past health policies and resource investments in chronic disease management. However, our analyses reveal potentially inefficient healthcare

utilization patterns, with many chronic disease patients receiving primarily medication and nursing care during hospitalization, suggesting opportunities for more cost-effective outpatient management for multimorbidity.

An interesting finding is the super-additive effect observed in certain multimorbidity patterns, where combined costs exceed the sum of individual diseases. This phenomenon results from disease complexity (e.g., physiological differences in mental–physical multimorbidity treatment cumulatively drive higher healthcare costs), polypharmacy-related risks (e.g., adverse drug events and inappropriate prescriptions), and overlapping healthcare utilization (e.g., redundant diagnostics). Multimorbidity further amplifies costs through bidirectional pathways, such as inflammation escalation, impaired self-management and frailty-associated care demands, which compound these challenges (8). Conversely, most triad multimorbidity patterns exhibited a sub-additive effect, suggesting that combined spending is less than the sum of individual conditions. This may result from synergistic or detrimental effects in care-seeking behaviors, where the presence of multiple conditions influences how patients seek and receive care. These insights underscore the need for tailored interventions to effectively manage specific multimorbidity patterns, ensuring efficient and effective use of healthcare resources.

The findings highlight several key implications for clinical practice and policy development. First, optimizing comprehensive medical care models through multidisciplinary teams (including geriatricians, nurses, and rehabilitation specialists) could enhance clinical outcomes while shortening hospitalization stays (9). Second, implementing transitional care programs, such as pre-discharge planning and community health service integration, could minimize unplanned readmissions. Third, exploring alternative therapeutic approaches, such as traditional Chinese medicine, might offer cost-effective disease management options. From a policy perspective, current reimbursement systems inadequately address cost variations across multimorbidity patterns, potentially burdening vulnerable populations (10). Strategic reforms should focus on 1) shifting from disease-centered to patient-centered care models to reduce duplicate procedures and polypharmacy; 2) optimizing diagnosis-intervention packetage reimbursement payment systems and commercial insurance programs by incorporating more complex risk-adjusted multimorbidity patterns instead of simple Charlson Comorbidity Index; 3) public health priorities should balance high-prevalence and high-cost patterns, as the former dominate aggregate expenditures despite lower hospitalization costs; 4) improving primary care quality and accessibility for rural and low-income populations as prevention management. More evidence needs to be explored for multimorbidity management in China's aging population.

This study has several limitations that warrant acknowledgment. The analysis focused exclusively on primary diagnosis codes, excluded patients without chronic conditions, and utilized data from a single metropolitan area, which may limit the generalizability of findings to other populations and healthcare systems. Despite these constraints, the comprehensive nature of this study's dataset — encompassing real-world data from 273 public hospitals and medical institutions, analyzing 40 distinct chronic conditions, and providing detailed examination of both individual diseases and multimorbidity patterns — offers robust and reliable estimates for hospitalization expenditures among older adults.

In conclusion, this study quantifies the substantial direct hospitalization costs associated with chronic diseases and multimorbidity among older adults in Guangzhou City, underscoring the urgent need for targeted interventions and integrated care models. These findings provide essential evidence for policymakers and healthcare providers to develop comprehensive strategies for preventing and managing chronic diseases and multimorbidity. Such strategies should ultimately optimize resource allocation, improve patient outcomes, and reduce the overall economic burden on healthcare systems. Future research should examine diverse populations across different geographic regions and healthcare settings to enhance our understanding of the economic impact and evaluate the cost-effectiveness of various care delivery models, thereby extending the applicability of these findings to broader healthcare contexts.

Corresponding author: Zhuo Chen, zhuo.chen@nottingham.edu.cn.

¹ School of Economics, Faculty of Humanities and Social Sciences, University of Nottingham Ningbo China, Ningbo City, Zhejiang Province, China; ² School of Economics and Management, Southeast University, Nanjing City, Jiangsu Province, China; ³ School of International Pharmaceutical Business, China Pharmaceutical University, Nanjing City, Jiangsu Province, China; ⁴ School of Health Management, Guangzhou Medical University, Guangzhou City, Guangdong Province, China; ⁵ Department of Accounting, Economics, and Finance, Texas A&M University-Texarkana, Texarkana, TX, USA; ⁶ Department of Health Policy and Management, College of Public Health, University of Georgia, Athens, GA, USA.
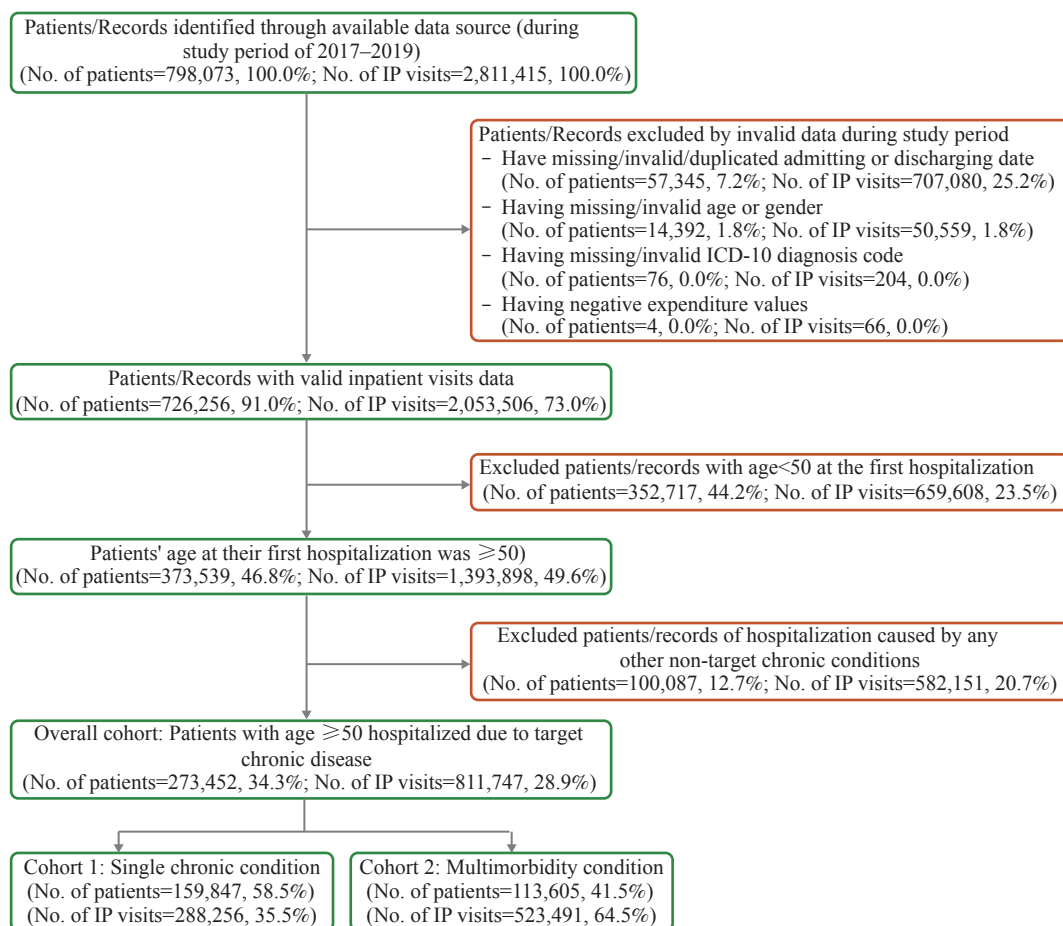
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SUPPLEMENTARY MATERIALS

Chronic Conditions Considered in this Study

A total of 40 chronic conditions (Supplementary Table S1) were selected based on diseases most frequently cited in multimorbidity literature that were deemed to significantly impact long-term treatment outcomes and quality of life among elderly Chinese populations (*1–3*).

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┌────────────────────────────────────────────────┐
│ Patients/Records identified through available   │
│ data source (during study period of 2017–2019)  │
│ (No. of patients=798,073, 100.0%; No. of IP     │
│ visits=2,811,415, 100.0%)                        │
└────────────────────────────────────────────────┘
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Patients/Records excluded by invalid data during study period
 – Have missing/invalid/duplicated admitting or discharging date
   (No. of patients=57,345, 7.2%; No. of IP visits=707,080, 25.2%)
 – Having missing/invalid age or gender
   (No. of patients=14,392, 1.8%; No. of IP visits=50,559, 1.8%)
 – Having missing/invalid ICD-10 diagnosis code
   (No. of patients=76, 0.0%; No. of IP visits=204, 0.0%)
 – Having negative expenditure values
   (No. of patients=4, 0.0%; No. of IP visits=66, 0.0%)

Patients/Records with valid inpatient visits data
(No. of patients=726,256, 91.0%; No. of IP visits=2,053,506, 73.0%)

Excluded patients/records with age<50 at the first hospitalization
(No. of patients=352,717, 44.2%; No. of IP visits=659,608, 23.5%)

Patients' age at their first hospitalization was ≥50)
(No. of patients=373,539, 46.8%; No. of IP visits=1,393,898, 49.6%)

Excluded patients/records of hospitalization caused by any other non-target chronic conditions
(No. of patients=100,087, 12.7%; No. of IP visits=582,151, 20.7%)

Overall cohort: Patients with age ≥50 hospitalized due to target chronic disease
(No. of patients=273,452, 34.3%; No. of IP visits=811,747, 28.9%)

Cohort 1: Single chronic condition
(No. of patients=159,847, 58.5%)
(No. of IP visits=288,256, 35.5%)

Cohort 2: Multimorbidity condition
(No. of patients=113,605, 41.5%)
(No. of IP visits=523,491, 64.5%)

SUPPLEMENTARY FIGURE S1. Study flow diagram for population selection.
Abbreviation: No.=Number; IP=Inpatient.

Statistical Methods

For descriptive analysis, continuous variables with skewed distributions of hospitalization expenditures (THE and OOPE) were presented as median (Q1, Q3), while normally distributed HCRUs were expressed as mean (±standard deviation). Between-group comparisons of mean measurements were conducted using t-tests and ANOVA, while median measurements were compared using non-parametric Wilcoxon rank sum tests and Kruskal-Wallis rank sum tests. Chi-square tests were employed to assess differences in categorical variables.

In GLM analysis, the association between multimorbidity (binary or multivariate) and hospitalization expenditures (annual total and OOPE) was modeled as:

$$\ln\left(E\left(Y_i|X_i\right)\right) = \beta_{0i} + \beta_{1i}x_{multimorbidity_i} + \beta_{2i}x_{age_i} + \beta_{3i}x_{gender_i} + \beta_{4i}x_{insurancetype_i} + \varepsilon_i$$

To estimate hospitalization spending related to specific chronic diseases and multimorbidity patterns, and to assess super-additive, additive, and sub-additive effects, we employed the following model:
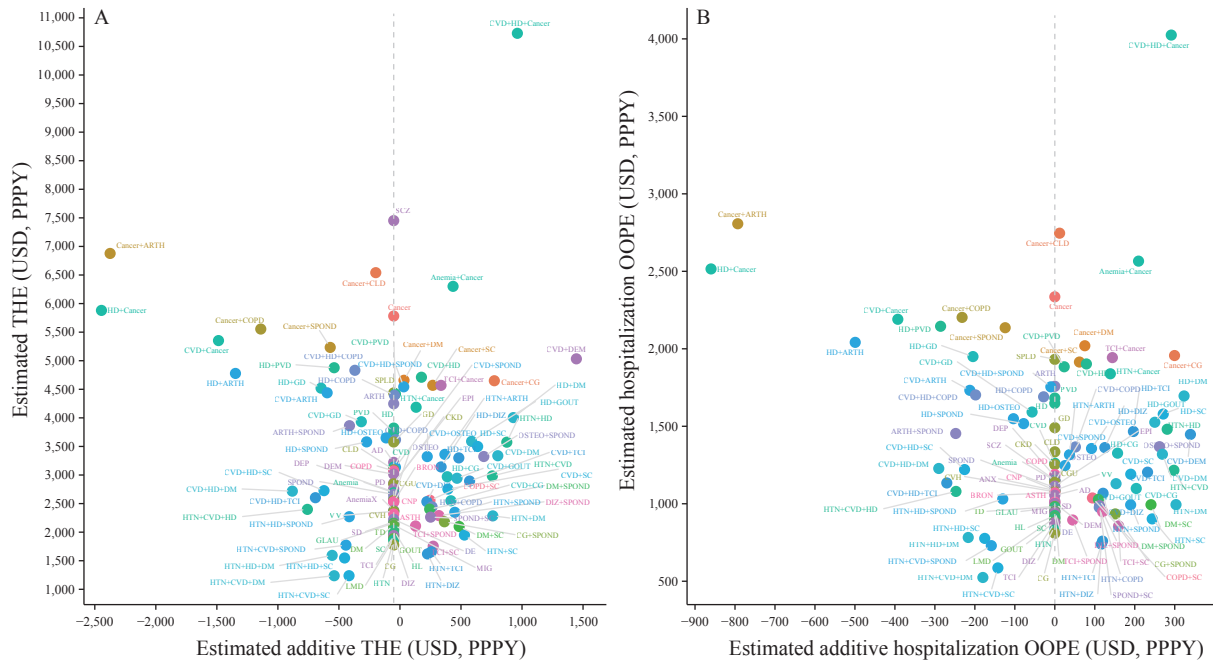
SUPPLEMENTARY FIGURE S2. Estimated annual hospitalization expenditures for chronic diseases and multimorbidity patterns. (A) Estimated Annual Total Hospitalization Expenditure; (B) Estimated Annual Hospitalization Out-of-Pocket Expenditure.

Abbreviation: THE=total hospitalization expenditure; PPPY=per patient per year; OOPE=out-of-pocket expenditure.

$$\ln\left(E\left(Y_i|X_i\right)\right) = \beta_{0i} + \sum_{j=1}^{J}\beta_{ij}dx_{ij} + \sum_{k=1}^{K}\beta_{ik}dyad_{ik} + \sum_{l=1}^{L}\beta_{il}triad_{il} + \beta_{2i}x_{agei} + \beta_{3i}x_{genderi} + \beta_{4i}x_{insurancetypei} + \varepsilon_i$$

Where i represents the patient, Y_i denotes the outcome variables including annual THE and annual hospitalization OOPE. X_i represents a matrix of explanatory variables and covariates where dx_{ij} indicates each of the 40 target chronic conditions, $dyad_{ik}$ and $triad_{il}$ represent the interaction terms for possible chronic condition dyads and triads, respectively. x_{agei}, $x_{genderi}$, and $x_{insurancetypei}$ are covariates and ε_i represents the error term.

All expenditure variables were adjusted for inflation to 2019 Chinese Yuan using the national Consumer Price Index and converted to 2019 US dollars (1.0 CNY = 0.1449 USD). All statistical analyses were performed using SAS (version 9.4, SAS Institute Inc., Cary, NC, USA).

SUPPLEMENTARY TABLE S1. List of chronic conditions with ICD-10 codes.

Chronic condition name	ICD-10 Code
Cancers	
Cancer	C00-C97
Heart/vascular diseases	
Hypertension (HTN)	I10-I15
Varicose veins (VV)	I83
Cerebrovascular disease (CVD)	I60-I69
Heart disease (HD)	I05-I09, I20-I27, I34-I37, I44-I49, I50, I51.9
Peripheral vascular disease (PVD)	I70-I73.9
Anemia	D50-D64
Endocrine/metabolic diseases	
Thyroid disorders (TD)	E02-E03, E05
Diabetes mellitus (DM)	E10-E14
Gout	E79, M10
Lipoprotein metabolism disorder (LMD)	E78
Respiratory diseases	
Chronic nasopharyngitis (CNP)	J31.0-31.2, J32
Chronic obstructive pulmonary disease (COPD)	J44
Asthma (ASTH)	J45-J46
Bronchiectasis (BRON)	J47
Neurological/Mental disorders	
Alzheimer's disease (AD)	G30
Epilepsy (EPI)	G40
Transient cerebral ischemia (TCI)	G45
Parkinson's disease (PD)	G20-G22
Migraine (MIG)	G43, G44
Anxiety disorders (ANX)	F40-F41
Schizophrenia (SCZ)	F20
Major depressive disorder (DEP)	F32-F33
Dementia (DEM)	F00-F03
Sleep disorders (SD)	F51, G47
Dizziness and vertigo (DIZ)	R42, H81.0-H82
Musculoskeletal/Dermatological conditions	
Osteoporosis (OSTEO)	M80-M82
Arthropathy (ARTH)	M15-M19
Spondylosis (SPOND)	M45-M49
Dermatitis and eczema (DE)	L20-L30
Digestive/Genitourinary diseases	
Gallstone disease (GD)	K80
Chronic liver disease (CLD)	K70, K71.3-K71.5, K71.7, K72.1, K73-E76
Chronic gastric ulcer (CGU)	K25.4-K25.9
Chronic gastritis (CG)	K29.3-K29.5
Chronic kidney disease (CKD)	N03-04, N06-N08, N11, N13

Continued

Chronic condition name	ICD-10 Code
Spleen disease (SD)	D73
Chronic viral hepatitis (CVH)	B18
Eye/Ear diseases	
Senile cataract (SC)	H25, H28.0-H28.2
Glaucoma (GLAU)	H40-H42
Hearing loss (HL)	H90-H91

Abbreviation: ICD-10=International classification of diseases, 10th revision, Chinese edition.

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