# Trends and inequalities in physical fitness and nutritional status among 0.72 million Chinese adults aged 20–59 years: an analysis of five successive national surveillance surveys, 2000–2020

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## Summary

**Background** Few comprehensive studies have assessed the long-term trends in physical fitness and nutritional status among Chinese adults, along with the socioeconomic inequalities. This study aimed to bridge this gap by examining the temporal changes and the evolution of socioeconomic disparities in physical fitness and nutritional status among Chinese adults aged 20–59, based on five successive national surveillance surveys.

**Methods** We integrated data from five consecutive rounds of National Physical Fitness Surveillance (2000, 2005, 2010, 2014, and 2020) among Chinese adults aged 20–59 years. BMI was categorized into underweight (<18.5 kg/m$^2$), overweight (24.0–27.9 kg/m$^2$), and obesity (≥28.0 kg/m$^2$). Central obesity was defined as a waist circumference ≥90 cm for males and ≥85 cm for females. A composite physical fitness indicator (PFI) was calculated by aggregating the Z-scores of all six components. Provinces were ranked by GDP per capita ($) and stratified into three socioeconomic strata from least (T1) to most developed (T3). Generalized additive models (GAMs), adjusted for age and sex, were employed to assess the associations between nutritional status, PFI, and both per capita GDP and urbanization levels.

**Findings** A total of 716,790 Chinese adults aged 20–59 were included in the analysis. The PFI score declined from 0.71 in 2000 to −0.84 in 2020, with a particularly sharp annual decline between 2014 and 2020. The underweight prevalence declined from 5.54% in 2000 to 3.51% in 2020, while the prevalence of overweight, obesity, and central obesity increased to 35.84%, 15.05%, and 32.10% in 2020, respectively. After 2005, the urban-rural disparities in physical fitness narrowed, whereas the gap between most and least developed regions widened, with urban and high-SES regions consistently showing better fitness. The prevalence of overweight, obesity, and central obesity in urban and economically developed regions was higher than in less economically developed and rural regions in earlier years, but this pattern reversed over time. The underweight prevalence showed the opposite trend. With increasing GDP per capita, PFI initially rose before declining at higher levels, and it showed a positive correlation with urbanization. Overweight prevalence increased with GDP per capita but slowed at higher levels, while obesity and central obesity exhibited an N-shaped relationship with GDP per capita. Moreover, prevalence of overweight, obesity, and central obesity were positively correlated with urbanization.

**Interpretation** During the first two decades of the 21st century, China experienced rapid economic growth accompanied by declining physical fitness and rising prevalence of overweight, obesity, and central obesity among adults

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aged 20–59 years. Inequalities in nutritional status between urban and rural areas and across socioeconomic strata reversed. Less developed and rural regions may face dual challenges of deteriorating physical fitness and the growing burden of overnutrition, which requires urgent attention. The complex interplay between socioeconomic development, urbanization, and physical health further emphasizes the need for health policies tailored to diverse socioeconomic contexts and subpopulations.

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**Keywords:** National physical fitness surveillance; BMI; Physical fitness; Nutritional status

## Research in context

### Evidence before this study

We searched PubMed for relevant articles published in English and Chinese on Dec 16, 2024, without date restrictions using the following terms: “BMI”, “obesity”, “underweight ”, “overweight”, “waist circumference”, “central obesity”, “physical activity”, “physical fitness”, “China”, “Chinese population”, “economic*” and “urbanization”. A previous study examined the rise in the prevalence of overweight, obesity, and central obesity, along with the decline in physical fitness among Chinese adults between 2000 and 2014. However, it did not investigate regional socioeconomic or urban-rural disparities and trends, nor did it provide a comprehensive evaluation of various physical fitness indicators. Moreover, most studies on socioeconomic and urban-rural inequalities in nutritional status or physical fitness preferred to focus on children and adolescents. Few comprehensive studies have utilized nationally representative, large-scale, and repeated cross-sectional surveys to assess the trends in physical fitness and nutritional status among Chinese adults and the associated socioeconomic inequalities over the first two decades of the 21st century.

### Added value of this study

This study is the first repeated cross-sectional analysis to comprehensively assess long-term trends and socioeconomic inequalities in physical fitness and nutritional status among 716,790 Chinese adults aged 20–59 over a 20-year period (2000–2020). We found a continuous decline in underweight prevalence and physical fitness throughout the survey period, alongside an increasing prevalence of overweight, obesity, and central obesity. After 2005, the urban-rural disparities in physical fitness narrowed, whereas the gap between most and least developed regions widened, with urban and high-SES regions consistently showing better fitness. The prevalence of overweight, obesity, and central obesity in urban and high-SES regions were higher than in low-SES and rural regions in earlier years, but this pattern reversed over time. In contrast, the underweight prevalence exhibited an opposite trend. Notably, urban-rural inequalities for nutritional status differed between male and female subgroups. As GDP per capita increased, PFI initially rose before declining at higher levels, while the prevalence of obesity and central obesity followed an N-shaped relationship with GDP per capita. Additionally, PFI and the prevalence of excess weight and central obesity were positively correlated with urbanization.

### Implications of all the available evidence

During the first two decades of the 21st century, China experienced rapid economic growth alongside a decline in the physical fitness among the main labor force and a sharp increase in the prevalence of overweight, obesity, and central obesity. Less economically developed regions and rural areas are likely to face dual challenges of worsening physical fitness and an increasing burden of overnutrition in the future, which requires urgent attention. The complex relationships between socioeconomic development, urbanization, and physical health further underscore the need for targeted health policies tailored to diverse socioeconomic contexts and subpopulations.

## Introduction

Over the past few decades, China has experienced rapid economic expansion and profound social transformations, which have substantially influenced the population health and well-being.[1,2] As the prime working age population, the physical fitness and nutritional status of the 20–59 age group, plays a crucial role in determining national productivity and social health outcomes.[3] Physical fitness, encompassing multiple dimensions such as cardiovascular endurance, muscular strength, flexibility, balance, and reaction time, serves as a key indicator of health and work capacity.[4] It is influenced by various factors, including nutritional status, lifestyle, and socioeconomic position.[4–6] Lower physical fitness is associated with an increased risk of various health problems, including cardiovascular diseases, hypertension, diabetes, and cancer.[7] Indeed, physical inactivity has been identified as the fourth leading risk factor for premature death.[8] Despite a moderate rise in physical activity among Chinese adults from 2000 to 2014, metrics like lung capacity, muscular strength, flexibility, and balance have consistently declined.[9] Body mass index (BMI) and waist circumference serve as important measures of nutritional status.[10,11] Both underweight and obesity are associated with negative health outcomes throughout the lifespan.[10–12] While the underweight prevalence has declined in recent years, the prevalence of overweight, obesity, and central obesity has increased worldwide.[13] Many countries have transitioned from underweight to obesity as the predominant issue among adults, partly driven by increasing BMI in rural areas, which has become a major contributor to the global obesity epidemic.[14] Obesity has become a major risk factor for the non-communicable disease (NCDs), particularly in low- and middle-income countries.[15,16] Thus, optimal nutrition and health policies should address both undernutrition and overnutrition, as highlighted in Sustainable Development Goal (SDG) 2.2, which aims to the elimination of all forms of malnutrition.[13]

Declining physical fitness and poor nutritional status directly affect labor productivity, increase the risk of chronic diseases, and subsequently hamper overall societal productivity.[7,8,10–12] The complex interplay between social and economic development, physical fitness and nutritional status remains poorly understood, marked by considerable regional and social disparities.[17–19] Therefore, this study aimed to examine the long-term temporal changes and evolution of socioeconomic disparities in physical fitness and nutritional status among Chinese adults aged 20–59, based on five successive national surveillance surveys (2000–2020), hoping to shed light on the broader health dynamics within this population amid economic development and social transformations.

## Methods

### Study design and participants

The National Physical Fitness Surveillance (NPFS) is a nationwide program led by the General Administration of Sport of China, designed to assessing the physical fitness across the entire population. As previously reported, the NPFS employs a multistage, stratified probability cluster sampling design to ensure national representativeness, conducting standardized testing across all 31 provinces, autonomous regions, and municipalities in mainland China.[9] Initiated in 2000 and conducted every five years (2000–2020), with the fourth round advanced to 2014, the NPFS has consistently maintained sampling and measurement protocols using standardized procedures, equipment and quality control measures. The detailed sampling process has been outlined in previous publication and Supplementary Methods.[9] We integrated data from five consecutive rounds of the NPFS (2000, 2005, 2010, 2014, and 2020), excluding 21,796 participants (2.95%) with missing data or implausible physical fitness measures. Additionally, we performed a sensitivity analysis using the 2020 census data as the standard population to assess robustness (Supplementary Methods).

### Procedures

Height (cm), body weight (kg), waist circumference (cm) and BMI (kg/m$^2$) were measured according to standardized protocols by trained staff, as previously described.[9] In accordance with the characteristics of the Chinese population,[20] BMI was categorized as follows: underweight (<18.5 kg/m$^2$), overweight (24.0–27.9 kg/m$^2$), and obesity (≥28.0 kg/m$^2$). Central obesity was defined as a waist circumference ≥90 cm for males and ≥85 cm for females. Considering both the scientific basis from previous literature and the feasibility of large-scale national surveys,[9] physical fitness was assessed using six core indicators representing different domains: cardiorespiratory fitness was measured by resting heart rate (RHR)[21,22] and forced vital capacity (FVC),[23] muscular strength by hand grip strength,[24,25] flexibility by the sit-and-reach test,[26] balance by the one-leg stand with eyes closed,[27,28] and reaction speed by the choice reaction time test[29] (Supplementary Methods). To provide a comprehensive evaluation, a summary physical fitness indicator (PFI) was calculated the sum of the Z-scores of all six components with equal weighting.[5,30] The formula for calculating PFI is as follows:

$$PFI = \sum_{i=1}^{6} \omega_i Z_i$$

where $Z_i$ represents the Z-scores of the six physical fitness components, with reverse coding applied to RHR and choice reaction time, and $\omega_i$ denotes the corresponding weighting for each component. Additionally, we adjusted the weightings of different indicators contributing to PFI to evaluate the robustness of the results in sensitivity analyses (Supplementary Methods).

Economic performance and urbanization levels were obtained from the *Statistical Yearbooks* (Tables S1 and S2).[31] GDP per capita (¥) for each survey year was converted to GDP per capita ($) using purchasing power parity for cross-regional comparisons.[32] Provinces were ranked based on GDP per capita ($) and classified into three socioeconomic strata: T1 (10 provinces with the lowest GDP), T2 (11 provinces with moderate GDP), and T3 (10 provinces with the highest GDP). Urbanization levels were defined as the proportion of the permanent urban population relative to the total provincial population in each survey year.[31]

### Statistical analysis

All analyses were weighted to account for the complex sampling design, non-responders, and stratification.

Post-stratification weights were derived for 496 strata based on provincial regions, sex, and age groups, using Chinese census data.[33] Since the national census is conducted every ten years, no census data were available for 2005 and 2014. Therefore, based on previous study used NPFS,[9] in the five consecutive rounds of the NPFS (2000, 2005, 2010, 2014, and 2020), the 2000 census data were used to weight the NPFS estimates for both 2000 and 2005, the 2010 census data for both 2010 and 2014, and the 2020 census data for 2020. Thus, the weighted estimates were representative of the civilian, non-institutionalized Chinese population.

Descriptive statistics were used to present continuous variables as means with standard deviations (SD) and categorical variables as frequencies and percentages. The Mann–Kendall trend test was used to assess temporal trends. The annual percentage change (APC) for the prevalence of different nutritional statuses and specific physical fitness indicators between two consecutive survey years was calculated as:

$$APC\ (\%) = \left(\left(\frac{\text{Ending Value}}{\text{Starting Value}}\right)^{\frac{1}{\text{Number of Years}}} - 1\right) \times 100\%$$

For the PFI, annual changes were assessed by calculating the mean difference between consecutive surveys (e.g., Annual change = $PFI_{2005}$-$PFI_{2000}$)/5). The T3–T1 differences and urban–rural differences quantified the socioeconomic and residence-based inequalities in physical fitness and nutritional status. Referring to previous population studies focusing on physical fitness,[5,18,34] generalized additive models (GAMs) from the mgcv package in R were utilized to examine the relationships between nutritional status, PFI, and both GDP per capita and urbanization levels between 2000 and 2020, with adjustments for age and sex. Separate subgroup analyses by age, sex, and socioeconomic status (SES) were also conducted. Sensitivity analyses were conducted using the 2020 census data as the standard population and adjusting the weightings of indicators contributing to PFI to assess robustness. All statistical analyses were conducted using R 4.4.0 and Stata 17.0, with statistical significance defined as a two-sided P value less than 0.05.

### Ethics approval

The study protocol was approved by the Ethical Review Committee of the China Institute of Sport Science and its collaborating institutions (GJTYZJ-2019021). Written informed consent was obtained from all participants at enrolment.

### Role of the funding source

The funder had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had final responsibility for the decision to submit for publication.

## Results

### Basic characteristics of the study population

Between 2000 and 2020, 716,790 (97.05%) of 738,586 Chinese adults aged 20–59 years with complete data in NPFS were finally included in this study, comprising 150,499 in 2000, 159,980 in 2005, 152,276 in 2010, 136,994 in 2014, and 117,041 in 2020 (Table 1). Moreover, the urbanization rate increased from 37.31% in 2000 to 64.22% in 2020, and GDP per capita rose from \$2917.58 to \$17934.29.

### Temporal trends in physical fitness status and nutritional status of Chinese adults

In terms of physical fitness, the composite PFI score for Chinese adults declined from 0.71 in 2000 to −0.84 in 2020, with a particularly sharp decline between 2014 and 2020 (Table 1). Similar downward trends were observed across all age and sex subgroups (Fig. 1a and Table S3). Males and younger age groups generally exhibiting higher PFI scores. Compared to 2000, the six specific physical fitness indicators all showed poorer levels in 2020 (Fig. S1 and Table S3). Additionally, as shown in Fig. 1b, adults with normal weight and without central obesity exhibited higher PFI scores than those who were underweight, obese, or had central obesity. Females who were obese and centrally obese generally demonstrated poorer physical fitness than males. Tables S4–S10 and Fig. S2 also display the physical fitness levels across specific dimensions for adults in different nutritional statuses.

Regarding nutritional status, a decline in the underweight prevalence was observed from 2000 to 2020, falling to 3.51% in 2020. In contrast, the prevalence of overweight, obesity, and central obesity increased to 35.84%, 15.05%, and 32.10%, respectively, in 2020 (Table 1). Notably, the prevalence of obesity and central obesity in 2020 was more than twice the prevalence in 2000. Furthermore, throughout all survey years, the prevalence of overweight, obesity, and central obesity increased with age, whereas the prevalence of underweight showed the opposite trend (Fig. 1c and Table S11). Compared to females, males showed higher prevalence of weight excess, including overweight, obesity, and central obesity, and this disparity continued to widen annually. In addition, temporal trends in physical fitness status and nutritional status of Chinese adults remained robust in sensitivity analyses (Tables S12–S16).

### Urban-rural and socioeconomic inequalities in physical fitness from 2000 to 2020

As shown in Fig. 2a and Table S17, the PFI scores in urban areas declined between 2005 and 2020, while rural areas experienced a general decrease in PFI, with a slight rebound in 2014. The urban-rural difference in PFI scores was consistently positive throughout all survey years, reflecting better physical fitness in urban

| Characteristics | 2000 | 2005 | 2010 | 2014 | 2020 | $P_{trend}$ |
|---|---|---|---|---|---|---|
| **Sample size** | 150,499 (100.00%) | 159,980 (100.00%) | 152,276 (100.00%) | 136,994 (100.00%) | 117,041 (100.00%) | |
| **Sex** | | | | | | |
| Male | 75,719 (51.40%) | 80,351 (51.40%) | 76,587 (50.79%) | 68,972 (50.79%) | 58,527 (51.29%) | 0.433 |
| Female | 74,780 (48.60%) | 79,629 (48.60%) | 75,689 (49.21%) | 68,022 (49.21%) | 58,514 (48.71%) | 0.433 |
| **Age group (years)** | | | | | | |
| 20–24 | 19,197 (13.04%) | 19,840 (13.04%) | 19,123 (15.28%) | 18,024 (15.28%) | 14,355 (9.14%) | 1.000 |
| 25–29 | 19,103 (16.22%) | 19,959 (16.22%) | 18,935 (12.11%) | 18,071 (12.11%) | 14,528 (11.21%) | 0.068 |
| 30–34 | 19,001 (17.56%) | 20,333 (17.56%) | 19,076 (11.65%) | 18,020 (11.65%) | 14,788 (15.15%) | 0.433 |
| 35–39 | 18,943 (15.05%) | 19,919 (15.05%) | 19,008 (14.15%) | 17,662 (14.15%) | 14,636 (12.08%) | 0.068 |
| 40–44 | 19,032 (11.20%) | 20,650 (11.20%) | 19,121 (14.96%) | 16,836 (14.96%) | 14,758 (11.34%) | 0.433 |
| 45–49 | 18,835 (11.79%) | 19,978 (11.79%) | 19,071 (12.66%) | 16,553 (12.66%) | 14,842 (13.94%) | 0.068 |
| 50–54 | 18,602 (8.73%) | 19,911 (8.73%) | 19,092 (9.44%) | 16,362 (9.44%) | 14,722 (14.78%) | 0.068 |
| 55–59 | 17,786 (6.40%) | 19,390 (6.40%) | 18,850 (9.75%) | 15,466 (9.75%) | 14,412 (12.37%) | 0.068 |
| **Residence** | | | | | | |
| Rural | 48,953 (32.56%) | 53,132 (33.26%) | 50,186 (33.02%) | 43,991 (31.47%) | 39,027 (33.81%) | 0.806 |
| Urban | 101,546 (67.44%) | 106,848 (66.74%) | 102,090 (66.98%) | 93,003 (68.53%) | 78,014 (66.19%) | 0.806 |
| **Socioeconomic status**[b] | | | | | | |
| T1 | 49,557 (28.89%) | 49,252 (28.86%) | 48,758 (24.89%) | 44,560 (33.09%) | 37,398 (23.41%) | 0.462 |
| T2 | 51,118 (33.93%) | 56,676 (35.21%) | 54,112 (36.21%) | 50,888 (28.01%) | 40,548 (34.75%) | 1.000 |
| T3 | 49,824 (37.18%) | 54,052 (35.94%) | 49,406 (38.90%) | 41,546 (38.90%) | 39,095 (41.84%) | 0.130 |
| **Urbanization (%)**[c] | 37.31 (13.22) | 43.73 (12.29) | 50.94 (12.18) | 55.76 (10.77) | 64.22 (8.91) | <0.05[a] |
| **GDP per capita ($)**[d] | 2917.58 | 5056.98 | 9256.12 | 12,700.52 | 17,934.29 | |
| **Nutritional status** | | | | | | |
| Underweight | 7606 (5.54%) | 8032 (5.42%) | 6702 (4.68%) | 5651 (4.19%) | 4458 (3.51%) | <0.05[a] |
| Normal | 88,080 (60.59%) | 92,010 (59.16%) | 81,640 (54.15%) | 72,349 (52.64%) | 54,569 (45.59%) | <0.05[a] |
| Overweight | 43,863 (27.24%) | 47,061 (27.96%) | 48,938 (31.41%) | 44,673 (32.84%) | 41,035 (35.84%) | <0.05[a] |
| Obesity | 10,950 (6.63%) | 12,877 (7.47%) | 14,996 (9.76%) | 14,321 (10.32%) | 16,979 (15.05%) | <0.05[a] |
| Central obesity | 25,823 (15.40%) | 31,847 (18.06%) | 37,081 (23.39%) | 37,802 (27.24%) | 37,459 (32.44%) | <0.05[a] |
| **Physical fitness status**[c] | | | | | | |
| Resting heart rate (bpm) | 77.85 (9.26) | 78.01 (9.20) | 76.92 (9.12) | 78.09 (9.71) | 81.00 (11.60) | 0.221 |
| Forced vital capacity (ml) | 2994.76 (855.53) | 2915.25 (884.28) | 2884.14 (896.34) | 2900.84 (907.08) | 2868.96 (876.84) | 0.086 |
| Hand grip strength (kg) | 37.80 (11.41) | 37.17 (11.43) | 36.13 (11.50) | 35.61 (11.34) | 35.14 (10.74) | <0.05[a] |
| Sit-and-reach (cm) | 9.11 (7.65) | 8.19 (8.17) | 7.46 (8.54) | 7.48 (8.39) | 7.24 (8.40) | 0.086 |
| Standing on one leg with eyes closed (s) | 31.09 (38.19) | 29.82 (31.73) | 26.35 (31.66) | 24.58 (26.54) | 24.64 (23.01) | 0.086 |
| Choice reaction time (s) | 0.5400 (0.1307) | 0.5046 (0.1295) | 0.5103 (0.1369) | 0.5064 (0.1119) | 0.5931 (0.1038) | 0.806 |
| PFI | 0.71 (3.17) | 0.65 (3.16) | 0.39 (3.14) | 0.21 (2.97) | −0.84 (2.85) | <0.05[a] |

Notes: Weighted mean, SD, and percentages (%) are presented in alternate years, whereas the frequencies (n) are reported as unweighted. GDP, gross domestic product; NPFS, National Physical Fitness Surveillance; PFI, physical fitness indicator; SD, standard deviation. [a]$P_{trend}$ for trend was examined by Mann–Kendall trend test, and P value less than 0.05 was considered as statistically significant. [b]31 Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). [c]Data on urbanization and physical fitness status are presented as means (SD), all other data are expressed as n (%). [d]We directly used the national level per capita GDP (￥) provided by the National Bureau of Statistics to convert per capita GDP ($), so no standard deviation was provided.

*Table 1:* **Characteristics, nutritional status, and physical fitness status of participants aged 20–59 years in NPFS from 2000 to 2020.**

areas. However, the urban-rural gap in PFI initially expanded but gradually converged afterward, peaking in 2005. The urban-rural difference was more pronounced among females. Regarding socioeconomic disparities, T2 and T3 regions showed a decline in PFI scores from 2000 to 2020, whereas the T1 region showed an increase in PFI until 2005, then declined (Fig. 2b and Table S18). Moreover, the T3-T1 PFI score difference remained above zero throughout all survey years, narrowing sharply around 2005 before gradually widening.

Fig. 3 illustrates the urban-rural differences in PFI scores stratified by SES status and sex. The urban-rural differences remained consistently positive across all SES regions, gradually narrowing and approaching over time. The disparity in the T3 region was notably larger than those in the other two regions in the early years. We also reported the urban-rural and socioeconomic inequalities of six specific physical fitness indicators in Figs. S3–S15 and Tables S19–S21. Urban-rural and socioeconomic inequalities in physical fitness were similar in sensitivity analyses (Tables S22 and S23).

### Urban-rural inequalities in nutritional status from 2000 to 2020

Both urban and rural areas showed consistent annual declines in underweight prevalence from 2000 to 2020,

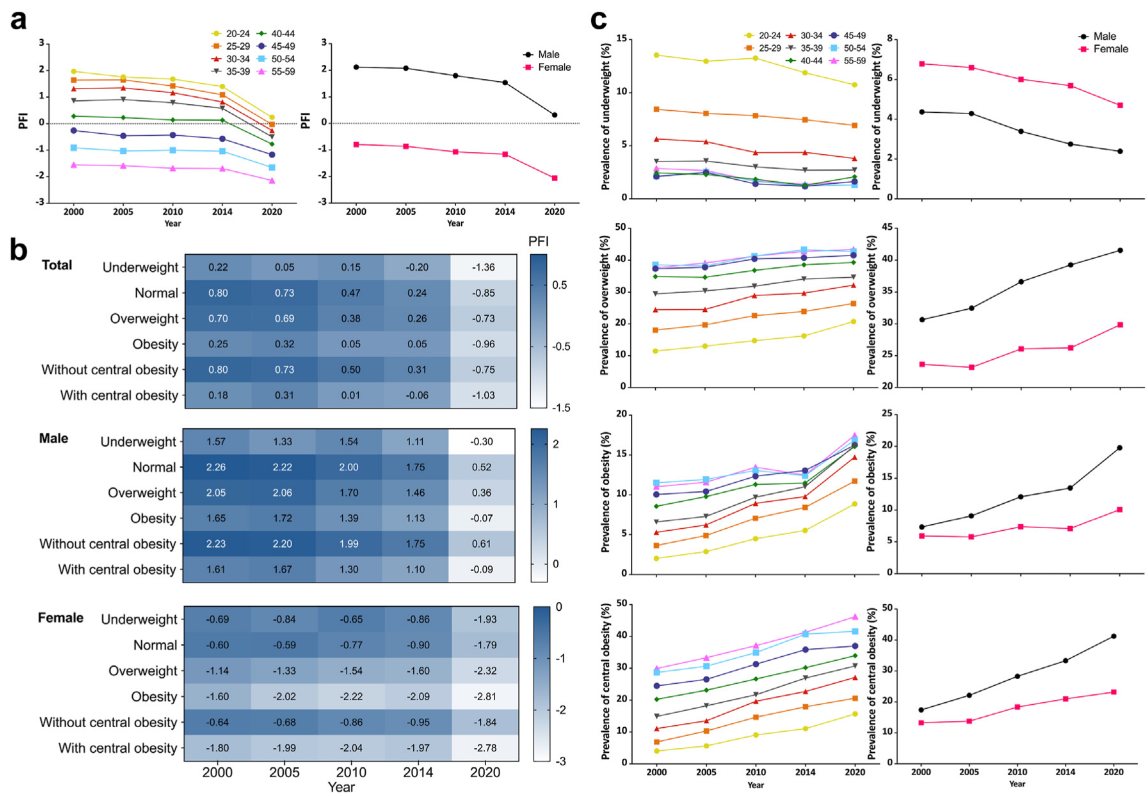

*Fig. 1:* **Temporal trends in physical fitness and nutritional status of Chinese adults aged 20–59 years, by age and sex, 2000–2020**. (a) PFI scores by age and sex. (b) PFI scores by nutritional status; (c) Nutritional status prevalence by age group and sex. PFI, physical fitness indicator.

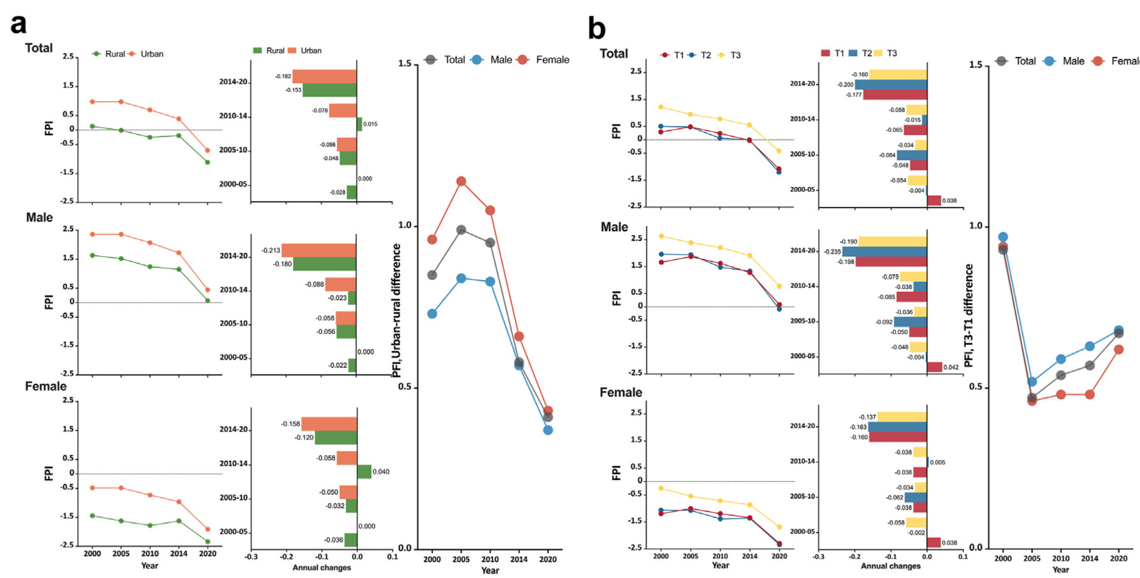

*Fig. 2:* **Inequalities in physical fitness among Chinese adults aged 20–59 years by urban-rural residence (a) and socioeconomic status (b), 2000–2020**. Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). GDP, gross domestic product; PFI, physical fitness indicator.

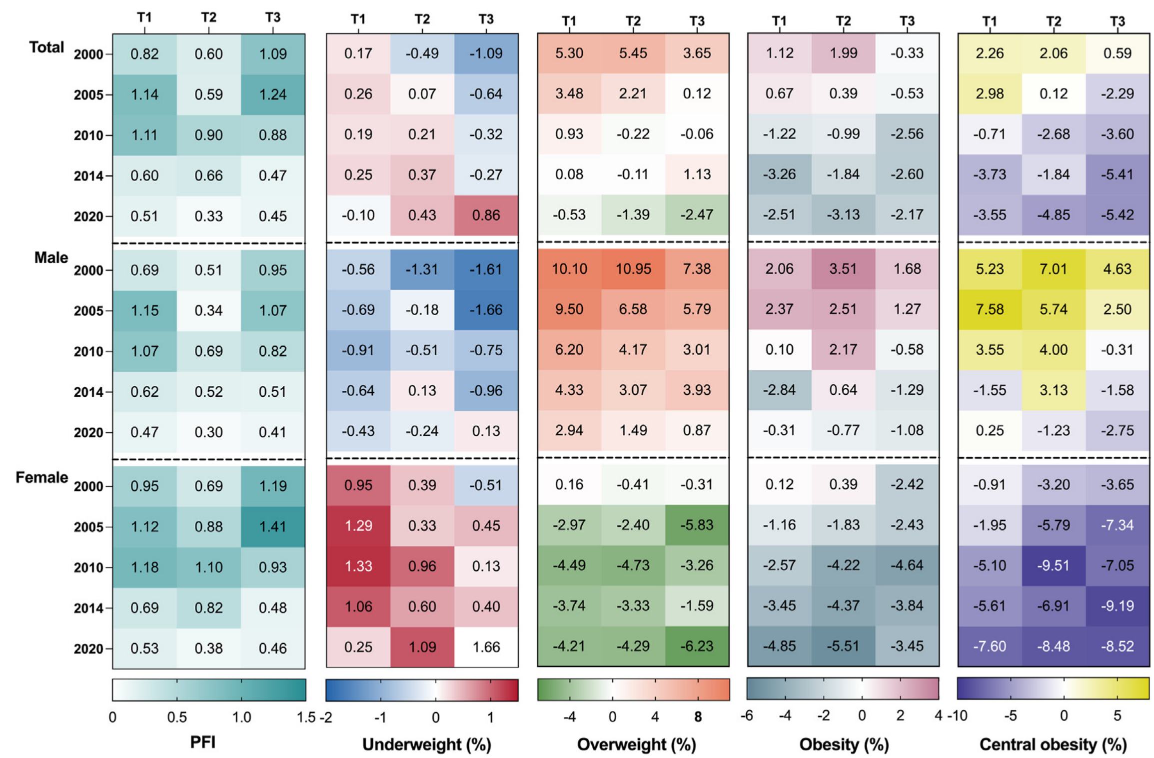


*Fig. 3:* **Urban-rural differences in physical fitness and nutritional status among Chinese adults aged 20–59 years by socioeconomic status and sex, 2000–2020**. Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). GDP, gross domestic product; PFI, physical fitness indicator.

with a slight annual increase of 0.20% in underweight prevalence among urban males between 2000 and 2005 (Fig. 4a and Table S24). The urban underweight prevalence surpassed that of rural areas after 2010 (urban-rural difference: −0.52% in 2000 vs. 0.46% in 2020). Interestingly, underweight prevalence among rural males declined more rapidly, narrowing the gap with urban areas, while the urban-rural disparity for females widened from 0.22% in 2000 to 1.10% in 2020.

As shown in Fig. 5a and Table S24, prior to 2014, urban areas had a higher prevalence of overweight than rural areas, but this gap narrowed rapidly from 4.78% in 2000 to 0.43% in 2014. By 2020, the prevalence of overweight in rural areas (36.92%) surpassed that in urban areas (35.29%). The urban-rural difference among males narrowed sharply from 9.47% in 2000 to 1.55% in 2020, whereas the difference among females remained negative, fluctuating between −0.20% and −5.01% throughout the study period.

Additionally, although obesity prevalence steadily increased in both urban and rural areas for the overall population and males, females showed a fluctuating upward trend (Fig. 6a and Table S24). The obesity prevalence in urban areas was higher than in rural areas before 2005, but rural areas surpassed urban areas, with the gap widening thereafter. The urban-rural difference for females remained negative, ranging from −0.72% to −4.41%.

The urban-rural disparity in central obesity prevalence narrowed before 2005, but later widened to −4.69% in 2020, reflecting a substantial reversal after 2005 (Fig. 7a and Table S24). Among males, the urban-rural difference dropped from 5.66% in 2000 to −1.46% in 2020, whereas in females, rural central obesity prevalence consistently exceeded urban levels, rising from 2.64% in 2000 to 8.19% in 2020.

Urban-rural inequalities in nutritional status were robust in sensitivity analyses (Table S25). Fig. 3 and Tables S26–S29 also illustrates the urban-rural differences in nutritional status, stratified by SES and sex. Compared to the T1 region, the T3 region, representing higher SES levels, had a lower urban prevalence of underweight in the early survey years. However, this trend reversed in recent years. At almost all survey points, females in urban areas tended to have higher underweight prevalence compared to males (Table S26). Regarding overweight, obesity and central obesity, areas with higher early SES and urban regions in the early survey years exhibited higher prevalence; however, as

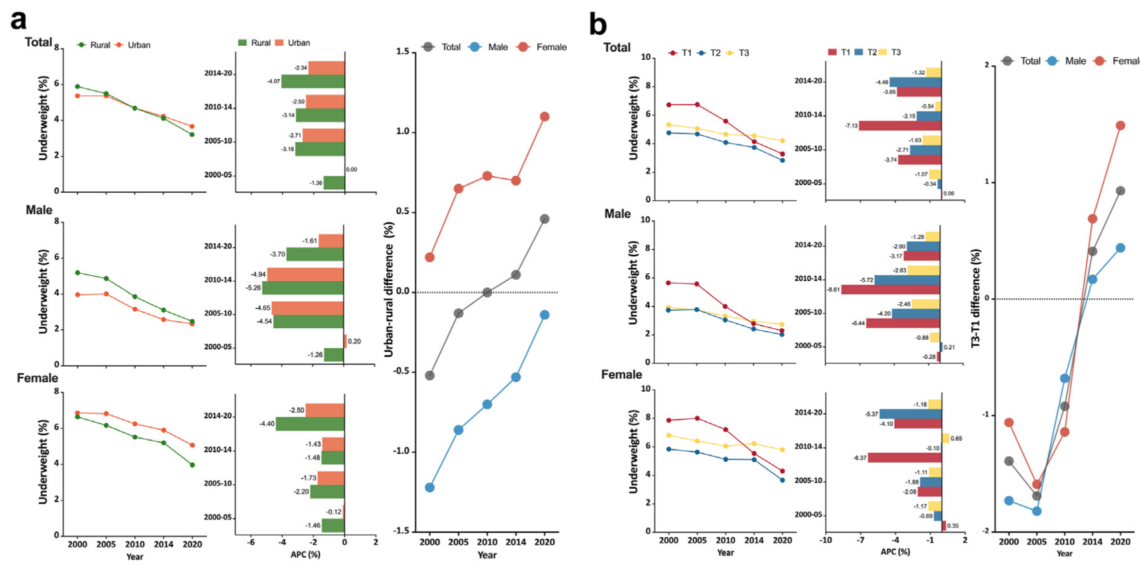


*Fig. 4:* **Inequalities in underweight prevalence among Chinese adults aged 20–59 years by urban-rural residence (a) and socioeconomic status (b), 2000–2020**. Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). APC, annual percentage change; GDP, gross domestic product.

economic levels improved over time, the prevalence of overweight, obesity and central obesity of rural areas began surpassing that of urban areas. Interestingly, at almost all survey points, the rural areas in the female subgroup showed a higher prevalence of excess weight (Tables S27–S29).

## Socioeconomic inequalities in nutritional status from 2000 to 2020

Compared to the T2 and T3 regions, underweight prevalence in T1 region declined more sharply between 2000 and 2020, decreasing from 6.73% to 3.28% (Fig. 4b and Table S30). Before 2010, underweight prevalence in

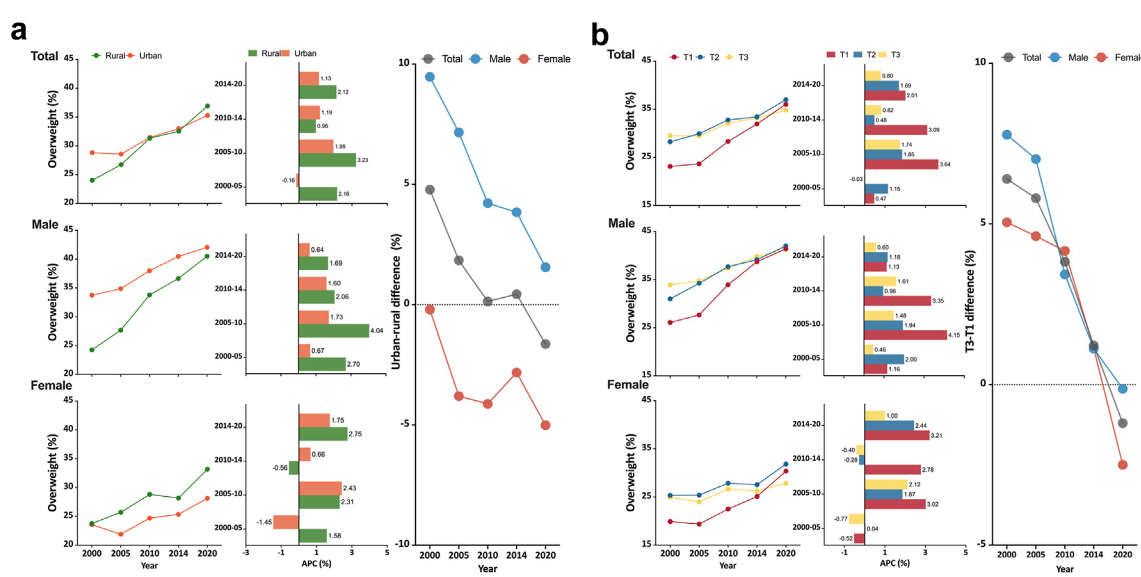


*Fig. 5:* **Inequalities in overweight prevalence among Chinese adults aged 20–59 years by urban-rural residence (a) and socioeconomic status (b), 2000–2020**. Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). APC, annual percentage change; GDP, gross domestic product.

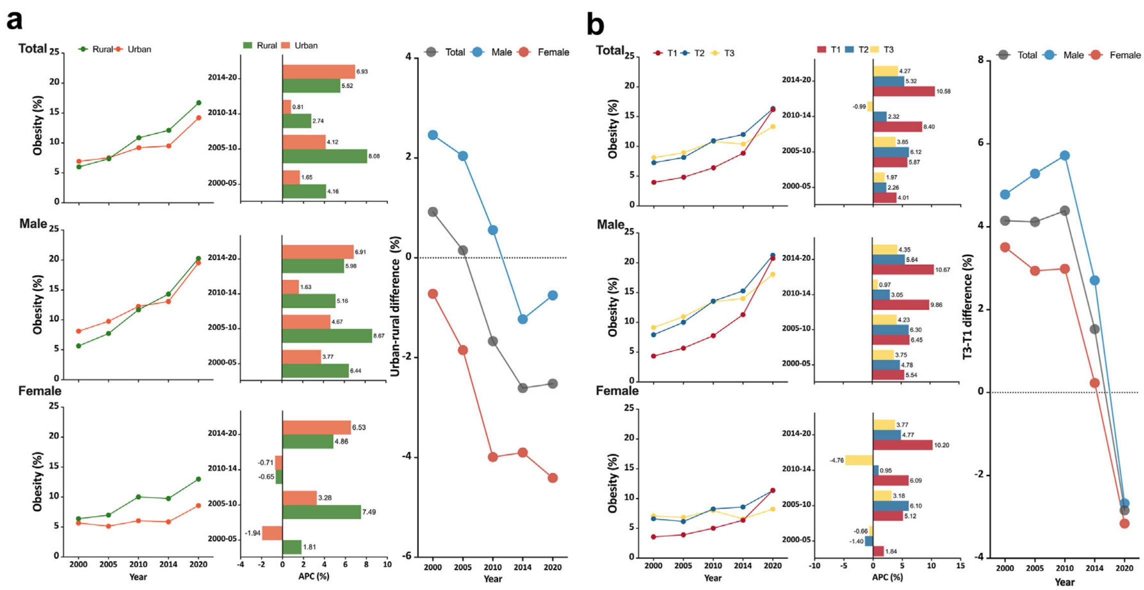


*Fig. 6:* **Inequalities in obesity prevalence among Chinese adults aged 20–59 years by urban-rural residence (a) and socioeconomic status (b), 2000–2020**. Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). APC, annual percentage change; GDP, gross domestic product.

T1 region was significantly higher than that in the other two regions. However, between 2010 and 2020, underweight prevalence in the T3 region surpassed that in the T1 region (0.93%), particularly among females.

Except for the T3 region between 2000 and 2005, overweight prevalence increased across all SES strata throughout the study period (Fig. 5b and Table S30). The T1 region experienced the most rapid increase in

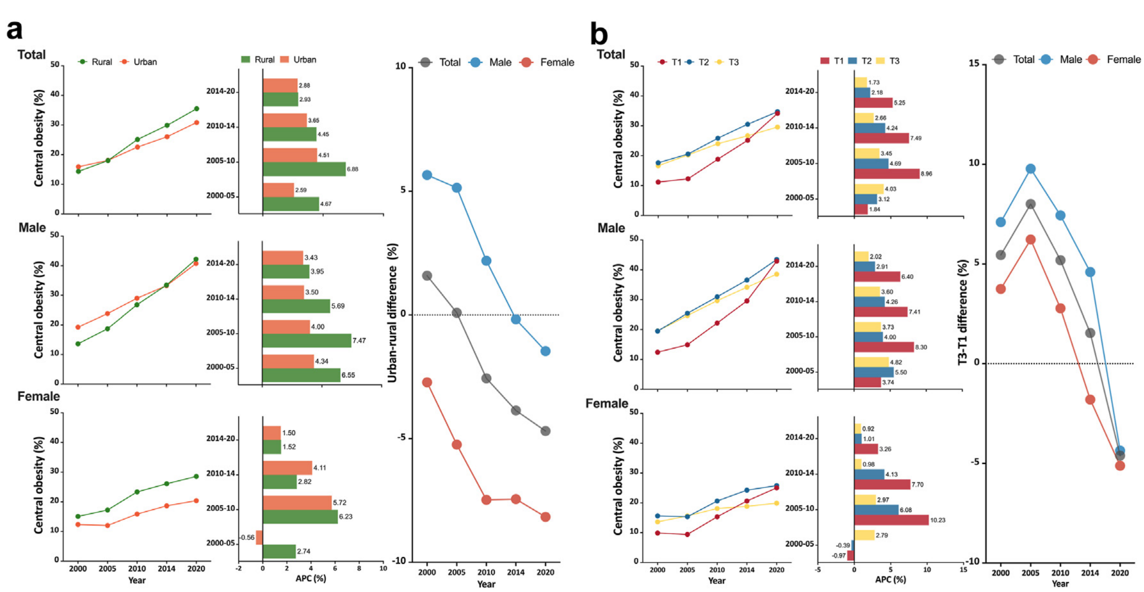


*Fig. 7:* **Inequalities in central obesity prevalence among Chinese adults aged 20–59 years by urban-rural residence (a) and socioeconomic status (b), 2000–2020**. Provinces were ranked by GDP per capita ($) and grouped into three group in ascending order: T1 (10 provinces with the lowest GDP per capita), T2 (11 provinces with moderate GDP per capita), and T3 (10 provinces with the highest GDP per capita). APC, annual percentage change; GDP, gross domestic product.

overweight prevalence, rising from 23.12% in 2000 to 36.01% in 2020. The T3-T1 difference narrowed from 6.40% in 2000 to 1.22% in 2014, with overweight prevalence in the T3 region dropping below that in the T1 region in 2020 (–1.63%). This trend was consistent among males (7.78% in 2000 vs. –0.13% in 2020) and females (5.05% in 2000 vs. –2.50% in 2020).

From 2000 to 2020, obesity prevalence increased across nearly all SES strata, with the most pronounced increase observed in the T1 region between 2014 and 2020 (Fig. 6b and Table S30). Females in the T3 region experienced a significant 4.76% decrease in obesity prevalence from 2010 to 2014. From 2000 to 2014, overall obesity prevalence in T3 region remained higher than in T1 region, with the gap peaking at 4.39% in 2010. However, by 2020, T1 region surpassed T3 region (16.18% vs. 13.34%).

The prevalence of central obesity rapidly increased among all SES regions across all survey periods, except for females from 2000 to 2005 (Fig. 7b and Table S30). From 2000 to 2014, the T3-T1 difference remained positive throughout, peaking at 7.60% in 2005. However, central obesity prevalence in T1 region significantly surpassed that in T3 region in 2020, with female experiencing this reversal as early as 2014. Moreover, sensitivity analyses showed the robust socioeconomic disparities in nutritional status (Table S25).

### Associations between PFI, nutritional status and social development indicators

As shown in Fig. 8, with increasing GDP per capita, the physical fitness of Chinese adults initially remained stable, then gradually improved, before eventually declining. The PFI scores exhibited a general positive correlation with urbanization levels. Furthermore, as both GDP per capita and urbanization levels increased, the underweight prevalence showed a near-linear decline, though this trend was not statistically significant. The overweight prevalence was positively correlated with GDP per capita, but its growth slowed at higher GDP levels. Both obesity and central obesity displayed an N-shaped relationship with GDP per capita. Additionally, the prevalence of overweight, obesity, and central obesity exhibited a near-linear positive correlation with urbanization levels. Subgroup analyses for males and females are presented in Figs. S16 and S17. The associations between PFI, nutritional status and social development indicators were similar in sensitivity analysis (Figs. S18 and S19).

## Discussion

In our study, we found a continuous decline in underweight prevalence and physical fitness throughout the survey period, alongside an increasing prevalence of overweight, obesity, and central obesity. After 2005, the urban-rural disparities in physical fitness narrowed, whereas the gap between most and least developed regions widened, with urban and high-SES regions consistently showing better fitness. The prevalence of overweight, obesity, and central obesity in urban and high-SES regions were higher than in low-SES and rural regions in earlier years, but this pattern reversed over time. In contrast, the underweight prevalence exhibited an opposite trend. Notably, urban-rural inequalities for nutritional status differed between male and female subgroups. As GDP per capita increased, PFI initially rose before declining at higher levels. Overweight prevalence increased with GDP per capita but slowed at higher levels, while obesity and central obesity exhibited an N-shaped relationship with GDP per capita. Moreover, prevalence of overweight, obesity, and central obesity were positively correlated with urbanization. This study provides an empirical foundation for health policy development to focus on improving physical fitness and addressing the health imbalance between undernutrition and overnutrition, aiming to enhance the health of the working-age population and support the achievement of the Healthy China initiative.[35]

Physical inactivity has become critical public health concern, impacting not only individual physical and mental health but also societal well-being.[36–38] The continuous decline in PFI from 2000 to 2020 of our results, with the accelerated drop between 2014 and 2020, is consistent with global trends of decreasing physical activity levels. A study led by World Health Organization (WHO) analyzing data from 507 population-based surveys across 163 countries and territories found that the global age-standardized prevalence of insufficient physical activity increased from 23.4% in 2000 to 26.4% in 2010 and 31.3% in 2022.[39] In China, the proportion of insufficiently active adults also rose from 19.8% in 2000 to 23.8% in 2022.[39] This abovementioned decline is likely driven by multiple factors, including changes in occupational and transport-related physical activity and changes in lifestyle, increasing academic and work pressures, and the widespread adoption of digital entertainment, particularly among younger and middle-aged populations.[40–43] Studies have shown that the COVID-19 pandemic in 2020 may further restrict physical activity, negatively impacting physical fitness, with students and office workers being disproportionately affected.[44,45] In addition, multiple studies have also reported a higher inactivity rate among men than women in China,[39,46] which may explain the faster decline in PFI observed among males in our study.

According to our results, while the urban-rural gap in physical fitness has narrowed since 2005, the disparity between economically developed and less developed regions has widened. This divergence can be attributed to multiple factors. Improvements in nutrition, infrastructure, healthcare, and education in rural areas have contributed to reducing the urban-rural gap in physical

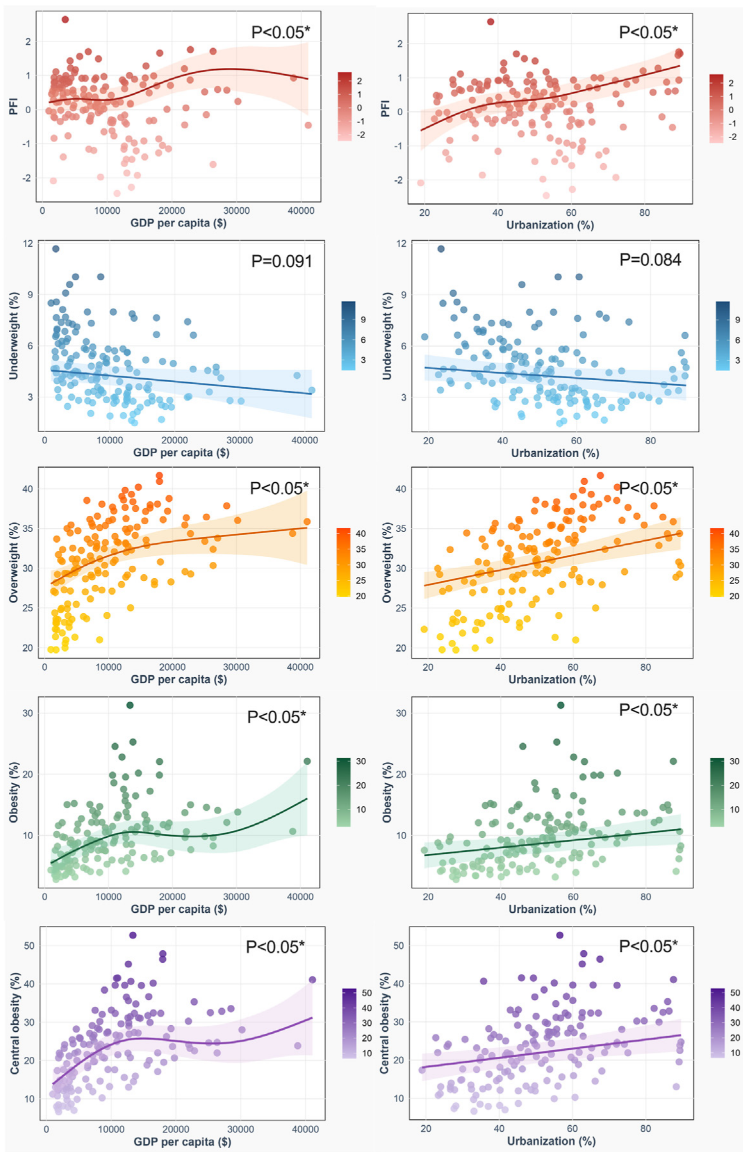


***Fig. 8:*** **Associations between physical fitness, nutritional status and economic indicators among Chinese adults aged 20–59 years, from 2000 to 2020**. Age and sex were adjusted in all generalized additive models from the mgcv package in R. GDP, gross domestic product; PFI, physical fitness indicator. *P < 0.05 was considered as statistically significant.

fitness.[35,47] Meanwhile, the greater availability and rapid expansion of health resources, coupled with higher health awareness in more developed regions, may partly contribute to the widening disparity between economically developed and less developed regions.[48–51] To some extent, this has mitigated the negative effects of social development on physical fitness in developed regions, while less developed regions may have struggled to implement health policies and awareness campaigns to effectively address the unique challenges in physical fitness that come with economic development.[48–52] As economic inequalities continue to expand, disparities in physical fitness may further intensify. Clearly, the ongoing decline in physical fitness, both in China and globally, contradicts the trajectory of the global health goals set for 2030.[7,53] In response, WHO has advocated for evidence-based policy actions to foster active societies, environments, individuals, and systems, emphasizing that individual motivation to engage in physical activity (PA) is a critical gateway for more physically active at the population level.[7,54] Furthermore, data from the National Health and Nutrition Examination Survey (NHANES 2007–2018) indicated that individuals aged 18–25 years with higher educational attainment tended to engage in less occupational activity but more exercise activity, underscoring the role of education in promoting healthy behaviors among the new generation of adults.

China has undergone significant nutritional and lifestyle transitions amid rapid social development.[47,55] Over our study period, the overall prevalence of underweight among young and middle-aged adults in China has steadily declined. In contrast, the prevalence of overweight and obesity in China has risen dramatically over the past two decades, reaching 35.84% and 15.05%, respectively, by 2020. This upward trend has been largely attributed to shifts in dietary patterns, rising sedentary behavior, and decreased physical activity.[9,56,57] Studies have shown that the COVID-19 pandemic may also have further contributed to increased physical inactivity and weight gain in 2020.[44,45] A global meta-analysis highlights that reductions in the double burden of malnutrition (DBM) have been predominantly driven by declining underweight prevalence, while the increases in DBM have been fueled by rising obesity prevalence.[58] This has resulted in a shift from underweight dominance to obesity dominance in many countries.[13] The rapid rise in overweight and obesity has become a major contributor to the decline in physical fitness among Chinese adults.[4,59] Central obesity, characterized by excessive accumulation of abdominal fat, is widely recognized as a critical risk factor for metabolic syndrome and numerous chronic diseases (e.g., cardiovascular diseases, type 2 diabetes, and certain cancers).[60,61] While BMI is commonly used for obesity diagnosis, it fails to accurately reflect fat distribution, leading to underdiagnosis of central obesity and delayed health interventions.[62] Our findings reveal that the prevalence of central obesity in China reached 32.1% in 2020, more than doubling from 13.71% in 2000. A meta-analysis including 13.2 million participants demonstrated a global increase in central obesity prevalence across different periods: 1985–1999 (31.3%), 2000–2004 (38.3%), 2005–2009 (46.3%), and 2010–2014 (48.3%). Notably, the overall prevalence of central obesity was lower in the Asian population (31.3%) than in Caucasian population (46.6%) and African population (45.7%).[63] Compared with individuals of normal weight, those who are overweight, obese, centrally obese, or underweight exhibit poorer physical fitness, highlighting the detrimental impact of malnutrition—whether overnutrition and undernutrition—on physical fitness.[13] In certain countries, such as Japan, South Korea, China, Germany, France, the United Kingdom, and the United States, excess weight is more prevalent among males, which also stands in stark contrast to the global average.[64,65]

Moreover, our findings indicate that the prevalence of excess weight (overweight and obesity) and central obesity has increased more rapidly in less developed regions and rural areas than in economically developed regions and urban areas, surpassing the latter by 2020. The potential driving factors behind this trend reversal are complex, with the nutrition transition theory providing a partial explanation.[66–68] Traditionally, less developed regions and rural areas, historically characterized by undernutrition and limited food diversity, have increasingly adopted energy-dense processed and diverse foods—a shift closely linked to economic development and urbanization.[66–68] Additionally, reduced physical activity, driven by agricultural mechanization and a transition toward sedentary occupations, has further contributed to the increase in obesity.[69,70] In contrast, while excess weight and central obesity were initially more prevalent in economically developed regions and urban areas, greater health awareness and the implementation of public health interventions—such as nutrition education and physical activity programs—may have helped slow the obesity increase in these areas.[52,71] Some studies suggest that rising BMI in rural areas has been a major driver of the global increase in adult obesity.[14,18] Similar patterns have been observed in other countries and territories, particularly during periods of nutritional transition and urbanization.[13,72,73] Furthermore, in economically developed regions and urban areas, women tend to place greater emphasis on weight management than men.[74,75] Therefore, implementing tailored strategies for preventing both underweight and obesity prevention—accounting for regional economic development stages and population characteristics—is essential for addressing this public health challenge effectively.

Economic development and urbanization exert multifaceted effects on residents' physical fitness and nutritional status, highlighting the complexity of health challenges in modernization process.[76,77] Talukdar et al., analyzing 40 years of data from 147 countries, identified a positive, non-linear relationship between per capita GDP and obesity prevalence, with a stronger association at lower income levels—closely aligning with our findings.[78] This phenomenon may reflect the positive influence of heightened health awareness, improved dietary structures, increased engagement in PA, and greater implementation of PA interventions in more developed economies.[79] Importantly, the near-linear positive correlation between overweight, obesity, and central obesity prevalence and the level of urbanization is consistent with previous findings, suggesting that accelerated urbanization fosters the adoption of unhealthy lifestyles.[80,81] In the early stages of economic development, improved resource availability, such as access to healthcare services, better nutrition, and physical activity infrastructure (e.g., parks, sports facilities), tends to enhance physical fitness.[47,55,82] However, as economic development advances, the widespread adoption of sedentary behaviors, increased consumption of high-calorie diets, and reduced physical activity may erode these initial benefits.[9,56,57] Future research should explore the heterogeneous mechanisms across sex, regions, and age groups to deepen our understanding of the nuanced impacts of economic development and urbanization on health.

This study presents several notable strengths, including a nationally representative sample of adults aged 20–59, a continuous 20-year monitoring period, a multidimensional assessment of physical fitness and nutritional status, and standardized approaches applied across 5 surveillance rounds. Nonetheless, several limitations should be acknowledged. First, the 2000 census data were used to weight the 2005 NPFS survey, and the 2010 census for the NPFS 2014 survey, assuming minimal population structure changes during these periods.[9] Notably, the sensitivity analysis using the 2020 census data as the standard population also yielded consistent results. Second, although the composite PFI in this study effectively reflected overall physical fitness to some extent, it did not encompass other dimensions such as explosive power and endurance due to data limitations. However, the consistency of findings across five survey rounds supports the validity of PFI. Third, provincial-level socioeconomic indicators (e.g., GDP per capita, urbanization) were employed, which did not capture individual-level variations. Additionally, urbanization was measured solely by the proportion of the urban population, which may not fully capture the broader lifestyle changes associated with urbanization. Future studies incorporating individual-level data and multiple indicators would enhance the precision and applicability of the findings.

In conclusion, China's rapid economic growth during the first two decades of the 21st century coincided with declining physical fitness and increasing prevalence of overweight, obesity, and central obesity among adults aged 20–59. Less developed and rural regions are likely to face dual challenges of worsening physical fitness and growing burden of overnutrition, which requires urgent attention. The complex relationships between socioeconomic development, urbanization, and physical health further emphasize the need for health policies that tailored to diverse socioeconomic contexts and subpopulations.

#### Contributors

Conceptualization, CQ, CF, and JL; methodology and analysis, CQ; visualization, CQ; writing-original draft preparation, CQ; review and editing, CF, QL, and J.W; supervision, H.W, J.L. and Q.F. Besides, CQ, CF, and JL directly accessed to all raw data and verified the underlying data reported in the study. JL, HW, and QF were responsible for the decision to submit the manuscript. All authors have read and agreed to the published version of the manuscript.

#### Data sharing statement

The National Physical Fitness Surveillance Center provides all data in the study. Anonymized individual patient data analyzed during this study are available from the corresponding author on reasonable request. Data requests should be sent to fengqiang@ciss.cn.

#### Declaration of interests

The authors declare no conflict of interests.

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#### Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2025.101542.

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