Preplanned Studies

National Survey on the Prevalence and Geospatial Variation of Body Fat Percentage Among Preschoolers — 31 PLADs, China, 2020

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Summary

What is already known on this topic?

Body fat percentage (BF%) is a fundamental indicator of body composition that provides critical insights into fat distribution patterns. However, comprehensive national data on BF% and its geographical distribution patterns among the Chinese preschoolers aged 3 to 6 years remain limited.

What is added by this report?

This study presents novel national data analyzing the prevalence and geographical patterns of BF% among Chinese preschool children, along with key determinants. The findings reveal a mean BF% of 20.7% among the Chinese preschoolers, with distinct geographical clustering patterns. The analysis identifies significant hotspots and cold spots aligned with major geographical boundaries, while demonstrating that sex, parental characteristics, education level, and environmental factors significantly influence preschool children's BF%.

What are the implications for public health practice?

These findings provide critical baseline data on preschool children's BF% levels and reveal substantial geographical disparities. The observed regional variations suggest the need for targeted public health interventions and region-specific strategies for childhood obesity prevention, emphasizing the importance of implementing evidence-based health education and intervention programs tailored to local contexts.

ABSTRACT

Introduction: Body fat percentage (BF%) refers to the proportion of adipose tissue relative to total body weight. Compared to body mass index (BMI), BF% demonstrates superior sensitivity in predicting cardiometabolic risk and insulin sensitivity in children. Elevated BF% is associated with multiple adverse health outcomes, including reduced bone mineral density, lower extremity injuries, and systemic inflammation. Despite its clinical significance, comprehensive national data on BF% and its geographical distribution patterns among the Chinese preschoolers aged 3 to 6 years remain limited. This study aims to examine BF% prevalence among preschoolers and identify associated factors, while analyzing geospatial variations across the 31 provincial-level administrative divisions (PLADs) to elucidate regional disparities.

Methods: Data were derived from the 5th Chinese National Physical Fitness Surveillance (CNPFS) conducted in 2020, encompassing 40,222 preschoolers. Geospatial analyses, including hotspot and cold spot identification, were performed using ArcGIS 10.8 software and ArcToolbox with the Hot Spot Analysis (Getis-Ord Gi*) tool.

Results: The study revealed a mean BF% of 20.7% among Chinese preschool children, with females exhibiting significantly higher values (22.1±5.0)% compared to males (19.2±5.4)%. The geographical distribution demonstrated distinct clustering patterns, with hotspots predominantly concentrated in Northeast China and cold spots clustered in southern PLADs. Notably, the distribution of hotspots and cold spots showed symmetrical patterns along China's natural geographical boundaries — the Qinling-Huaihe Line and Bo-Tai Line. Key determinants of preschool children's BF% included sex, parental weight status, education level, and residential environment characteristics.

Conclusions: These findings underscore the necessity for targeted interventions to address regional inequalities and promote healthy development among preschoolers.

Body fat percentage (BF%) represents the proportion of adipose tissue relative to the total body weight. Compared to body mass index (BMI), BF% demonstrates superior sensitivity in predicting cardiometabolic risk (*1*) and insulin sensitivity (*2*) in children. Elevated BF% is associated with multiple adverse health outcomes, including decreased bone mineral density (*3*), increased risk of lower extremity injuries (*4*), and heightened systemic inflammation (*5*).

The preschool period represents a critical window for physical growth and development. Children who accumulate excessive body fat during this stage face an increased likelihood of maintaining obesity through adolescence and into adulthood (*6*). Since 2000, the Chinese National Physical Fitness Surveillance (CNPFS) has conducted quinquennial assessments using skinfold-thickness measurements to estimate body composition. However, significant concerns persist regarding the consistency, precision, and accuracy of skinfold-thickness measurements. Notably, the absence of a universally accepted predictive formula has precluded the estimation and reporting of national BF% data for the Chinese preschoolers. The implementation of bioelectrical impedance analysis (BIA) in place of skinfold-thickness measurements in the 5th CNPFS in 2020 established a foundation for objective evaluation of body fat mass. This study aims to examine BF% prevalence among preschoolers and identify associated factors, thereby advancing our understanding of childhood obesity in China. Additionally, we analyze geospatial variation across the 31 provincial-level administrative divisions (PLADs) to elucidate regional disparities in childhood obesity.

This study analyzed data from the 5th CNPFS conducted between August and November 2020. As previously documented (*7*), the CNPFS employs a cross-sectional design every five years using a complex, stratified, multistage probability cluster sampling method. The study population comprised urban and rural preschoolers aged 3 to 6 years in China, representing 31 PLADs. Within each PLAD, three cities were selected based on socioeconomic status, with one urban and one rural district sampled per city, ensuring equal representation across age-sex groups (Supplementary Figure S1, available at https://weekly.chinacdc.cn/). The final analysis included 40,222 preschoolers with valid informed consent forms. The study protocol received approval from the institution's ethics committee (No. CISSLA-20240219).

BF% measurements were conducted using a BIA device (GMCS-TZL3, Jianmin, Beijing, China) with impedance set at 100 μA. All measurements were performed under standardized conditions following fasting and urination. Participants wore light clothing without metal objects and stood barefoot on the analyzer, ensuring contact between their hands and feet with the 8 electrodes (2 on the palms, 2 on the thumbs, 2 on the toes, and 2 on the heels) (*8*). The tetrapolar bioelectrical impedance method provided BF% measurements to 0.1% precision. Additional data on potential influencing factors were collected through proxy-reported questionnaires.

Statistical analyses were performed using SPSS (version 27.0, IBM SPSS, Armonk, NY, USA). Between-group differences in BF% were assessed using *t*-tests and analysis of variance (ANOVA). Multinomial linear regression identified factors influencing preschoolers' BF%, with statistical significance set at a two-sided P value < 0.05. Geospatial patterns of BF%, including hotspot and cold spot clusters, were analyzed using ArcGIS 10.8 software and ArcToolbox with the Hot Spot Analysis (Getis-Ord Gi*) tool. The Getis-Ord Gi* statistic generated Z-scores for BF% characteristics across the 31 PLADs, quantifying the degree to which regional BF% characteristics clustered with similar high or low values. High positive Z-scores indicated high-value clusters (hotspots), while low negative Z-scores indicated low-value clusters (cold spots).

This study included 40,222 preschoolers aged 3 to 6 years, comprising 20,150 males (50.1%) and 20,072 females (49.9%). The urban-rural distribution was nearly equal, with 19,813 (50.3%) urban and 19,511 (49.7%) rural preschoolers. The mean (standard deviation) values for height, weight, BMI, and BF% were 110.4 (8.4) cm, 19.3 (3.9) kg, 15.7 (1.8) kg/m^2, and 20.7 (5.4)%, respectively. While height, weight, and BMI showed age-related increases, BF% exhibited a general declining trend. Females demonstrated significantly higher BF% compared to males (t=−56.238, P<0.01), and urban residents showed notably higher values than their rural counterparts (t=7.889, P<0.01) (Table 1).

Table 2 illustrates the stratification of BF% by sex, age, and residence. Females consistently demonstrated higher BF% than males across all residence-age groups. Similarly, urban preschoolers exhibited higher BF% compared to their rural counterparts across all sex-age subgroups. However, the age-related progression of BF% from 3 to 6 years showed no consistent pattern within residence-sex subgroups, with notable fluctuations observed between ages 4 and 5.

TABLE 1. Preschoolers' anthropometric measurements in China in 2020.

Variables	Sample size *n* (%)	Height Mean[(SD), cm]	Weight Mean [(SD), kg]	BMI Mean [(SD), kg/m^2]	BF% Mean (SD)
Total	40,222 (100.0)	110.4 (8.4)	19.3 (3.9)	15.7 (1.8)	20.7 (5.4)
Sex					
Male	20,150 (50.1)	111.0 (8.4)	19.7 (4.0)	15.9 (1.8)	19.2 (5.4)
Female	20,072 (49.9)	109.9 (8.4)	18.8 (3.7)	15.5 (1.7)	22.1 (5.0)
t		13.22	22.86	22.93	−56.24
P		<0.01	<0.01	<0.01	<0.01
Age(years)					
3.0	10,200 (25.4)	101.4 (4.8) *†§	16.1 (2.1) *†§	15.6 (1.5) *†§	21.1 (4.9) *†
4.0	10,392 (25.8)	107.5 (4.9) *†¶	18.1 (2.5) *†¶	15.6 (1.6) †¶	20.4 (5.1) *†
5.0	10,438 (26.0)	114.7 (5.2) *§¶	20.8 (3.4) *§¶	15.8 (1.9) *§¶	20.9 (5.6) *§
6.0	9,192 (22.9)	119.0 (5.6) †§¶	22.5 (3.9) †§¶	15.8 (2.0) †¶	20.2 (6.0) †§¶
F		22387.77	8586.05	39.66	59.17
P		<0.01	<0.01	<0.01	<0.01
Residence					
Urban	20,274 (50.4)	110.1 (8.5)	19.1 (3.9)	15.7 (1.8)	20.4 (5.4)
Rural	19,948 (49.6)	110.8 (8.4)	19.4 (3.9)	15.7 (1.8)	20.9 (5.3)
t		8.59	7.98	1.73	7.89
P		<0.01	<0.01	0.084	<0.01
Region					
Northeast	3,796 (9.4)	111.8 (8.5) *†§**††§§	20.3 (4.2) *†§**††§§	16.1 (1.9) *†§**††§§	22.6 (5.6) *†§**††§§
North	6,552 (16.3)	111.0 (8.5) ¶**††§§	19.5 (4.1) ¶**††	15.8 (1.9) *†¶**††§§	21.3 (5.6) ¶**††
Northwest	6,340 (15.6)	110.7 (8.1) ¶**††§§	19.4 (3.7) ¶**††	15.7 (1.8) §¶**††	20.9 (5.2) ¶**††
East	9,114 (22.7)	111.0 (8.3) ¶**††§§	19.5 (3.9) ¶**††	15.8 (1.7) §¶**††	20.9 (5.2) ¶**††
Central	3,995 (9.9)	110.2 (8.8) *†§¶**††	19.3 (4.0) ¶**††	15.8 (1.8) §¶**††§§	20.7 (5.2) ¶**††
Southwest	6,313 (15.7)	109.3 (8.5) *†§¶**§§	18.6 (3.6) *†§¶**§§	15.5 (1.6) *†§¶**§§	19.8 (4.9) *†§¶**§§
South	4,112 (10.2)	108.7 (8.2) *†§¶††§§	18.2 (3.5) *†§¶††§§	15.3 (1.7) *†§¶††§§	18.3 (5.3) *†§¶††§§
F		78.84	138.68	89.87	279.18
P		<0.01	<0.01	<0.01	<0.01

Abbreviation: BMI=body mass index; BF%=body fat percentage; SD=standard deviation.
* compared with age at 6 years in age groups or East in region groups, *P*<0.05.
† compared with age at 5 years in age groups or Northwest in region groups, *P*<0.05.
§ compared with age at 4 years in age groups or North in region groups, *P*<0.05.
¶ compared with age at 3 years in age groups or Northeast in region groups, *P*<0.05.
** compared with South in region groups, *P*<0.05.
†† compared with Southwest in region groups, *P*<0.05.
§§ compared with Central in region groups, *P*<0.05.

Figure 1 illustrates the spatial distribution of BF% among preschoolers across PLADs in China. A distinct north-south gradient emerged, with higher values in northern regions and lower values in southern regions. The highest BF% prevalence was observed in Heilongjiang Province (23.3%), Liaoning Province (23.0%), and Xinjiang Uygur Autonomous Region (22.5%). Conversely, the lowest prevalence was found in Hainan Province (18.4%), Guangdong Province (18.4%), and Guangxi Zhuang Autonomous Region (17.9%). Using the Getis-Ord Gi* statistic, significant spatial clustering patterns were identified (Figure 2). Hotspots are predominantly concentrated in Northeast China, while cold spots are clustered in the southern PLADs. Notably, the distribution of these clusters exhibited symmetrical patterns along both the Qinling-

Huaihe Line and Bo-Tai Line, which represent China's natural geographical and developmental boundaries.

Multiple factors were significantly associated with higher BF% in the multinomial logistic regression analysis. Female sex showed the strongest positive association (β=2.92), followed by urban residence (β=0.43). Parental education levels demonstrated a dose-response relationship, with higher education corresponding to increased BF% (paternal: senior high school/junior college, β=0.56; college and above, β=0.79; maternal: senior high school/junior college, β=0.60; college and above, β=0.89). Parental body weight status also showed strong associations, with parental obesity having the largest effect (paternal: thin, β=−1.10; overweight, β=1.20; obese, β=2.39; maternal: thin, β=−0.98; overweight, β=1.13; obese, β=1.56). Protective factors included daily moderate-to-vigorous physical activity (MVPA) of 180 minutes or more (β=−0.28) and access to neighborhood playgrounds (β=−0.30) or recreational facilities (β=−0.22) (Table 3).

TABLE 2. Body fat percentage among preschoolers by sex, age, and residential area.

Age (years)	3	4	5	6
Urban-Female	23.2 (4.5) *†§	22.1 (4.7) *†	22.4 (4.9) *†§	21.7 (5.4) *†§
Rural-Female	22.8 (4.6) *†¶	22.0 (4.6) *†	21.9 (5.3) *†¶	20.8 (5.5) *†¶
Urban-Male	19.3 (4.6) §¶	18.9 (5.1) *§¶	19.8 (5.6) §¶	19.7 (6.1) *§¶
Rural-Male	19.1 (4.5) §¶	18.6 (4.8) †§¶	19.5 (5.9) §¶	18.8 (6.2) †§¶
F	590.60	403.11	186.45	108.62
P	<0.01	<0.01	<0.01	<0.01

* compared with Rural-Male in sex-age groups, P<0.05.
† compared with Urban-Male in sex-age groups, P<0.05.
§ compared with Rural-Female in sex-age groups, P<0.05.
¶ compared with Urban-Female in sex-age groups, P<0.05.

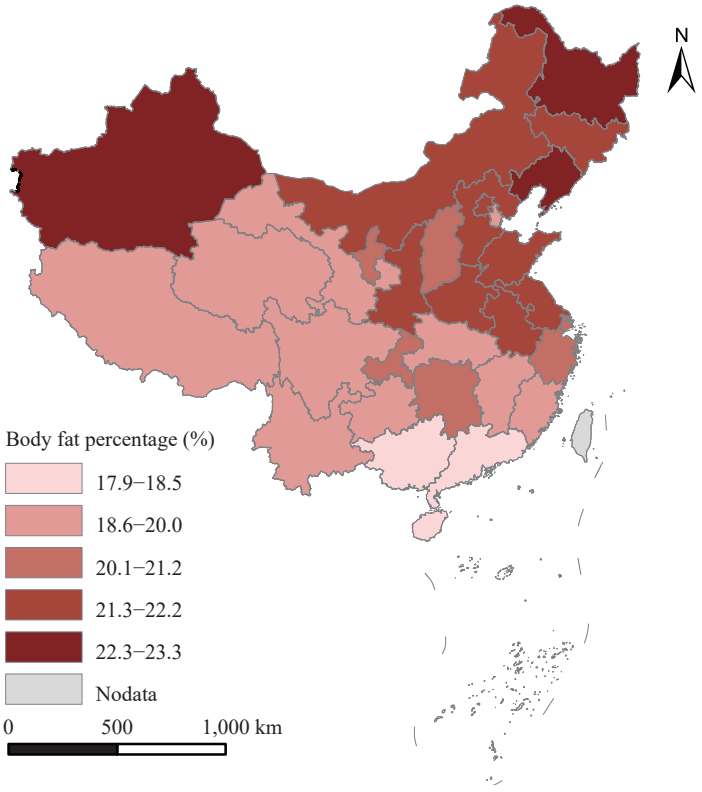

FIGURE 1. Body fat percentage of preschoolers aged 3–6 years across 31 provincial-level administrative divisions in China. Map approval number: GS 京 (2025) 0574 号.

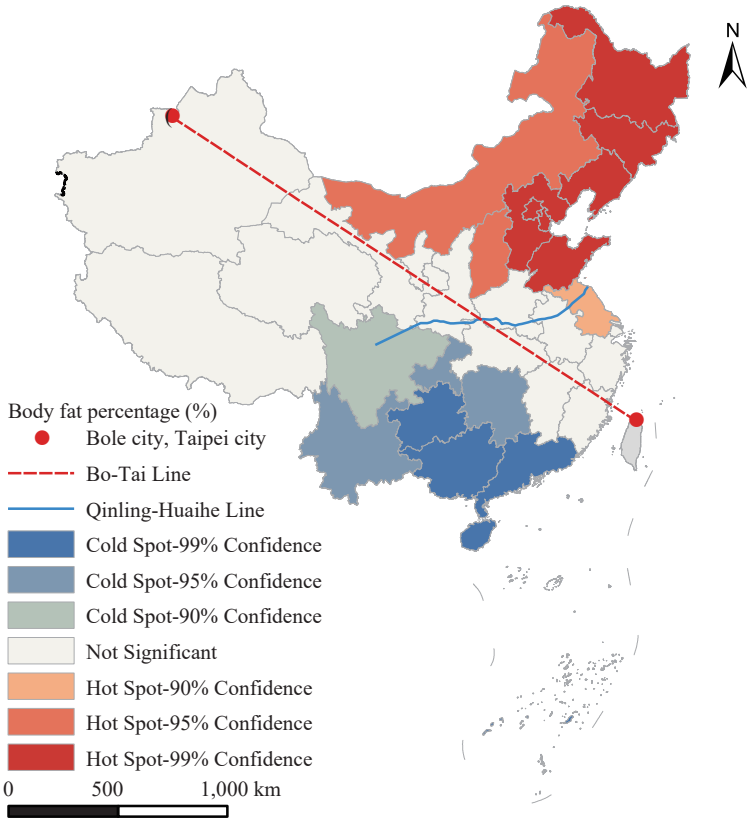

FIGURE 2. Clusters of BF% hotspots among preschoolers aged 3–6 years, combined with geographical boundaries of the Qinling-Huaihe Line and Bo-Tai Line.
Map approval number: GS 京 (2025) 0574 号.

DISCUSSION

This national study examined the prevalence and geospatial patterns of BF% among the Chinese preschoolers and explored its determinants using a representative sample. Our findings revealed significant sex-based differences, with females exhibiting higher BF% (21.1%) compared to males (19.2%), and residential variations, with urban preschoolers showing elevated BF% (20.9%) relative to their rural counterparts (20.4%). The analysis demonstrated distinct north-south geographical clustering patterns, characterized by higher BF% concentrations in northern regions and lower values in southern areas. Key determinants of preschoolers' BF% included sex, parental characteristics, residential environment, and physical activity behaviors.

The observed mean BF% of 20.7% among the Chinese preschoolers aged 3 to 6 years aligns with previous research from Poland, which reported a BF% of 20.4% in children aged 5 to 6 years (*9*). The higher BF% found in urban areas likely reflects socioeconomic disparities and distinct dietary patterns across residential settings. The consistent sex-based difference, with males showing lower BF%, may be attributed to higher levels of physical activity participation among boys. While adiposity rebound (AR) typically occurs between 6 and 8 years of age, marking the second rise in body mass index (*10*), our cohort of 3- to 6-year-olds did not exhibit this phenomenon. However, the observed BF% variations across different residence-sex subgroups suggest this period represents a critical window of adiposity sensitivity.

A key methodological innovation of this study was the application of the Getis-Ord Gi* statistic, which revealed significant north-south geospatial clustering patterns aligned with the Qinling-Huaihe Line and Bo-Tai Line (*11*). The Bo-Tai Line, connecting Bole in Xinjiang Uygur Autonomous Region to Taipei in Taiwan, China, serves as a developmental boundary aimed at promoting balanced growth between the northern and southern regions. These geographical boundaries are supported by genetic evidence (*12*), with Han population genetics showing differentiation along the Qinling-Huaihe Line. Environmental factors likely contribute to these north-south differences, as

TABLE 3. Multinomial linear regression analysis of the factors influencing BF% among preschoolers aged 3–6 years in China, 2020.

Variables	*n* (%)	*β* (95% *CI*)	*P*
Sex			
Male	20,150 (50.1)	Ref.	
Female	20,072 (49.9)	2.92 (2.82, 3.02)	<0.01
Residence			
Rural	19,948 (49.6)	Ref.	
Urban	20,274 (50.4)	0.43 (0.32, 0.53)	<0.01
Parental education			
Paternal education level			
Junior high school and below	9,087 (22.6)	Ref.	
Senior high school/junior college	16,596 (41.3)	0.56 (0.43, 0.70)	<0.01
College and above	13,285 (33.0)	0.79 (0.65, 0.94)	<0.01
Missing	1,254 (3.1)		
Maternal education level			
Junior high school and below	8,969 (22.3)	Ref.	
Senior high school/junior college	16,670 (41.4)	0.60 (0.47, 0.74)	<0.01
College and above	13,486 (33.5)	0.89 (0.75, 1.03)	<0.01
Missing	1,097 (2.7)		
Parental body weight status (BMI, kg/m^2)			
Normal (18.5–23.9)	16,394 (40.8)	Ref.	
Thin (<18.5)	665 (1.7)	−1.10 (−1.51, −0.69)	<0.01
Overweight (24.0–27.9)	15,611 (38.8)	1.20 (1.08, 1.32)	<0.01
Obese (≥28.0)	4,381 (10.9)	2.39 (2.21, 2.56)	<0.01
Missing	3,171 (7.9)		
Maternal body weight status (BMI, kg/m^2)			
Normal (18.5–23.9)	26,515 (65.9)	Ref.	
Thin (<18.5)	3,378 (8.4)	−0.98 (−1.17, −0.79)	<0.01
Overweight (24.0–27.9)	6,113 (15.2)	1.13 (0.98, 1.28)	<0.01
Obese (≥28.0)	1,282 (3.2)	1.56 (1.26, 1.86)	<0.01
Missing	2,934 (7.3)		
Neighborhood environment			
Playground of residence			
Yes	30,296 (75.3)	Ref.	
No	9,044 (22.5)	−0.28 (−0.41, −0.15)	<0.01
Missing	822 (2.2)		
Facility of residence			
Yes	21,825 (54.3)	Ref.	
No	17,481 (43.5)	−0.30 (−0.41, −0.20)	<0.01
Missing	916 (2.3)		
Movement Behavior			
MVPA			
<180 min/d	13,198 (32.8)	Ref.	
≥180 min/d	18,865 (46.9)	−0.22 (−0.34, −0.10)	<0.01
Missing	8,159 (20.3)		

Abbreviation: BF%=body fat percentage; *CI*=confidence interval; Ref.=reference; BMI=body mass index; MVPA=moderate-to-vigorous physical activity.

colder northern temperatures necessitate greater fat accumulation for thermal regulation. The observed geospatial variations in preschooler BF% may also reflect differences in urban livability (*13*), precipitation patterns, ambient particulate matter pollution, and regional dietary habits. These disparities underscore the importance of analyzing early childhood body composition using nationwide data to identify and address regional inequalities.

The determinants of preschoolers' BF% levels appear to emerge from complex social and environmental interactions. Consistent with existing literature, elevated childhood BF% shows strong associations with parental overweight (*14*). This relationship likely reflects both genetic predisposition and the direct influence of family dynamics on children's physical activity patterns, dietary behaviors, and weight management practices (*15*). Additionally, residential environmental characteristics emerge as crucial determinants of preschooler BF%, including green space availability and accessibility (*16*), fine particulate matter exposure (*17*), and school neighborhood characteristics (*18*).

Several limitations warrant consideration in interpreting our findings. First, the cross-sectional nature of the study design precludes establishing causal relationships between the identified factors and BF%. Second, key determinants of BF% in the Chinese preschoolers, including dietary patterns and sleep behaviors, were not comprehensively assessed in this analysis. Lastly, although this study utilized the latest nationally representative data (5th CNPFS, 2020), BF% may have changed over time. Future research should explore spatiotemporal trends in preschool children's BF% to capture potential variations.

Our study provides the first comprehensive assessment of BF% prevalence among the Chinese preschoolers aged 3–6 years, establishing a foundation for developing standardized BF% criteria for defining overweight and obesity in this population. The identification of significant BF% disparities across residential areas and the 31 PLADs addresses a critical gap in the current literature. These findings underscore the urgent need for targeted policy interventions aimed at reducing regional health inequalities and promoting optimal development during this crucial developmental period.

Conflicts of interest: The authors declare no conflicts of interest.

Ethical statement: Received ethical approval from the Ethics Committee of the China Institute of Sport Science (approval number: CISSLA-20240219).

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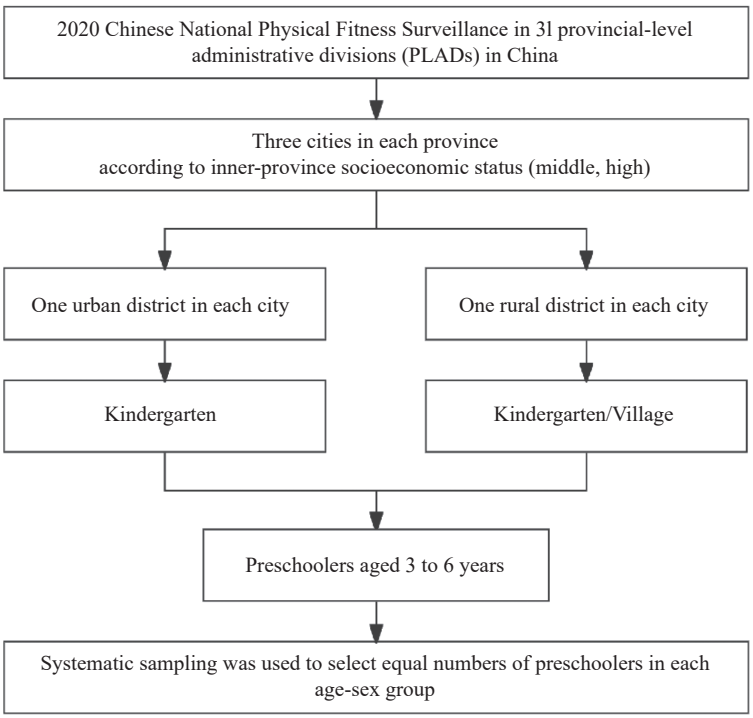
SUPPLEMENTARY MATERIAL



SUPPLEMENTARY FIGURE S1. Flow chart of sampling design in the 2020 Chinese National Physical Fitness Surveillance.