Health and Metabolism

Article

Associations of Obesity and Hypertension with Health-Related Physical Fitness among Women Living in Tibet: A Cross-Sectional Study

Ting Chen [1,†], Jiaqiao Zhang [2,†], Xin Zhao [3], Jiajuan Wang [1], Xiaocan Li [1], Yaohan Peng [1], and Dandan Jia [2,*]

[1] Key Laboratory of Plateau Hypoxia Environment and Life and Health, Plateau Sports and Health Research Center, Xizang University for Nationalities, Xianyang 712082, China
[2] School of Exercise and Health, Shanghai University of Sports, Shanghai 200438, China
[3] Xizang University for Nationalities Hospital, Xianyang 712082, China
* Correspondence: jiadandan@sus.edu.cn
† These authors contributed equally to this work.
Received: 13 February 2026; Revised: 28 April 2026; Accepted: 15 June 2026; Published: 20 August 2026

Abstract: Objectives**:** To investigate the relationship between hypertension, obesity, and physical health in women at high altitude, and to identify modifiable associated factors. Methods: This cross-sectional study included 1736 women residing in Tibet aged 20–69 years from three altitudinal regions. Anthropometry, blood pressure, and health-related physical fitness (body composition, cardiorespiratory endurance, muscle strength, muscle endurance, flexibility) were measured. Group differences were examined using chi-square tests and one-way ANOVA, and binary logistic regression was used to identify factors associated with hypertension, obesity, and HPF qualification status. Results: Hypertension and obesity were highly prevalent. Regular exercise and higher education were independently associated with lower odds of both obesity and hypertension. Hypertension alone was not associated with an increased risk of physical unfitness; however, its co-presence with obesity was associated with a markedly elevated risk of unfitness. Conclusions: Hypertension alone was not significantly associated with unqualified HPF status, whereas the co-presence of hypertension and excess waist circumference was associated with poorer HPF outcomes. Different hypertension subtypes showed distinct patterns of association with selected HPF indicators. Regular exercise and higher education were associated with lower odds of obesity, hypertension, or unqualified HPF status. Integrated strategies targeting both adiposity and blood pressure are essential for metabolic health in high-altitude populations.

Keywords: Tibetan women; hypertension; obesity; health-related physical fitness

1. Introduction

The Tibetan people constitute a distinctive indigenous ethnic group that inhabits the Qinghai-Tibet Plateau, the world's highest and largest plateau, with an average elevation exceeding 4500 m above sea level. Approximately six million Tibetans reside in China, while smaller populations live in neighboring countries, particularly India, due to historical circumstances. Within China, the Tibetan population is primarily distributed across five provincial-level administrative regions: the Tibetan Autonomous Region (TAR), Qinghai, Sichuan, Yunnan, and Gansu provinces. The TAR hosts the largest concentration of Tibetans, with a population of 3.14 million, accounting for 86% of the region's total population. Consequently, demographic and socioeconomic indicators from the TAR can serve as reliable proxies for the broader Tibetan population.

Although rising from 68.17 years in 2010 to 72.19 years in 2020 [1], the average life expectancy of the Tibetan population was significantly lower than the national average in 2023 (78.6 years) [2]. Their suboptimal health status is closely related to their special living environment and relatively underdeveloped socioeconomic conditions. Among these factors, high altitude is one of the independent risk factors for hypertension. Research indicates that altitude (3000–4300 m) was positively correlated with the prevalence of hypertension [3], while negatively correlated with awareness of hypertension prevention and control [4,5]. In addition, obesity is another risk factor for hypertension. Studies have shown that the risk of hypertension in overweight and obese individuals is 1.16 and 1.28 times higher than that in normal-weight individuals, respectively [6]. Compared with Han people living on the plateau, there are many differences in metabolic parameters among Tibetans [7]. A cross-sectional study has found that obesity and hypertension are the most common metabolic abnormalities in high-altitude regions [8]. Among Tibetans, women generally have higher fat mass and body fat percentage than men across ages [9–12], positioning Tibetan women as a key population for obesity and hypertension. Furthermore, emerging evidence suggests that estrogen plays a protective role in adipose tissue by alleviating hypoxia-induced dysfunction via the HIF-1α/VEGF pathway [13]. Consequently, blood pressure and obesity patterns in women living in Tibet are shaped by an interplay of hypoxia, estrogen changes, and metabolic adaptations that remains incompletely understood. Findings from low-altitude or other populations may not be directly generalizable, warranting further investigation in this unique group.

Health-related physical fitness (HPF) serves as a key indicator of holistic health in individuals and is typically assessed through five core dimensions: body composition, cardiorespiratory endurance, muscular strength, muscular endurance, and flexibility [14]. Existing evidence suggests that HPF can effectively identify patients with prevalent diabetes and hypertension [15]. Specifically, enhanced flexibility and grip strength have been linked to a lower prevalence of hypertension in normoxic conditions [16]. Nevertheless, the relationship between these physical attributes and the occurrence of hypertension and obesity under high-altitude environmental stress remains insufficiently characterized.

To contribute to a clearer understanding, this study evaluated 11 parameters covering five HPF domains among women residing in Tibet. Given that coordination of muscle movements may indirectly affect HPF, we also included two extra parameters concerning balance and reaction ability. These included anthropometric indicators associated with body composition (body mass index, BMI; chest circumference, CC; waist circumference, WC; hip circumference, HC); cardiorespiratory fitness measures (step index, SI; vital capacity, VC); muscular strength and power assessments (grip strength, GS; back strength, BS; vertical jump, VJ); an index of muscular endurance (sit-up, SU); flexibility-related metrics (sit-and-reach, SAR); and neuromuscular fitness (choice reaction time, CRT; eye-closed unilateral stance time, CUST). By investigating the associations of these HPF components with hypertension and obesity, this work aims to establish a scientific foundation for developing targeted health and fitness strategies for women residing in the TAR.

2. Materials and Methods

2.1. Participants

The data utilized in this investigation were derived from a physical fitness monitoring program conducted in the TAR by the Tibet Institute of Sport Science.

Consistent with the real-world ethnic composition of the region, both Han and Tibetan women were included. To guarantee adequate representativeness of the sample, three municipalities—Lhasa (elevation 3658 m), Nyingchi (3100 m), and Nagqu (4500 m)—were purposively selected as survey locations based on their distinct altitudinal gradients. Within each location, participants were recruited in equal proportions through a stratified random sampling approach, taking into account different socioeconomic strata (low, middle, and high) and urban or rural residency.

Inclusion criteria were as follows: (1) female sex; (2) age between 20 and 69 years; (3) permanent residence in one of the three selected municipalities (Lhasa, Nyingchi, or Nagqu); (4) completion of all core measurements, including anthropometry, blood pressure, and the health-related physical fitness tests. Exclusion criteria included: (1) missing data for any of the primary outcome variables; (2) self-reported history of severe cardiovascular disease (e.g., heart failure, myocardial infarction), chronic kidney disease, or other conditions that would preclude safe participation in physical fitness testing; (3) current pregnancy, as ascertained by self-report during the questionnaire interview. A total of 1736 female participants were included in the final analysis.

The study procedures received ethical approval from the Biomedical Ethics Committee of Xizang University for Nationalities (approval No. 2021-31) and were carried out in full compliance with the principles set forth in the Declaration of Helsinki.

2.2. Measurements

2.2.1. Basic Information

Basic information included age, region, urban and rural areas, nationality, education level, occupational status, and physical activity (never exercise: never participated in physical activity in the past year; regular exercise: participated in physical activity more than 3 times a week and more than 30 min of physical activity each time; occasional exercise: participated in physical activity in the past year but did not meet the above criteria). Information above was collected through a questionnaire by trained interviewers prior to the physical fitness test.

2.2.2. HPF Indicators Measurement and Calculations

Anthropometric parameters were obtained as follows: height (m) and weight (kg) were measured using an electronic stadiometer and an electronic scale. Chest circumference (CC, cm), waist circumference (WC, cm), and hip circumference (HC, cm) were measured using a flexible, non-elastic nylon measuring tape. The remaining HPF components including vital capacity (VC, mL), step index (SI), grip strength (GS, kg), vertical jump (VJ, cm), sit-up (SU, times/min), choice reaction time (CRT, s), eye-closed unilateral stance time (CUST, s), sit-and-reach (SAR, cm), and back strength (BS, kg) were evaluated in accordance with the National Physical Fitness Measurement Standards Manual (2003 Edition) [17], the then-current standardized national testing protocol issued by the General Administration of Sport of China, employing equipment provided by the National Physical Fitness Monitoring Centre, the State Sport General Administration. Briefly, VC was measured by spirometry (best of two maximal exhalations); SI was derived from heart rate recovery after a 3-min step test and calculated as (duration of exercise (s)/sum of three pulse counts taken at 1–1.5 min, 2–2.5 min, and 3–3.5 min post-exercise) × 100. GS was assessed with a hand dynamometer (maximum of two attempts per hand); VJ was performed on a jump mat (best of two trials); SU were counted over one minute; CRT was measured using an electronic reaction timer; CUST was timed (60-s maximum); SAR was performed on a standard box; and BS was measured with a back dynamometer.

The related anthropometric indices were calculated as follows: BMI = weight/height^2. The comprehensive result of the HPF indicators was then rated by dividing it into qualified (including excellent, good, and pass) and unqualified, according to the National Physical Fitness Measurement Standards Manual (2003 Edition) which provides age- and sex-specific percentile-based cut-off values for each HPF component. A composite score was calculated by summing the weighted scores across the five fitness domains. Participants whose total composite score met or exceeded the national standard threshold for their age and sex group were classified as "qualified"; those scoring below the threshold were classified as "unqualified". The detailed rating standard is provided in Supplemental Material S1.

2.2.3. Hypertension and Obesity Diagnoses

Overweight was defined as a BMI ≥ 24 kg/m^2, obesity as a BMI ≥ 28 kg/m^2, and abdominal obesity as a WC ≥ 85 cm for women, based on the Chinese criteria [18].

Heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) were measured using an electronic sphygmomanometer. Participants were instructed to refrain from consuming caffeinated beverages, smoking, and engaging in vigorous physical activity for at least 30 min before the measurement. After a seated rest period of at least 5 min with the back supported and feet flat on the floor, two consecutive readings were taken from the non-dominant arm at a 1-min interval. If the systolic or diastolic difference between the first two readings exceeded 5 mmHg, a third reading was obtained, and the average of the two closest readings was used as the final blood pressure value. Heart rate was recorded simultaneously by the device. Pulse pressure difference (PPD) was calculated as SBP—DBP. The diagnosis of Hypertension was based on the 2018 Chinese guidelines for the management of Hypertension [6]: SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg in individuals not taking antihypertensive medication. Those who met only the systolic or diastolic diagnostic criteria were defined as isolated systolic hypertension (ISH) or isolated diastolic hypertension (IDH), respectively, while those who met both criteria were defined as systolic and diastolic hypertension (SDH).

2.3. Statistics Method

Data from physical fitness monitoring and questionnaire surveys were calculated statistically in EXCEL and SPSS 26.0. A non-parametric one-sample K-S test was used to test whether the data obeyed a normal distribution. For normally distributed variables, descriptive data were presented as $\overline{x} \pm s$. Comparisons of continuous HPF variables across different obesity categories and hypertension subtypes were performed using one-way analysis of variance (ANOVA). For comparisons of categorical variables (e.g., prevalence rates of obesity and hypertension, HPF qualification rates), the Chi-square test was employed. Binary logistic regression was used to examine factors associated with hypertension, obesity, and HPF qualification status. In all binary logistic regression models, covariates included hypertension status (no as reference), obesity status (no as reference), age (20–39 as reference), altitude of residence (Nyingchi as reference), education level (primary and below as reference), and physical activity (never exercise as reference), unless the variable itself served as the primary exposure. $p < 0.05$ was considered significant, and $p < 0.01$ was considered highly significant.

Health Metab. **2026**, *3*(3), 4 https://doi.org/10.53941/hm.2026.100018

3. Results

3.1. General Characteristics of Participants

Table 1 shows that a total of 1736 women aged from 20 to 69 were included, with an average age of 42.65 ± 13.91 years. Of the total participants, 232 (13.4%) were Han and 1504 (86.6%) were Tibetan. A total of 466 (26.84%) were diagnosed with hypertension, including 47 (2.71%) with isolated systolic hypertension (ISH), 307 (17.68%) with isolated diastolic hypertension (IDH), and 112 (6.45%) with combined systolic and diastolic hypertension (SDH).

Table 1. General characteristics of the participants.

Characteristic	Category	n (%)
Age	20–39	746 (42.97%)
	40–59	731 (42.11%)
	60–69	259 (14.92%)
Nationality	Han	232 (13.36%)
	Tibetan	1504 (86.64%)
Region	Nyingchi	604 (34.79%)
	Lhasa	567 (32.66%)
	Naqu	565 (32.55%)
Area	Rural	557 (32.09%)
	Urban	1179 (67.91%)
Education level	Primary and below	750 (43.20%)
	Middle school	507 (29.21%)
	College or above	479 (27.59%)
Occupational status	Unemployed	21 (1.21%)
	Employed	1715 (98.79%)
Physical activity	Never exercise	1147 (66.07%)
	Occasional exercise	129 (7.43%)
	Regular exercise	460 (26.50%)
Hypertension	No	1270 (73.16%)
	ISH	47 (2.71%)
	IDH	307 (17.68%)
	SDH	112 (6.45%)
Overweight, general obesity or abdominal obesity	No	896 (51.61%)
	Yes	840 (48.39%)

Note: ISH, isolated systolic hypertension; IDH, isolated diastolic hypertension; SDH, combined systolic and diastolic hypertension.

Among women with hypertension, a significantly higher rate of IDH and SDH was observed in the Tibetan, rural area, the group with high school education or below, and the overweight, obesity/abdominal obesity group (Table 2, all $p < 0.05$).

Table 2. Prevalence of hypertension in women aged 20–69 years in Tibet [n (%)].

Indicators		Type of Hypertension					
		ISH	x^2/p	IDH	x^2/p	SDH	x^2/p
Age	20–39 (n = 746)	11 (1.47%)	8.05/0.02	63 (8.45%)	86.10/<0.01	3 (0.40%)	154.64/<0.01
	40–59 (n = 731)	25 (3.42%) *		164 (22.44%) **		51 (6.98%) **	
	60–69 (n = 259)	11 (4.25%) *		80 (30.89%) **##		58 (22.39%) **##	
Nationality	Han (n = 232)	2 (0.86%)	3.46/0.06	23 (9.91%)	11.11/<0.01	6 (2.59%)	6.63/0.01
	Tibetan (n = 1504)	45 (2.99%)		284 (18.88%) **		106 (7.05%) *	
Region	Nyingchi (n = 604)	5 (0.83%)	20.93/<0.01	102 (16.89%)	57.93/<0.01	36 (5.96%)	10.37/0.01
	Lhasa (n = 567)	29 (5.11%) **		54 (9.52%) **		25 (4.41%)	
	Naqu (n = 565)	13 (2.30%) ##		151 (26.73%) **##		51 (9.03%) #	
Area	Rural (n = 557)	15 (2.69%)	0.00/0.98	122 (21.90%)	10.03/<0.01	54 (9.69%)	14.29/<0.01
	Urban (n = 1179)	32 (2.71%)		185 (15.69%) **		58 (4.92%) **	
Overweight, general obesity or abdominal obesity	No (n = 896)	20 (2.33%)	1.59/0.21	107 (11.94%)	41.95/<0.01	30 (3.35%)	29.55/<0.01
	Yes (n = 840)	27 (3.21%)		200 (23.81%) **		82 (9.76%) **	

Table 2. *Cont.*

Indicators		Type of Hypertension					
		ISH	x^2/p	IDH	x^2/p	SDH	x^2/p
Education level	Primary and below (n = 750)	24 (3.20%)	1.43/0.49	173 (23.07%)	38.69/<0.01	72 (9.60%)	32.08/<0.01
	Middle school (n = 507)	13 (2.56%)		90 (17.75%)		33 (6.51%)	
	College or above (n = 479)	10 (2.09%)		44 (9.19%) **##		7 (1.46%) **##	
Occupational status	Unemployed (n = 21)	2 (9.52%)	1.59/0.21	8 (38.10%)	4.75/0.03	1 (4.76%)	0.00/1.00
	Employed (n = 1715)	45 (2.62%)		299 (17.43%) *		111 (6.47%)	
Physical activity	Never exercise (n = 1147)	39 (3.40%)	6.95/0.03	213 (18.57%)	5.57/0.06	92 (8.02%)	13.82/<0.01
	Occasional exercise (n = 129)	2 (1.55%)		28 (21.71%)		4 (3.10%)	
	Regular exercise (n = 460)	6 (1.30%)		66 (14.35%)		16 (3.48%) **	

Note: ISH, isolated systolic hypertension; IDH, isolated diastolic hypertension; SDH, combined systolic and diastolic hypertension. Compared with 20–39, Han, Nyingchi, Rural, no overweight obese/abdominal obesity, unemployed, primary and below, never exercise groups, * indicates $p < 0.05$, ** indicates $p < 0.01$; Compared with 40–59, Lhasa, middle school group, # indicates $p < 0.05$, ## indicates $p < 0.01$.

The general prevalence of overweight/obesity was 48.39%. The prevalence rates of overweight, obesity, and abdominal obesity among participants were 28.23%, 12.44%, and 30.36%, respectively (Table 3).

Table 3. Prevalence of overweight and obesity in women aged 20–69 years in Tibet [n (%)].

Variant	n	Overweight	x^2/p	General Obesity	x^2/p	Abdominal Obesity	x^2/p
Age							
20–39	746	171 (22.92%)	31.28/<0.01	47 (6.30%)	50.88/<0.01	119 (15.95%)	128.85/<0.01
40–59	731	213 (29.14%) **		114 (15.60%) **		297 (40.63%) **	
60–69	259	106 (40.93%) **##		55 (21.24%) **		111 (42.86%) **	
Nationality							
Han	232	72 (31.03%)	1.04/0.31	15 (6.47%)	8.78/<0.01	57 (24.57%)	4.24/0.04
Tibetan	1504	418 (27.79%)		201 (13.36%) **		470 (31.25%) *	
Region							
Nyingchi	604	177 (29.30%)	20.43/<0.01	83 (13.74%)	38.09/<0.01	209 (34.60%)	28.70/<0.01
Lhasa	567	123 (21.69%) **		33 (5.82%) **		124 (21.87%) **	
Naqu	565	190 (33.63%) ##		100 (17.70%) ##		194 (34.34%) ##	
Hypertension							
No	1270	324 (25.51%)	17.20/<0.01	116 (9.13%)	47.54/<0.01	317 (24.96%)	65.17/<0.01
Yes	466	166 (35.62%) **		100(21.46%) **		210 (45.06%) **	
Education level							
Primary and below	750	226 (30.13%)	5.89/0.05	109 (14.53%)	7.67/0.02	246 (32.80%)	5.85/0.05
Middle school	507	149 (29.39%)		63 (12.43%)		155 (30.57%)	
College or above	479	115 (24.01%)		44 (9.19%) *		126 (26.30%)	
Physical activity							
Never exercise	1147	336 (29.29%)	3.00/0.22	163 (14.21%)	10.23/0.01	382 (33.30%)	17.90/<0.01
Occasional exercise	129	29 (22.48%)		14 (10.85%)		41 (31.78%)	
Regular exercise	460	125 (27.17%)		39 (8.48%) *		104 (22.61%) **	

Note: Compared with 20–39, Han, Nyingchi, rural, primary and below, hypertension, never exercise, * indicates $p < 0.05$, ** indicates $p < 0.01$; Compared with 40–59, Lhasa, # indicates $p < 0.05$, ## indicates $p < 0.01$.

A significantly higher prevalence of abdominal obesity was found in the group with a primary education or below (all $p < 0.05$). Binary logistic regression analysis with hypertension status as the dependent variable is shown in Figure 1.

The results indicated that age, altitude, obesity, education level, and physical activity were the influencing factors of hypertension in women in Tibet, with 40–59 years old (OR = 3.68, 95% CI: 2.73–4.96), 60–69 years old (OR = 8.16, 95% CI: 5.62–11.84), living in Naqu (OR = 1.96, 95% CI: 1.44–2.66), and overweight, general obesity or abdominal obesity (OR = 1.62, 95% CI: 1.26–2.08) positively associated with hypertension, while living in Lhasa (OR = 0.70, 95% CI: 0.50–0.97), college and above education (OR = 0.56, 95% CI: 0.38–0.82) and regular exercise (OR = 0.71, 95% CI: 0.52–0.97) negatively associated. Notably, overweight, general obesity or abdominal obesity had a significant association specifically with DBP.

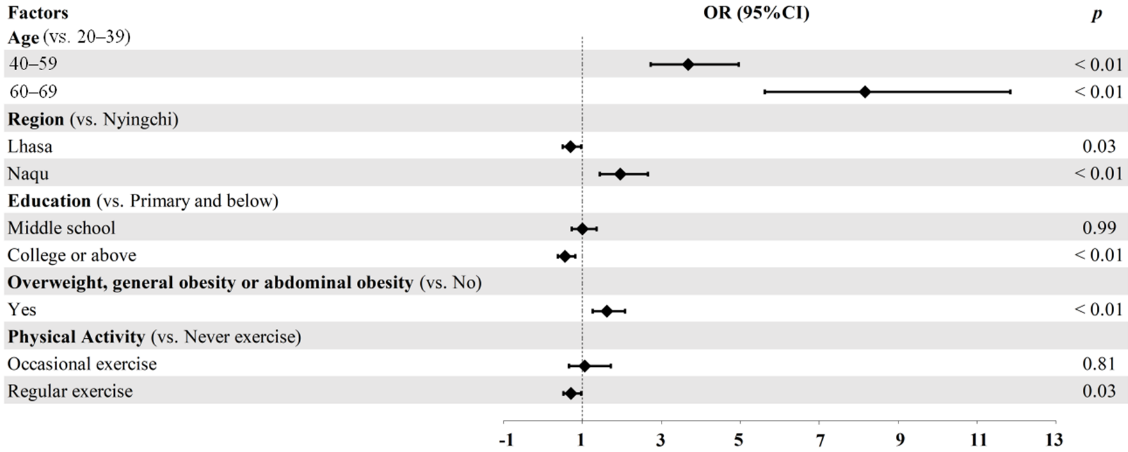

Figure 1. Forest plot of OR and 95% CI for factors associated with hypertension among women living in Tibet. The covariates in the binary regression model include age, nationality, region, rural/urban, occupational status, education level, obesity status and physical activity. The vertical dashed line represents an OR of 1.0 (no association). OR > 1 indicates a positive association; OR < 1 indicates an inverse association.

Binary logistic regression analysis with obesity status as the dependent variable (Figure 2) showed that age, altitude, hypertension, and physical activity were the influencing factors, with 40–59 years old (OR = 3.48, 95% CI: 2.69–4.49), 60–69 years old (OR = 4.23, 95% CI: 3.00–5.98), hypertension (OR = 1.62, 95% CI: 1.26–2.08) positively correlated with obesity in women, and living in Lhasa (OR = 0.52, 95% CI: 0.39–0.68), regular exercise (OR = 0.67, 95% CI: 0.51–0.87) negatively associated (all $p < 0.05$).

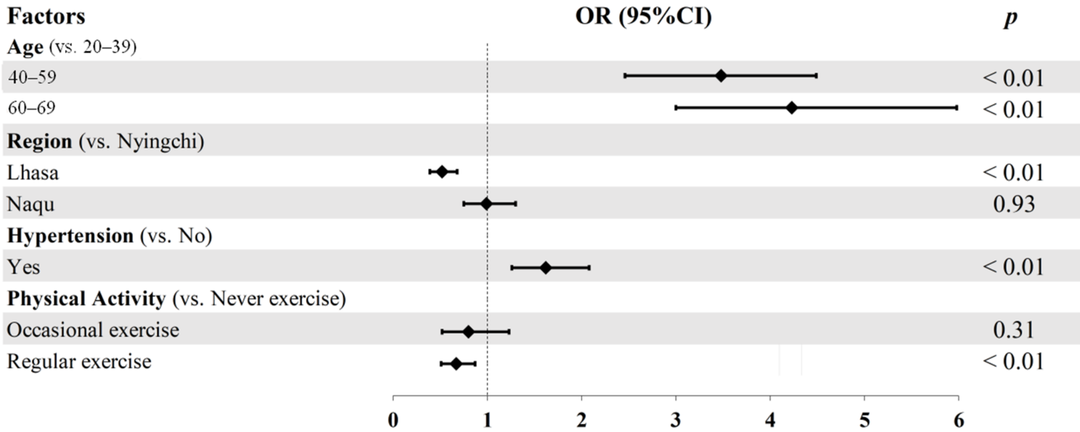

Figure 2. Forest plot of OR and 95% CI for factors associated with overweight, general obesity or abdominal obesity among women living in Tibet. The covariates in the binary regression model include age, region, nationality, education level, hypertension status and physical activity. The vertical dashed line represents an OR of 1.0 (no association). OR > 1 indicates a positive association; OR < 1 indicates an inverse association.

3.2. Health-Related Physical Fitness Test

As the test items for women of different age groups varied slightly, we first calculated the overall qualification rate for the HPF test to observe its general characteristics. The general qualification rate was 77.36%, as shown in Table 4. Overweight women (75.71%) had a higher rate than hypertensive women (74.25%), abdominally obese women (66.98%), and obese women (41.20%). A higher qualification rate was also found in the group aged 20–39, the urban group, the group with college education or above, and the regular exercisers. Women with normal waist circumferences had a higher qualification rate than those with abdominal obesity (Table 4, all $p < 0.05$).

Binary logistic regression results displayed in Figure 3 showed that education level and physical activity were influential factors for the physical fitness and health of women aged 20–69 years in Tibet. Education level of college or above (OR = 0.49, 95% CI: 0.34–0.72) and regular exercise (OR = 0.58, 95% CI: 0.42–0.79) were associated factors for women's physical health.

Table 4. Physical qualification rate of women aged 20–69 in Tibet [n (%)].

Indicators	Qualified [n (%)]	Unqualified [n (%)]	x^2/p	Indicators	Qualified [n (%)]	Unqualified [n (%)]	x^2/p
Age			7.44/0.02	BMI			220.12/<0.01
20–39	596 (79.89%)	150 (20.11%)		Normal	843 (87.09%)	125 (12.91%)	
40–59	561 (76.74%)	170 (23.26%)		Thin	40 (64.52%) **	22 (35.48%)	
60–69	186 (71.81%) *	73 (28.19%)		Overweight	371 (75.71%) **	119 (24.29%)	
Area			15.37/<0.01	Obese	89 (41.20%) **##▲▲	127 (58.80%)	
Rural	399 (71.63%)	158 (28.37%)		Abdominal obesity			46.54/<0.01
Urban	944 (80.07%) **	235 (19.93%)		No	990 (81.89%)	219 (18.11%)	
Nationality			0.01/0.93	Yes	353 (66.98%) **	174 (33.02%)	
Han	180 (77.59%)	52 (22.41%)		Blood pressure			7.15/0.07
Tibetan	1163 (77.33%)	341 (22.67%)		Normal	997 (78.50%)	273 (21.50%)	
Occupational status			0.43/0.51	ISH	37 (78.72%)	10 (21.28%)	
Unemployed	18 (85.71%)	3 (14.29%)		IDH	233 (75.90%)	74 (24.10%)	
Employed	1325 (77.26%)	390 (22.74%)		SDH	76 (67.86%)	36 (32.14%)	
Education level			32.69/<0.01	Physical activity			28.17/<0.01
Primary and below	545 (72.67%)	205 (27.33%)		Never exercise	844 (73.58%)	303 (26.42%)	
Middle school	384 (75.74%)	123 (24.26%)		Occasional exercise	106 (82.17%)	23 (17.83%)	
College or above	414 (86.43%) **##	65 (13.57%)		Regular exercise	393 (85.43%) **	67 (14.57%)	

Note: Compared with 20–39, rural, primary and below, normal BMI, never exercise group, * indicates $p < 0.05$, ** indicates $p < 0.01$; Compared with thin, middle school group, # indicates $p < 0.05$, ## indicates $p < 0.01$; Compared with overweight group, ▲ indicates $p < 0.05$, ▲▲ indicates $p < 0.01$.

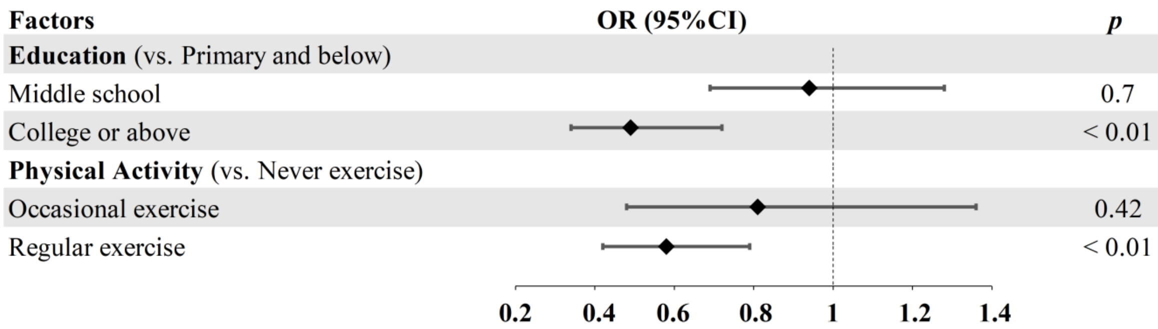

Figure 3. Forest plot of OR and 95% CI for factors associated with unqualified HPF among women living in Tibet. The covariates in the binary regression model include age, rural/urban, education level and physical activity. The vertical dashed line represents an OR of 1.0 (no association). OR > 1 indicates a positive association with physical unfitness; OR < 1 indicates an inverse association.

3.3. Association between Hypertension and HPF Results

To further understand the correlations between hypertension and HPF, we compared test scores in women with different WC and blood pressure (Supplemental Table S1). In spite of the fact that there were significant differences in fitness scores between different WC and hypertension types, the risk of failing to meet the HPF qualification standards showed no statistically significant difference in those with different hypertension types (all $p > 0.05$). These findings suggest that overweight, general obesity, and abdominal obesity are associated with a higher risk of unqualified HPF status, whereas hypertension alone was not significantly associated with HPF qualification status.

Analysis of HPF test item results among patients with different subtypes of hypertension in Table 5 revealed that BMI, WC, VC, SI, GS, BS, SAR, CRT, and CUST were significantly associated with hypertension. However, women with ISH exhibited significant differences from the normotensive group only in SI, BS and CUST, with BS being significantly elevated relative to the normotensive group. Women with IDH showed significant differences from the normotensive group in CC, WC, BMI, BS, and CRT; notably, their BS was significantly lower than that of women with ISH but still significantly higher than that of the normotensive group. In contrast, women with SDH presented significant differences from the normotensive group in CC, WC, BMI, VC, GS, SAR, CRT and CUST. Intergroup comparisons indicated that patients with SDH had poorer muscle strength, cardiopulmonary fitness and flexibility than those with ISH and IDH.

Table 5. Physical test results of different types of hypertension in women aged 20–69 in Tibet.

Indicators		**Normal (n = 1270)**	**ISH (n = 47)**	**IDH (n = 307)**	**SDH (n = 112)**	**F**	***p***
Anthropometric indicators	CC/cm	86.50 ± 7.05	87.91 ± 6.49	88.67 ± 8.24 **	89.81 ± 9.81 **	12.31	<0.01
	WC/cm	79.44 ± 9.20	81.67 ± 10.79	84.49 ± 10.19 **	84.77 ± 10.87 **	30.42	<0.01
	HC/cm	91.09 ± 7.68	90.35 ± 6.85	91.89 ± 9.53	92.84 ± 11.17	2.30	0.08
	BMI (kg/m^2)	23.29 ± 3.28	24.82 ± 3.79	24.87 ± 3.86 **	26.10 ± 3.80 **$^{\blacktriangle}$	37.15	<0.01
Cardiorespiratory endurance	HR/bpm	78.61 ± 8.25	79.98 ± 8.37	79.31 ± 8.99	78.08 ± 8.38	1.15	0.33
	SBP/mmHg	110.55 ± 12.83	143.64 ± 3.55 **	125.43 ± 6.85 **$^{\#\#}$	146.03 ± 7.07 **$^{\#\blacktriangle\blacktriangle}$	507.42	<0.01
	DBP/mmHg	75.74 ± 7.90	80.72 ± 5.75 **	94.67 ± 6.04 **$^{\#\#}$	100.48 ± 7.37 **$^{\#\#\blacktriangle\blacktriangle}$	795.82	<0.01
	PPD/mmHg	34.81 ± 10.31	62.91 ± 6.83 **	30.75 ± 7.28 **$^{\#\#}$	45.54 ± 7.68 **$^{\#\#\blacktriangle\blacktriangle}$	195.67	<0.01
	VC/ml	1785.42 ± 560	1919.30 ± 582.69	1776.31 ± 524.07	1593.69 ± 461.45 **$^{\#\#\blacktriangle\blacktriangle}$	5.32	<0.01
	SI	60.51 ± 9.85	52.21 ± 9.57 **	58.62 ± 10.88 $^{\#\#}$	57.56 ± 13.32	10.42	<0.01
Muscular strength and power	GS/kg	26.64 ± 5.72	26.33 ± 7.06	26.25 ± 6.44	24.20 ± 5.09 **$^{\blacktriangle\blacktriangle}$	6.07	<0.01
	BS/kg	71.35 ± 21.77	104.36 ± 15.42 **	80.21 ± 17.96 **$^{\#\#}$	76.33 ± 48.64	11.39	<0.01
	VJ/cm	20.62 ± 5.41	23.44 ± 3.76	21.80 ± 7.21	26.33 ± 3.29	2.72	0.04
Muscular endurance	SU	15.81 ± 8.97	27.82 ± 10.56 *	16.71 ± 8.39 $^{\#}$	22.33 ± 3.51	7.12	<0.01
Flexibility	SAR	8.18 ± 6.91	9.40 ± 7.86	7.06 ± 6.95	5.09 ± 7.40 **$^{\#}$	8.90	<0.01
Neuromuscular fitness	CRT	0.61 ± 0.17	0.61 ± 0.20	0.68 ± 0.19 **	0.77 ± 0.24 **$^{\#\#\blacktriangle\blacktriangle}$	33.90	<0.01
	CUST	16.08 ± 16.30	10.91 ± 6.93 **	13.91 ± 14.49	10.69 ± 10.50 **	6.45	<0.01

Note: CC, chest circumference; WC, waist circumference; HC, hip circumference; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure; PPD, pulse pressure difference; VC, vital capacity; SI, step index, sample size for the actual analysis: 1477; GS, grip strength; BS, back strength, sample size for the actual analysis: 746; VJ, vertical jump, sample size for the actual analysis: 746; SU, sit-up, sample size for the actual analysis: 746; SAR, sit-and-reach; CRT, choice reaction time; CUST, eye-closed unilateral stance time. Compared with normal blood pressure, * indicates $p < 0.05$, ** indicates $p < 0.01$; Compared with ISH, $^{\#}$ indicates $p < 0.05$, $^{\#\#}$ indicates $p < 0.01$; Compared with IDH group, $^{\blacktriangle}$ indicates $p < 0.05$, $^{\blacktriangle\blacktriangle}$ indicates $p < 0.01$.

3.4. Association between Hypertension, Abdominal Obesity and HPF Results

Through our preceding investigation, we discovered that obesity and hypertension are closely associated among women in TAR. To further understand the correlations between obesity, hypertension, and HPF, we compared test scores in women with different BMI, WC, and blood pressure. The synergized influence of hypertension and obesity was shown in Table 6.

Table 6. Physical disqualification rate of women with different obesity and hypertension in Tibet [n (%)].

Indicators		**Physical Fitness Unqualified**			
		Normal	**ISH**	**IDH**	**SDH**
BMI	Normal	107 (13.82%)	3 (14.29%)	11 (7.91%)	4 (11.76%)
	Thin	19 (33.93%) **	1 (100.00%)	2 (40.00%)	0 (0.00%)
	Overweight	83 (25.62%) **	3 (17.65%)	22 (22.00%) **	11 (22.45%)
	Obese	64 (55.17%) **$^{\#\#}$	3 (37.50%)	39 (61.90%) **$^{\#\#}$	21 (72.41%) **$^{\#\#}$
	x^2/p	111.34/<0.01	5.00/0.17	66.35/<0.01	30.15/<0.01
WC	Normal	175 (18.36%)	5 (16.13%)	25 (15.24%)	14 (22.95%)
	Abdominal obesity	98 (30.91%) **	5 (31.25%)	49 (34.27%) **	22 (43.14%) *
	x^2/p	22.21/<0.01	0.68/0.41	15.11/<0.01	5.19/0.02

Note: Compared with normal BMI, normal waist circumference group, * indicates $p < 0.05$, ** indicated $p < 0.01$; Compared with overweight group, $^{\#}$ indicates $p < 0.05$, $^{\#\#}$ indicates $p < 0.01$.

In the IDH and SDH population, obese women had a higher prevalence of unqualified status than overweight women and those of normal weight. Women with excessive WC had a higher rate of physical-fitness unqualification than those with normal WC. While in the IDH population, a higher physical-fitness unqualification rate was found in overweight women than in women of normal weight (all $p < 0.05$). Therefore, hypertension synergized with obesity and excess waist circumference can significantly increase the risk of unqualified HPF status in women.

4. Discussion

In this study, the prevalence of hypertension was 26.8% among women in Tibet, higher than the recent estimates for China and globally. The causes of the high prevalence of hypertension in Tibet are closely related to high altitude, low oxygen, low pressure, high cold, unique lifestyles (high salt, high fat, lack of vegetables and fruits, etc.) in the plateau region, as well as genetic factors. One possible mechanism is that prolonged exposure to hypoxia increases sympathetic activity and alters autonomic regulation, thereby contributing to elevated blood pressure [19]. Studies on genetic adaptation have found that the C allele at the rs2070744 locus of the inducible nitric oxide synthase (NOS3) gene and the T allele at the rs4961 locus of the α-adducin 1 (ADD) gene, which are two regulatory genes, are significantly correlated with the high prevalence of hypertension in Tibetans [4].

Despite the high risk of malnutrition among Tibetans in early years, the prevalence of overweight and obesity among Tibetan adults shows a yearly increasing trend today. Notably, 48.39% of our participants experienced obesity (abdominal obesity rate > overweight > obesity), with women over 40 and hypertensive individuals identified as key prevention targets. Our study also found a higher prevalence of abdominal obesity in Tibetan females, consistent with a previous study [9]: alterations in female body fat are mainly influenced by endocrine and other endogenous factors, and the risk of overweight, obesity and related complications increases in Tibetan females after 41.

Among all the influencing factors we found, age is strongly associated with both blood pressure and BMI, with a higher prevalence of hypertension and obesity observed in women aged 40 to 59, also known as pre-menopause. For older women, with the sudden decrease of estrogen, significant fat metabolism and distribution alterations occurred, mainly manifested by the increase of abdominal subcutaneous fat to abdominal visceral fat. Between the ages of 50 and 60, the amount of visceral and subcutaneous fat in women appeared to have a sudden increase, followed by a milder increase. Research showed that the menopausal transition is associated with negative changes in weight gain and fat deposition. In addition to the increase in total body fat and adverse changes in fat mass distribution, the loss of lean body mass and the expansion and redistribution of adipose tissue contribute to the increased risk of obesity in older women [20]. In premenopausal women, estrogen favors subcutaneous fat deposition while restraining visceral fat expansion. Estrogen depletion shifts fat distribution toward the visceral depot, thereby increasing the risk of insulin resistance and metabolic syndrome, and abdominal obesity is also exacerbated for reasons related to the down-regulation of estrogen and other changes in the endocrine system in postmenopausal women [21,22]. Animal studies have demonstrated that chronic hypoxia reduces visceral fat mass, adipocyte size, and triglyceride content but elevates free fatty acid release [23]. Weight and fat loss have also been documented in humans exposed to high altitude. Estrogen alleviates adipose tissue hypoxia via the HIF-1α/VEGF pathway and preserves visceral fat function [13,24], implying that adequate estrogen may partially counteract hypoxia-induced visceral fat dysfunction in women residing at high altitude. Accordingly, in perimenopausal women at high altitude, estrogen deficiency removes the constraint on visceral fat expansion and compromises the adaptive capacity of adipose tissue to hypoxic stress. Concurrently, high-altitude hypoxia exaggerates insulin resistance and adipose dysfunction through HIF-1α activation. These combined results may underlie the higher prevalence of abdominal obesity and a more severe metabolic burden associated with hypertension in women residing at high altitude compared with those at low altitude. Hypertension also becomes more common in women after menopause. Therefore, menopausal women are a key population for the prevention and control of hypertension and obesity.

In this study, the association between hypertension and HPF was not significant. This may be attributed to the high prevalence of hypertension in high-altitude environments, which could obscure the association between physical fitness and hypertension in women living in Tibet. In addition, comparison of detailed HPF item results revealed significant differences among patients with different subtypes of hypertension. Among them, notable abnormal items in ISH patients included SI and BS. As is known, the main cause of ISH is arteriosclerosis, which could lead to decreased arterial elasticity, making it impossible for arteries to dilate effectively when the heart contracts and ejects blood. Poor vascular elasticity may be one reason explaining the low SI values in ISH patients. Another notable finding was that women with ISH and IDH exhibited significantly higher BS compared to normotensive women, despite ISH patients showing lower GS. Currently, we have observed similar findings for upper limb strength from hypertension studies among elderly individuals [16] and sub-plateau populations [25], but no supporting evidence has yet been found for high BS in hypertension. This dissociation between trunk and distal muscle strength warrants a mechanistic interpretation. Thus, we hypothesize that sympathetic overactivity in early hypertension [26] may exert anabolic effects on constantly recruited postural muscles via β-adrenoceptor stimulation, whereas intermittently recruited hand muscles remain unaffected or undergo adverse remodeling. In addition, existing studies have demonstrated that an increase in BMI and waist circumference is associated with elevated absolute strength of the trunk flexors and extensors [27]. We therefore suggest that higher body strength may be partly attributed to compensatory hypertrophy in obese individuals, given its close association with hypertension. This also points out the direction for our further research. Women with SDH exhibited abnormal performance on anthropometric indicators, vital capacity, grip strength, and flexibility, but no significant differences were observed in muscle endurance among the three subtypes of hypertension. Additionally, the co-presence of hypertension and obesity/excess waist circumference was associated with a higher rate of physical-fitness unqualification. This suggests that improving the physical health of women living in Tibet cannot focus on a single factor of blood pressure or obesity, but needs to be considered comprehensively.

This study also found that education and exercise habits were identified as associated factors of HPF for women in TAR. Residents in high-altitude environments have limited exercise approaches, which may fail to meet the recommended exercise volume and potentially threaten cardiovascular health. As an intervention with low side effects that can simultaneously control obesity and blood pressure, exercise is well-recommended and has great potential in the field of public health. On the one hand, exercise may be related to obesity and obesity-related metabolic abnormalities. Evidence suggests that exercise can promote fat loss, improve adipocyte metabolism, and may be effective in "replacing" estrogen and improving the overall health of menopausal women, with overweight/obese postmenopausal women especially sensitive to physical activities [20]. Presently, interval and resistance exercise are the two most commonly mentioned methods for female weight control in the literature. Data have shown that 8 weeks of high-intensity interval training had an effect on reducing total body fat in overweight/obese women, which was more significant in premenopausal women than in postmenopausal women [22]. Resistance training was also proven to be effective in controlling risk factors for metabolic syndrome in menopausal women by lowering blood glucose, waist circumference, and body fat percent, and increasing lean body mass, with a 16-week resistance training pronouncedly improving lean body mass and body fat amount in menopausal women [28]. Meanwhile, exercise is also a common complementary treatment for hypertension. The combination of aerobic and resistance exercise provides the best non-pharmacological means for the management of blood pressure, cardiorespiratory fitness and body composition in hypertensive patients. Studies have shown that moderate aerobic exercise is more beneficial to the cardiovascular health of postmenopausal hypertensive women compared to no exercise or resistance training alone [29]. Besides, aerobic exercise won out on increasing parasympathetic modulation and improving pressure reflex sensitivity compared to resistance exercise. Data showed that 8 weeks of aerobic exercise reduced SBP, DBP and HR in postmenopausal hypertensive women by approximately 3.8%, 5.9% and 3.9%, respectively [29].

However, considering extremely complex environmental impacts such as low oxygen, high ultraviolet light, and large diurnal temperature, the actual situation of the plateau limits participation in outdoor exercises. The content and form of the Tibetan physical exercise is also relatively simple, with fewer resistance exercises and other skill-requiring programs. Most of the exercises are ethnic traditional sports such as Guozhuang dance, and other programs including walking, using fitness equipment, setting the prayer wheels, and kowtowing. Therefore, it is recommended that close attention be paid to the dynamic change characteristics of women's physical fitness, and that publicity on the awareness of the dangers of obesity and hypertension should be increased in the TAR. Specifically, public-health programs should encourage women living in Tibet to participate in regular, culturally appropriate physical activity and gradually increase exercise intensity and duration according to individual health status and environmental conditions.

To our knowledge, this study is the first to explore the association between multidimensional HPF outcomes and hypertension in women residing in the TAR. The study found that hypertension was associated with the pass rate of HPF tests only when combined with abnormal waist circumference, providing a basis for future public policies in the TAR. The mechanistic hypotheses proposed herein regarding back strength and estrogen-hypoxia interactions require validation through longitudinal designs and direct biomarkers (e.g., arterial stiffness measurement, estrogen levels, HIF-1α expression), which were not available in this cross-sectional study.

Several limitations of this study should be acknowledged. First, as a cross-sectional study, the present work can only identify associations between variables and cannot establish causal relationships. Any mechanistic interpretations—including the proposed interplay between hypoxia, estrogen, and metabolic adaptations—remain speculative and require validation through longitudinal studies with direct biomarker measurements (e.g., arterial stiffness indices, serum estrogen levels). Second, physical activity was assessed by self-report, which is subject to recall bias and may have attenuated the observed associations with exercise. Third, the sample was drawn from three cities in Tibet and may not fully represent the heterogeneity of Tibetan communities across the entire plateau, limiting the generalizability of the findings. Future longitudinal and interventional studies incorporating objective physical activity measurement (e.g., accelerometry) and direct biomarker assessments are needed to confirm and extend these results.

Supplementary Materials: The following supporting information can be downloaded at: https://media.sciltp.com/articles/others/2608201124060982/HM-26020085-SI1.pdf.

Author Contributions: Literature search, T.C.; data curation, X.Z. and J.W.; formal analysis, X.L. and Y.P.; writing—original draft preparation, T.C. and J.Z.; writing—review and editing, J.Z. and D.J.; supervision, D.J. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Natural Science Foundation of China (grant no. 82060422) and the Shanghai Baiyulan Talent Program Pujiang Project Funding (24PJC067).

Institutional Review Board Statement: This study involving human participants was conducted according to the guidelines of the Declaration of Helsinki and was reviewed and approved on 9 March 2021 by the Bio-medical Ethics Committee of Xizang University for Nationalities (ethics approval number: 2021-31).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is provided within the manuscript and supplementary information files.

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

Use of AI and AI-Assisted Technologies: During the preparation of this work, the authors used DeepSeek (V3 version) to check grammar and polish wording. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

References

1. The State Council Information Office of the People's Republic of China. *Human Rights in Xizang in the New Era*; State Council Information Office of the People's Republic of China: Beijing, China, 2025. (In Chinese)
2. National Health Commission of the People's Republic of China. Statistical Bulletin of China's Health Development in 2023. *Chin. J. Viral. Dis.* **2024**, *14*, 416–424. https://doi.org/10.16505/j.2095-0136.2024.0083. (In Chinese)
3. Peng, W.; Li, K.; Yan, A.F.; Shi, Z.; Zhang, J.; Cheskin, L.J.; Hussain, A.; Wang, Y. Prevalence, Management, and Associated Factors of Obesity, Hypertension, and Diabetes in Tibetan Population Compared with China Overall. *Int. J. Environ. Res. Public Health* **2022**, *19*, 8787. https://doi.org/10.3390/ijerph19148787.
4. Li, T.; Shuai, P.; Wang, J.; Wang, L. Prevalence, Awareness, Treatment and Control of Hypertension among Ngawa Tibetans in China: A Cross-Sectional Study. *BMJ Open* **2021**, *11*, e052207. https://doi.org/10.1136/bmjopen-2021-052207.
5. Hu, J.; Thompson, B.; Wang, S.; Guo, M.; Yan, C.; Ding, F.; Guo, P.; Chen, L.; Cao, Z.; Wang, J. Rate and Risk Factors of Metabolic Components and Component Combinations according to Hypertension Status in Tibetans in a Cross-Sectional Study. *Medicine* **2022**, *101*, e31320. https://doi.org/10.1097/md.0000000000031320.
6. Joint Committee for Guideline Revision. 2018 Chinese Guidelines for Prevention and Treatment of Hypertension—A report of the Revision Committee of Chinese Guidelines for Prevention and Treatment of Hypertension. *J. Geriatr. Cardiol.* **2019**, *16*, 182–241. https://doi.org/10.11909/j.issn.1671-5411.2019.03.014.
7. Yuan, Z.; Zou, Y.; Liu, X.; Wang, L.; Chen, C. Longitudinal Study on Blood and Biochemical Indexes of Tibetan and Han in High Altitude Area. *Front. Public Health* **2023**, *11*, 1282051. https://doi.org/10.3389/fpubh.2023.1282051.
8. Huang, X.; Hu, Y.; Du, L.; Lin, X.; Wu, W.; Fan, L.; Li, L.; Zhong, X.; Gong, Q.; Gao, L.; et al. Metabolic Syndrome in Native Populations Living at High Altitude: A Cross-Sectional Survey in Derong, China. *BMJ Open* **2020**, *10*, e032840. https://doi.org/10.1136/bmjopen-2019-032840.
9. Li, W.; Li, X.; Huang, T.; Chen, Y.; Zhang, H.; Dai, H.; Wen, Y. Normative Reference Data for Body Composition in Healthy Indigenous Populations on the Qinghai-Tibet Plateau. *Front. Public Health* **2022**, *10*, 986720. https://doi.org/10.3389/fpubh.2022.986720.
10. Jian, W.; Zhang, B.; Ma, Y.; Tang, X.; Nguyen, T.T.; Lv, M.; Meng, X.; Li, T.; Sun, X.; Wang, Y.; et al. Validation of Measurement of Body Composition by dual-energy X-ray Absorptiometry and Bioelectrical Impedance Analysis and Body Composition's Profiling in Tibetan's Adults. *Public Health Nutr.* **2025**, *28*, e96. https://doi.org/10.1017/s1368980025000291.
11. Zhang, Y.; Sun, J.; Zhao, M.; Magnussen, C.; Xi, B. Prevalence of Thinness, Overweight and Obesity among Tibetan Adolescents Aged 12–17 years. *Public Health Nutr.* **2021**, *24*, 4017–4022. https://doi.org/10.1017/s1368980021000215.
12. Yeung, F.; Kwok, T.; Helmer, C.; Woo, J.; Kwan, M.; Yuan, H. Nutritional Status of Older Tibetans in Rural Sichuan China. *J. Nutr. Health Aging* **2004**, *8*, 220–224.
13. Xu, J.; Xiang, Q.; Lin, G.-P.; Fu, X.; Zhou, K.; Jiang, P.; Zheng, S.; Wang, T. Estrogen Improved Metabolic Syndrome Through Down-Regulation of VEGF and HIF-1α to Inhibit Hypoxia of Periaortic and Intra-Abdominal Fat in Ovariectomized Female Rats. *Mol. Biol. Rep.* **2012**, *39*, 8177–8185. https://doi.org/10.1007/s11033-012-1665-1.
14. Liguori, G. *ACSM's Health-Related Physical Fitness Assessment Manual*; Wolters Kluwer: Hong Kong, China, 2018.
15. Patel, S.A.; Deepa, M.; Shivashankar, R.; Ali, M.K.; Kapoor, D.; Gupta, R.; Lall, D.; Tandon, N.; Mohan, V.; Kadir, M.M.; et al. Comparison of Multiple Obesity Indices for Cardiovascular Disease Risk Classification in South Asian adults: The CARRS Study. *PLoS ONE* **2017**, *12*, e0174251. https://doi.org/10.1371/journal.pone.0174251.

16. Luo, W.; Zhang, Y.; Liu, X.; Yan, Y.; Zhang, W.; Ke, S.; Zhao, S.; Yuan, T.; Wang, L.; Yang, M.; et al. Association between Health-related Physical Fitness and Incident Hypertension among the Elderly in Wuhan: A Seven-year Cohort Study. *BMC Public Health* **2025**, *25*, 4342. https://doi.org/10.1186/s12889-025-25635-3.
17. General Administration of Sport of China. *National Physical Fitness Measurement Standards Manual*; People's Sports Publishing House: Beijing, China, 2003. (In Chinese)
18. The National Health Commission of the People's Republic of China. *Health Industry Standards of the People's Republic of China—Criteria of Weight for Adults*; The National Health Commission of the People's Republic of China: Beijing, China, 2013. (In Chinese)
19. Mingji, C.; Onakpoya, I.J.; Perera, R.; Ward, A.M.; Heneghan, C.J. Relationship Between Altitude and the Prevalence of Hypertension in Tibet: A Systematic Review. *Heart* **2015**, *101*, 1054–1060. https://doi.org/10.1136/heartjnl-2014-307158.
20. Marsh, M.L.; Oliveira, M.N.; Vieira-Potter, V.J. Adipocyte Metabolism and Health after the Menopause: The Role of Exercise. *Nutrients* **2023**, *15*, 444. https://doi.org/10.3390/nu15020444.
21. Chen, Y.; Peng, Q.; Yang, Y.; Zheng, S.; Wang, Y.; Lu, W. The Prevalence and Increasing Trends of Overweight, General Obesity, and Abdominal Obesity among Chinese Adults: A Repeated Cross-Sectional Study. *BMC Public Health* **2019**, *19*, 1293. https://doi.org/10.1186/s12889-019-7633-0.
22. Dupuit, M.; Maillard, F.; Pereira, B.; Marquezi, M.L.; Lancha, A.H., Jr.; Boisseau, N. Effect of High Intensity Interval Training on Body Composition in Women before and after Menopause: A Meta-Analysis. *Exp. Physiol.* **2020**, *105*, 1470–1490. https://doi.org/10.1113/ep088654.
23. Liang, H.; Yan, J.; Song, K. Comprehensive Lipidomic Analysis Reveals Regulation of Glyceride Metabolism in Rat Visceral Adipose Tissue by High-altitude Chronic Hypoxia. *PLoS ONE* **2022**, *17*, e0267513. https://doi.org/10.1371/journal.pone.0267513.
24. Palmer, B.; Clegg, D. The Sexual Dimorphism of Obesity. *Mol. Cell. Endocrinol.* **2015**, *402*, 113–119. https://doi.org/10.1016/j.mce.2014.11.029.
25. Li, H.; Du, W.; Huang, C.; Zhang, M. Health-Related Physical Fitness Associated with Hypertension Risk in Adults Living in Sub-Plateau Environments. *J. Clin. Hypertens.* **2025**, *27*, e70184. https://doi.org/10.1111/jch.70184.
26. Grassi, G.; Pisano, A.; Bolignano, D.; Seravalle, G.; D'Arrigo, G.; Quarti-Trevano, F.; Mallamaci, F.; Zoccali, C.; Mancia, G. Sympathetic Nerve Traffic Activation in Essential Hypertension and Its Correlates: Systematic Reviews and Meta-Analyses. *Hypertension* **2018**, *72*, 483–491. https://doi.org/10.1161/hypertensionaha.118.11038.
27. Geissler, D.; Lison, A.; Schulze, C. Relevance of Body Weight Adaptation and Modern Obesity-defining Parameters in the Analysis of Isokinetic Trunk Strength in People with Obesity—A Retrospective Analysis. *Clin. Obes.* **2025**, *15*, e12736. https://doi.org/10.1111/cob.12736.
28. Son, W.M.; Park, J.J. Resistance Band Exercise Training Prevents the Progression of Metabolic Syndrome in Obese Postmenopausal Women. *J. Sports Sci. Med.* **2021**, *20*, 291–299. https://doi.org/10.52082/jssm.2021.291.
29. Lin, Y.Y.; Lee, S.D. Cardiovascular Benefits of Exercise Training in Postmenopausal Hypertension. *Int. J. Mol. Sci.* **2018**, *19*, 2523. https://doi.org/10.3390/ijms19092523.