Physical activity had significant association with lower body fat percentage among middle-aged adults: China Health and Nutrition Survey in 2015

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Abstract

Background As with the unprecedented economic and social development in China, physical activity (PA) have decreased dramatically and body fat percentage (BF%) have varied. In the lasted large scale field investigation, we described the distribution of PA and BF%, and their association across the entire percentiles. Methods Based on data from China Health and Nutrition Surveys (CHNS) in 2015, 5763 participants aged 40-64 years coming from 15 provinces were included. PA was calculated as metabolic equivalent task hours per day (MET·h/d). BF% was measured by bioelectrical impedance analysis (BIA). Kruskal-Wallis test was used to test the difference of PA among gender, age, BMI groups, education, income, region and urbanization. Gender-Body mass index (BMI)-stratified quantile regression (QR) analyses were utilized to describe the association between PA and BF% distribution. Results A part of non-overweight/obese participants had high body fat. Older adults, overweight/obese group, higher education, higher income, residents of central China and higher urbanization had lower PA. Participants who engaged in vigorous PA had median BF% 2.0% and 1.5% lower than the slightly PA group (23.4%, 34.8%) for men and women, respectively. For every additional hour of moderate PA (4.5 MET·h/d), the total BF% was reduced by a median of 0.0290%, 0.0539% and 0.0699% in the 50th, 75th and 90th percentiles respectively, and 0.0490%, 0.0854% and 0.0998% in trunk BF% at the correspondingly percentiles respectively. The association between PA and total BF% was the strongest in normal weight obesity participants than others. Females and the non-overweight/obese group had more statistical significant coefficients at multiple percentiles than males and the overweight/obese group, respectively. Conclusions In middle-aged adults in China, a part of normal weight obesity persons were in non-overweight/obese group and women prone to gain fat mass with BMI increasing but muscle in men. Individuals with vigorous PA had lower BF% comparing with slightly active ones, and an extra moderate leisure PA per day was recommended, especially for normal weight obesity and abdominal adipose individuals.

Background

With the unprecedented economic and social development in China, a host of lifestyle factors have changed daily life dramatically. The prevalence of overweight status increased from 22.8% in 2002 to 30.1% in 2012, with obesity increasing from 7.1% in 2002 to 11.9% in 2012(1, 2). People who are overweight or obese often face social prejudice, elevated risk of various life threatening diseases including cardiovascular diseases, diabetes and even cancer, and increased mortality (3-5). BMI is regularly used as a robust measure of normal weight, overweight and obesity due to its simplicity and the modest correlation with adiposity (6), however it is a poor measure of individual fat mass, and healthy persons with high muscle mass can be misclassified as overweight or even obese. Several studies have reported that high BF% is an independent risk factor for cardiovascular diseases, coronary events (7-10), and all-cause mortality (11-13). PA has been shown to reduce the risk of many of the chronic health conditions associated with high body fat (14). However, globally in 2016, around 28% of adults aged 18 years old and above did not meet the WHO-recommended minimum level of physical activity (15). Some evidence suggested a connection between PA and BF%, but previous studies have reported conflicting results. Due to the changes in metabolic machinery as people age(16), a negative association was observed between PA and BF% in middle-aged adults(17, 18), but a null association was reported in young adults whose average age was 21 years old, possibly due to the increasing of fat-free mass rather than the reduction of fat mass(19, 20). In addition, previous studies used multiple linear regression or categorical logistic regression analyses which sacrificed what can be learned about the entire distribution, and BF% is typically not normally distributed. Thus, quantile regression was more suitable for analyzing the association between PA and BF%, and there was little study to do so as far as we know. Therefore, the aim of this study is to 1) quantify the BMI-specific distribution of BF% in the latest field investigation of large scale middle-aged population of 15 provinces in China; 2) describe the sex-specific levels of PA in different age, education, BMI groups, household income, socioeconomic levels; 3) describe the distribution of total BF% at different levels of PA; 4) evaluate the associations between PA and BF% in gender-BMI-stratified with quantile regression.

Methods

Study design

The data of this study were derived from the CHNS, which was a prospective household-based study to longitudinally measure how sociological, economic and demographic factors change health and nutritional status across the life span of the Chinese population using a follow-up interval of two or three years. The CHNS selected individuals of various ages in ten rounds of surveys from 1989 to 2015, who lived in twelve diverse provinces including Shandong, Liaoning, Heilongjiang, Jiangsu, Henan, Guizhou, Hunan, Hubei, Zhejiang, Yunnan, Shanxi and Guangxi and three autonomous cities including Beijing, Shanghai and Chongqing (in 2011 and 2015). A multi-stage, stratified, random cluster sampling design was used to ensure a balanced representation of urban, suburban and rural areas. All data were collected by trained and certified health workers.

Study population

We analyzed the 2015 CHNS, the first wave to collect BIA data. We limited the sample to the participants aged between 40 and 64 years old with complete data on total PA and BF%. Participants with implausible BF% values (<5% □ >70%) were excluded from our study. We excluded individuals who were disabled or women who were pregnant or breastfeeding during the survey year (n=74) and subjects who had received diagnoses of hypertension, diabetes, myocardial infarction, stroke, cancer, fracture and asthma (n=1551). Individuals with implausible energy intakes values (<800 kcal/day or >6000 kcal/day for men, <600 kcal/day or >4000 kcal/day for women, n=236) (21-23) and BMI (<10 kg/m^2, >60 kg/m^2, n=5) were excluded. Our final analysis sample included 5763 observations with 2540 men and 3223 women.

Anthropometrics

Trained health workers measured weight, height, body fat percentages (including the total BF%, trunk BF%, and arm and leg BF%). Using a body composition analyzer (BC601, TANITA, method of BIA) weight was measured to the nearest 0.1 kg with the participant standing without shoes and wearing a single layer of clothing. Height was measured without shoes to the nearest 0.1 cm using SECA 206 wall-mounted metal tapes. Percentages of body fat were calculated using software with aproprietary algorithm which requires age, gender, height, and physical activity level inputs by technicians. According to the Chinese definitions, we defined the overweight and obesity based on BMI (the ratio of weight in kilograms and height in meters^2) cutoff points of 24 and 28 kg/m^2, respectively.

Total physical activity and sedentary behavior assessment

We used the standard physical activity questionnaire to calculate the average metabolic equivalents of task (MET) hours per day to indicate the PA level, which comprised four PA domains: travel, occupational, leisure and domestic. The ratio of a person's working metabolic rate relative to their resting (basal) metabolic rate defined was the definition of a MET unit. Thus, the average MET-hours per week measurements comprised both the time spent in each activity and the average intensity of each activity (or sub-activity). We categorized the total MET-hours per day into slightly PA, moderate PA, moderate-vigorous PA (MVPA) and vigorous PA according to the interquartile. Details on how these values were calculated were described elsewhere (24-26).

Sedentary behaviors were calculated as the average hours per day (hr/day) spent in various non-occupational recreational activities, including watching TV or movies/videos, reading/writing, board games and computer usage. Time spent engaged in these kinds of activities were summed to obtain total time expenditure on sedentary behaviors, which was not included in the physical activity calculation.

Assessment of covariates

Standard questionnaires were used by trained interviewers to collect sociodemographic characteristics, annual per household income, smoking, alcohol consumption, community information (urbanization index) and dietary intake. We categorized the educational level into low, medium and high for primary school education or less, middle school education and high school education and above, respectively. Marital status was grouped into two statuses (married and single). Participants reported their gross annual per capita household income according to household size, which was inflated to 2015 values and categorized into tertiles. Smoking status was classified as current smoking and no smoking now. Alcohol consumption refers to whether or not participants have drunk alcohol in the past year.

Energy intake per day and percentage of energy from fat were used as continuous variables, which were collected using a weighing method of condiments in combination with three consecutive 24-hour recall calculated using the China Food Composition Table over the same three-day period (21).

Region was grouped as Northern China (Heilongjiang, Liaoning and Beijing), Central China (Shangdong, Jiangsu, Shanghai, Henan and Shanxi) and Southern China (Hubei, Chongqing, Zhejiang, Guizhou, Hunan, Guangxi and Yunnan) due to climate and dietary habit differences. Community urbanization index was calculated based on 12 multidimensional components at the community level reflecting population density, economic activity, traditional markets, modern markets, transportation infrastructure, sanitation, communications, housing, education, diversity, health infrastructure and social services (27, 28), and was categorized into tertiles (high, middle and low). Others details were presented in previous analyses of the CHNS (25).

Statistical analysis

We calculated descriptive statistics for the individual demographic variables, which were stratified by gender. Continuous variables were expressed as medians, the 25^{th} percentile (Q1), and the 75^{th} percentile (Q3). Categorical variables were expressed as percentages. BF% was described as nuclear density figure by gender and BMI groups. Median (Q1, Q3) PA was described by gender and sociodemographic variables and Kruskal-Wallis tests were used for sociodemographic variables. Box plots were used to express the BF% by PA levels.

Due to a significant statistical interaction between gender and overweight/obese across the 10th , 25th , 50th , 75th , and 90th percentiles ($P<0.0001$), we use separate gender-BMI-stratified QR analyses to assess associations of the total PA, at total body and trunk BF% percentiles. 3 to 6 MET was defined as moderate intensity exercise (29), than we used 4.5 MET·h/d, such as half step jogging (30), to represent the average level of it and tested the association as an additional hour of moderate PA with lower BF%. Compared with the traditional linear regression based on means, QR allowed us to evaluate the distribution of BF% at several cut points, did not require any assumption about the distribution of the regression residuals, and was not influenced by skewness in the distribution of the dependent variable. This method provided greater statistical efficiency when outliers are present and is robust to varying effects of covariates at different percentiles of the response variable (31-33).

We constructed three models. Model 1 was controlled for the total PA only. The individual-level variables were then added to the equation to estimate Model 2, including the sedentary activity time, age, educational level, marital status, household income level, energy intake, energy percentage from fat, BMI, smoking status, alcohol consumption status and region. For Model 3, urbanization index level was add to Model 2. BF% included the total body and the trunk. $P<0.05$ were considered statistically significant. SAS 9.4 (SAS Institute, Inc., Cary, NC, USA) was conducted in descriptive and QR analyses.

Results

Demographic characteristics of the study samples

Table 1 shows the primary information about participants. Of the 5763 participants (mean age: 52.0 years old) included in the analyses, 1074 (18.6%) lived in northern China and 1892 (32.8%) in central China, 2802 (48%) were overweight/obese.

Table 1. Demographic characteristics of samples.

Variables	Male		Female	
	Non-overweight/obese (BMI<24kg/m^2)	Overweight/obese (BMI≥24kg/m^2)	Non-overweight/obese (BMI<24kg/m^2)	Overweight/obese (BMI≥24kg/m^2)
N (number)	1293(50.9%)	1247(49.1%)	1668(51.8%)	1555(48.2%)
Region (N, %)				
Northern	192(14.9%)	262(21.0%)	275(16.5%)	345(22.2%)
Central	378(29.2%)	435(34.9%)	556(33.3%)	523(33.6%)
Southern	723(55.9%)	550(44.1%)	837(50.2%)	687(44.2%)
Age (year)	53.0(46.3, 59.3)	50.9(45.8, 57.0)	51.4(45.3, 58.1)	51.8(46.3, 58.1)
Education (N, %)				
Low	444(38.5%)	517(44.7%)	524(38.7%)	426(33.9%)
Middle	473(41.0%)	478(41.3%)	561(41.5%)	529(42.1%)
High	237(20.5%)	163(14.1%)	268(19.8%)	302(24.0%)
Married (N, %)	1223(94.6%)	1208(96.9%)	1571(94.2%)	1460(93.9%)
Household income (1000 yuan)	15.7(7.2, 28.0)	18.0(8.9, 31.8)	16.6(7.3, 30.0)	15.7(7.2, 27.9)
Energy intake (1000 kcal/day)	2.1(1.7, 2.7)	2.2(1.8, 2.8)	1.8(1.4, 2.2)	1.8(1.5, 2.3)
Energy for fat (%)	35.1(27.1, 44.3)	35.6(28.2, 43.7)	35.4(27.7, 43.7)	35.5(27.6, 43.6)
BMI (kg/m^2)	21.8(20.3, 22.9)	26.3(25.2, 27.9)	22.0(20.7, 23.0)	26.4(25.1, 28.2)
Current smoking (N, %)	782(60.5%)	627(50.3%)	30(1.8%)	20(1.3%)
Alcohol consumption (N, %)	745(57.6%)	736(59.0%)	100(6.0%)	99(6.4%)
Urbanization Index (score)	67.7(54.2, 84.2)	74.9(58.5, 89.3)	73.6(57.1, 87.0)	73.3(57.3, 87.2)
Sedentary activity time (hr/week)	15.9(10.5, 27.0)	16.0(10.5, 28.0)	14.0(9.0, 24.5)	14.0(10.0, 24.5)

Values were expressed as medians (Q1, Q3) or number and percentage (N, %).

The body fat percentages of samples

Figure 1 shows the smoothed distribution curves of the total BF% and trunk BF% among men and women aged 45 – 64 years. Individuals were divided into non-overweight/obese group, overweight group and obesity group according to BMI (cutoff points was 24 kg/m^2 and 28 kg/m^2). For both genders, the three curves overlapped with each other, and the overweight curve was roughly between the non-overweight/obese curve and the obesity curve. The reference line was the standard (men: 25.0%; women: 35.0%) recommended by World Health Organization (WHO) for judging obesity according to the total percentage of body fat rather than the trunk body fat percentage (34). Most males in the obesity group and half males in the overweight group were judged as obesity by the standard of the total body fat percentage. However, a small part of non-overweight/obese in males were diagnosed obesity according to the BF% standard, which we called normal weight obesity (35). The pattern in females was similar with males'. However the overweight curve and the obesity curve in females were further to the right of the reference line than that in males. That meant that almost obese females and most overweight females judged by BMI were considered as obesity according to the BF% criteria, while only a half in overweight males and most in obese males. The patterns in trunk BF% were similar with the total BF%

Figure 1. Density diagram for BF% in BMI groups. Non-overweight/obese group, overweight group and obesity group were solid line, dash line and dash dot line, respectively. These three groups were divided according to BMI (cutoff points was 24 kg/m^2 and 28 kg/m^2). A and b were the total BF% in men and women, respectively. C and d were the trunk BF% in men and women, respectively. Reference line was the standard (men: 25.0%; women: 35.0%) recommended by World Health Organization (WHO) for judging obesity according to the total percentage of body fat.

Physical activity by sociodemographic variables

Table 2 shows PA by four domains, age, BMI groups, education level, household income level, regions and urbanization index level. The total PA, occupational PA and travel PA in men were statistically higher than that of women, but lower in domestic PA and leisure PA. Occupational PA was the main component of total PA and leisure PA was the least. For both genders, median PA was lower at older ages. PA in females decreased more dramatically than males as age increased, especially the reduction between 50-54 y (17.0 MET·h/d) and 55-59 y (11.9 MET·h/d). The overweight/obese in men had approximately 13% less PA than the non-overweight/obese ones. The median PA was nearly 90% and 66% higher in those with no formal education or primary school education than in those with a high school or university education in men and women, respectively. Persons with higher household income had lower PA in both sexes. Women who lived in central China had the lower PA than those in northern or southern China, but no statistical difference in region for men. Individuals who lived in low level urbanization area had nearly two times the amount of PA than those lived in high level urbanization area in both men and women.

Table 2. Physical activity by sociodemographic variables (MET·h/d)

Sociodemographic Variables	Male				Female			
	N	Q1	Median	Q3	N	Q1	Median	Q3
Total PA [c]	2540	8.6	19.2	35.2	3223	7.7	17.0	31.3
Occupational PA [c]	2540	3.4	15.7	32.0	3223	0.0	6.3	22.0
Travel PA [c]	2540	0.0	0.4	1.1	3223	0.0	0.0	0.5
Domestic PA [c]	2540	0.0	1.2	3.4	3223	3.6	5.7	8.8
Leisure PA [c]	2540	0.0	0.0	0.0	3223	0.0	0.0	0.0
Age [b]								
40-44	475	10.4	20.4	33.7	594	9.1	19.2	33.6
45-49	460	10.0	19.7	36.4	581	9.8	19.9	32.0
50-54	504	8.7	19.3	34.6	597	8.0	17.0	30.4
55-59	436	8.7	17.6	33.8	413	6.8	11.9	25.1
60-64	361	6.0	16.0	30.1	342	6.3	10.2	20.1
BMI Groups [a]								
Non-overweight/obese	1107	9.5	20.1	36.9	1304	8.0	16.5	29.5
Overweight/obese	1129	7.8	17.5	31.5	1223	7.6	16.3	29.9
Education [ab]								
High	947	7.6	14.9	24.7	934	7.2	13.8	22.4
Middle	907	8.7	21.2	39.5	1044	7.8	17.1	31.3
Low	382	12.9	28.5	48.2	549	9.4	22.9	41.1
Household Income [ab]								
High	807	8.8	17.5	29.4	921	7.6	15.7	27.3
Middle	757	8.7	19.3	33.2	847	8.2	17.1	29.7
Low	672	8.5	21.1	40.7	759	7.5	17.1	33.4
Region [b]								
Northern	429	9.1	18.8	38.3	545	8.5	18.0	31.8
Central	731	7.6	18.2	32.4	857	7.0	15.0	28.5
Southern	1076	9.1	19.7	36.2	1125	8.0	17.9	34.3

Urbanization Index [ab]								
High	772	5.9	13.6	22.8	1002	6.8	11.9	20.9
Middle	716	8.2	18.0	32.4	859	8.0	16.4	29.5
Low	748	14.6	28.7	50.6	666	12.0	27.1	44.4

[a] P < 0.05 in the Kruskal-Wallis test in males. [b] P < 0.05 in the Kruskal-Wallis test in females. [c] P < 0.01 in the Kruskal-Wallis test between gender.

BF% on different PA levels

The shape of the total BF% distribution differed across the levels of PA with respect to location, spread, and skewness (figure 2). Male participants who engaged in vigorous PA had median total BF% 21.4%, which was statistically significantly lower than the other three PA group (slightly PA: 23.4%, moderate PA: 23.0%, MVPA: 22.4%) (P<0.0001), but no statistically significant differences among each moderate, MVPA and vigorous PA groups. For women, individuals who engaged in vigorous PA group had median total BF% 33.3%, which was statistically significantly lower than MVPA group (34.2%) and slightly PA group (34.8%) (P<0.05).

Figure 2. Box plots of the total BF% by levels of PA. A for males and b for females. PA was grouped into slightly PA, moderate PA, MVPA and vigorous PA according to the interquartile.

The association between physical activity in different levels and body fat percentage at different percentiles

Table 3 illustrates that the total BF% and the trunk BF% at the 10th, 25th, 50th, 75th and 90th percentiles changes with 4.5 MET·h/d among men and women. Overall, one hour extra moderate PA (4.5 MET·h/d) was significantly associated with 0.0290%, 0.0539% and 0.0699% less total body fat at the 50th, 75th and 90th percentiles respectively, and 0.0490%, 0.0854% and 0.0998% less trunk fat at the correspondingly percentiles respectively. In non-overweight/obese and overweight/obese group in both gender, BF% was significantly associated inversely with physical activity at some special percentiles. The results obtained with Model 1 suggested that there were significant negative association between PA and BF% at most of the percentiles. However, the significant coefficients changed at different percentiles after adjusting for individual level and community level factors. Then we would talk about the results in Model 3 in the next paragraphs.

The results were different between men and women. Firstly, females had more statistical significant coefficients at multiple percentiles than males. Specifically, there were four significant coefficients of total BF% in women which were appeared at the 25^{th}, 50^{th}, 75^{th} and 90^{th} percentiles, respectively, but only two in men at the 75^{th} and 90^{th} percentiles, respectively. Secondly, for overweight/obese, the significant coefficient in men only at the 25^{th} percentiles, while women's appeared at the upper percentiles (50^{th}, 75^{th} and 90^{th}). Thirdly, its associations with PA and total BF% were somewhat weaker in females than that in males.

We found the absolute coefficients in overweight/obese were lower than in non-overweight/obese. The significant coefficients were at the upper percentiles (75^{th} and 90^{th}) in non-overweight/obesity men, and at the lower percentiles (25^{th}) in overweight/obesity men. The effective BF% range was approximately from 22% to 25% in males. The significant coefficients from the 25^{th} to the 90^{th} percentiles in non-overweight/obesity women were approximately twice over than overweight/obesity women's from the 50^{th} to the 90^{th} percentiles. Trunk BF%, the associations with PA, was relatively stronger than total BF%. However, there was no significant association between PA and trunk BF% in overweight/obesity men across entire percentiles.

Table 3. Quantile regression coefficients of PA on BF% at different percentiles in males and females.

Variables		Non-overweight/obese($BMI<24kg/m^2$)					Overweight/obese($BMI\geq24kg/m^2$)				
		10th	25th	50th	75th	90th	10th	25th	50th	75th	90th
Total Body											
Male	Model 1	-0.0751	-0.1503*	-0.1054*	-0.0852*	-0.1105*	-0.0792	-0.0840*	-0.1028*	-0.0682*	-0.0341
	Model 2	-0.0043	-0.0267	-0.0598*	-0.0788*	-0.0911*	-0.1005	-0.0690*	-0.0454*	-0.0019	-0.0544
	Model 3	0.0202	0.0028	-0.0321	-0.0787*	-0.1104*	-0.0981	-0.0708*	-0.0316	0.0137	-0.0517
Female	Model 1	-0.1191*	-0.1097*	-0.0805*	-0.0772*	-0.0818*	-0.0611	-0.0433	-0.0492*	-0.0821*	-0.1228*
	Model 2	0.0112	-0.0490*	-0.0594*	-0.0444	-0.0626*	-0.0019	-0.0210*	-0.0350*	-0.0319*	-0.0306*
	Model 3	0.0459	-0.0457*	-0.0725*	-0.0565*	-0.0976*	-0.0062	-0.0232	-0.0349*	-0.0389*	-0.0372*
Trunk											
Male	Model 1	-0.1327*	-0.1808*	-0.1300*	-0.1266*	-0.1518*	-0.1349*	-0.1572*	-0.1237*	-0.0782*	0.0309
	Model 2	-0.0535	-0.0440*	-0.0859*	-0.0978*	-0.1373*	-0.1283	-0.0784	-0.0606*	0.0073	-0.0181
	Model 3	0.0036	-0.0291	-0.1001*	-0.1040*	-0.1734*	-0.1280	-0.0758	-0.0543	0.0203	-0.0198
Female	Model 1	-0.0760	-0.1310*	-0.1152*	-0.1089*	-0.1042*	-0.1267	-0.0599	-0.0647*	-0.1144*	-0.1377*
	Model 2	-0.1159*	-0.0974*	-0.0672*	-0.0714*	-0.0810*	-0.0458	-0.0383*	-0.0557*	-0.0468*	-0.0545*
	Model 3	-0.0388	-0.1238*	-0.1083*	-0.0788*	-0.0830	-0.0396	-0.0357	-0.0588*	-0.0495*	-0.0534*

* $P<0.05$.

Discussion

In the 2015 wave of CHNS among the middle-aged (40-64 years old) population, PA showed marked sociodemographic variations and vigorous PA was associated with less adiposity compared to slightly PA, which was the same result with the study in Southern Tasmania (36). Occupational PA was the most part of the total PA in a developing country (25), especially for famers in rural area or city with a large number of construction. They had much higher total PA than that work in the office. On the contrary, leisure PA was rather low in Chinese than that seen in western populations (26). Domestic PA in women was much higher than that in men, and it seemed to be closer to the real situation in China. PA decreased dramatically as participants aged, and was closely related to social and economic development. On average, one hour extra moderate PA (4.5 MET·h/d) was significantly associated with less BF% only at the 50^{th}, 75^{th} and 90^{th} percentiles due to the QR method.

An additional hour of moderate PA was associated with lower total BF% in some special percentiles instead of across all the percentiles. The results were analyzed by QR method, which allowed the skewness distribution and the outliers that we could not exclude by judging the rationality. There were differences by gender in the relationship between PA and BF%, and might due to the physiological and basal metabolic rate difference between males and females. The negative association between PA and BF% was stronger for women at entire BF% distribution, while only BF% approximately from 22% to 25% in men. An extra hour of moderate exercise per day might not enough to reduce fat mass for a man with BF% over 25% and it could increase the fat-free mass rather than decrease fat mass for a man with healthy BF% (under 20%) (29). The value of significant coefficients in overweight/obesity women at the 50^{th} to 90^{th} percentiles were around a half compared to the one in non-overweight/obese. This suggested that overweigh/obese group of women should increase the intensity and duration of vigorous exercise to achieve the aim of BF% reduction.

Prior studies have reported that PA was associated with diminish body fat mass, and they were consistent with ours. However, we could not compare the strength of associations with adiposity observed in our study directly with those previously observed. These difference might be come from the different age of population, ethnic, measurements or other uncontrolled confounding. Huaidong DU reported that greater PA (14 MET·h/d) associated with 0.48 (95% CI: 0.45, 0.50) percentage points less body fat in the China Kadoorie Biobank study (17). Bradbury reported that compared with <5 excess MET·h/week at baseline, ≥100 excess MET·h/week was associated with a 2.8 percentage points lower body fat in men and 4.0 percentage points lower body fat in women in UK (18). Bowen reported that one MET-hour higher activity was associated with 145g less body fat (95% CI 73,218) in the middle-aged Indian (20).

Moreover, an extra hour per day moderate PA had negative association with trunk BF%, and the effect was more pronounced than the total BF% but except for overweight/obese group of men. We found that it was more common for men to gain trunk body fat (android), most of which was visceral rather than subcutaneous, whereas women store more fat in the gluteal-femoral region (gynoid) (see Additional file 1). As body weight increasing, the ratio of trunk and total BF% increased quickly and dramatically in men (see Additional file 2). Previous study reported that regional fat distribution in the android (abdomen) and gynoid (thigh) regions had different effects on lipid profiles, and fat in the android region may be an important factor in determining the risk of CVD (37) (38). It was reported that men had a higher standardized mortality rate of CVD than women in China from 1990 to 2013 (2).

Accurate assessment of habitual levels of physical activity behaviors and percentage of fat mass was a prerequisite for our study. However, in this 30-year large scale follow-up survey, it was impractical to obtain objective measures of usual activity level using accelerometer, and BF% measured by BIA. In our study, we used an interviewer-administered PA questionnaire, about frequency, duration, and intensity of PA within one week in several different domains, which had been tested, modified, and used from 1989. Although data on PA was accumulated from recalled might be prone to overestimation (19), we chose this approach because the questionnaire was revised from the international PA questionnaire and we have remained to use it consistently with each wave of the CHNS. BIA was more suitable and reasonable to measure the BF% in this large scale field investigation because of its cost-efficiency and easy-carried (6, 39). Some previous studies showed the highly agreement between BIA and dual energy x-ray absorptiometry (DXA) of some special population such as the Hispanic diabetics (40).

Overweight and obesity groups showed the higher BF% than non-overweight/obese group generally, however there was an intersection among the BF% density curves. About 10 percent of non-overweight/obese had high body fat. Several studies discuss the term “normal weight obesity”, which describes an individual with normal body weight and BMI (<24 kg/m^2) but high BF%, accompanied with total lean mass deficiency (7, 35, 41, 42).

Some studies have reported associations with normal weight obesity and a high prevalence of cardiometabolic dysregulation, metabolic syndrome, and CV risk factors (35, 43). In our study, these subjects were distributed at the 90th percentile and above of the non-overweight/obese group's total BF% (see Additional file 1), and an extra hour per day of moderate PA was stronger associated with the total BF% for them than others. For example, in non-overweight/obese at the 90th percentiles, an extra 4.5 MET·h/d PA was associated with 0.1104 and 0.0976 percentage points lower total BF% for men and women respectively, and this relationships were stronger than that at the 10th , 25th , 50th and 75th percentiles. Half of overweight men and most of overweight women were judged obesity according to the standard of BF%, which indicated that overweight men could be more likely to gain muscle, while overweight women were more likely to gain fat. Previous study reported that both light and moderate-to-vigorous intensities of activity had negative association with fat mass [48]. Indeed, to all segments of the population, health and functional benefits are visible from PA (28, 44, 45). Many countries have published guidelines to encourage increase of PA levels, including the USA, Canada, and China (32). However, guidance is general and not personalized for individuals with different BMI and BF%, especially for normal weight obesity. Thus, PA interventions might be more effective if greater encouragement could be focused on people with different body fat according to the statistical significant percentiles.

Additionally, some studies used the absolute value of fat mass (g) as the dependent variable, and it was reported to have more clinical significance (36). The percentage of body fat instead of absolute value we used seemed to be harder to reduce. For example, a person reduced 100g fat mass without decreased weight, which meant that fat-free mass increased 100g and the percentage of body fat decreased. However, if a person only reduced fat mass without fat-free mass increasing, the body weight should be diminished but BF% would not necessarily. This situation was related to the way we exercised. Overall, aerobic exercise and resistance exercise should be recommended together to make us healthier (30, 46).

This study has several limitations. CHNS was a long-term follow-up study, however, this was the first year to collect body composition data, and we would continue to do these data collection in the nearly future survey in order to find the causal relationship between PA and BF%. Then, we incorporated individual and community level factors into the model and considered an array of variables in the entire percentiles. However, some possibility confounders relating other lifestyle factors might not be excluded in this study, which may confound the observed associations. Lastly, the target subjects were middle aged people with similar demographic characteristics, which may limit the generalizability of the results to other populations. Although the limitations existed, our study was based on a large scale field survey comprising a lot of provinces through nearly 30 years, and our precise measurement ensured our accurate results, which imparted the ability to generalize the results to the Chinese population.

Conclusion

In summary, our findings suggest that a small part of normal weight obesity persons were in non-overweight/obese group and women prone to gain fat mass with BMI increasing but muscle in men. Older adults, overweight/obese group, higher education, higher income, living in central China and higher urbanization had lower PA. Individuals with vigorous PA had lower BF% comparing with slightly active ones, and an extra moderate leisure PA per day was recommended, especially for normal weight obesity and abdominal adipose individuals. The associations between PA and BF% were stronger in non-overweight/obese than overweight/obese, and the effect of one hour per day moderate PA to lose fat for a woman was better than that of a man.

Abbreviations

BF%: Body fat percentage; PA: Physical activity; BMI: Body mass index; CHNS: China Health and Nutrition Survey; QR: Quantile regression; Q1: The 25th percentile; Q3: The 75th percentile; MVPA: Moderate-vigorous physical activity; DXA: Dual energy x-ray absorptiometry; BIA: Bioelectrical impedance analysis.

Declarations

Ethics approval and consent to participate: Protocols, instruments, and the process used to obtain informed consent in this survey were approved by the institutional review committees of the University of North Carolina at Chapel Hill, as well as the National Institute for Nutrition and Health, Chinese Center for Disease Control and Prevention. All subjects gave written informed consent for their participation in the survey.

Consent for publication: Not applicable.

Availability of data and material: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing of Interest: The authors declare that they have no competing interests.

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References

1. Adair LS, Gordon-Larsen P, Du SF, Zhang B, Popkin BM. The emergence of cardiometabolic disease risk in Chinese children and adults: consequences of changes in diet, physical activity and obesity. Obes Rev. 2014;15 Suppl 1:49-59.
2. Bureau of National Health and Family Planning Commission Disease Prevention and Control. Report on Chinese Residents' Chronic Diseases and Nutrition. Beijing: People's medical publishing house; 2015.
3. Kleinert S, Horton R. Obesity needs to be put into a much wider context. The Lancet. 2019;393(10173):724-6.
4. Ashwell M, Mayhew L, Richardson J, Rickayzen B. Waist-to-height ratio is more predictive of years of life lost than body mass index. PLoS One. 2014;9(9):e103483.
5. Romero-Corral A, Montori VM, Somers VK, Korinek J, Thomas RJ, Allison TG, et al. Association of bodyweight with total mortality and with cardiovascular events in coronary artery disease: a systematic review of cohort studies. The Lancet. 2006;368(9536):666-78.
6. Volgyi E, Tylavsky FA, Lyytikainen A, Suominen H, Alen M, Cheng S. Assessing body composition with DXA and bioimpedance: effects of obesity, physical activity, and age. Obesity (Silver Spring). 2008;16(3):700-5.
7. Lee WS. Body fatness charts based on BMI and waist circumference. Obesity (Silver Spring). 2016;24(1):245-9.
8. Calling S, Hedblad B, Engstrom G, Berglund G, Janzon L. Effects of body fatness and physical activity on cardiovascular risk: risk prediction using the bioelectrical impedance method. Scand J Public Health. 2006;34(6):568-75.
9. Marques-Vidal P, Bochud M, Mooser V, Paccaud F, Waeber G, Vollenweider P. Obesity markers and estimated 10-year fatal cardiovascular risk in Switzerland. Nutr Metab Cardiovasc Dis. 2009;19(7):462-8.
10. Lahmann PH, Lissner L, Gullberg B, Berglund Gr. A Prospective Study of Adiposity and All-Cause Mortality: The Malmo¨ Diet and Cancer Study. Obes Rev. 2002;0(5):361-9.
11. Gomez-Ambrosi J, Silva C, Galofre JC, Escalada J, Santos S, Millan D, et al. Body mass index classification misses subjects with increased cardiometabolic risk factors related to elevated adiposity. Int J Obes (Lond). 2012;36(2):286-94.
12. Flegal KM, Graubard BI. Estimates of excess deaths associated with body mass index and other anthropometric variables. The American journal of clinical nutrition. 2009;89(4):1213-9.

13. Padwal R, Leslie WD, Lix LM, Majumdar SR. Relationship Among Body Fat Percentage, Body Mass Index, and All-Cause Mortality: A Cohort Study. Ann Intern Med. 2016;164(8):532-41.
14. Buchowski MS, Townsend KM, Chen KY, Acra SA, Sun M. Energy Expenditure Determined by Self-Reported Physical Activity Is Related to Body Fatness. Obesity research. 1999;7(1):23-33.
15. WHO. Prevalence of insufficient physical activity https://www.who.int/gho/ncd/risk_factors/physical_activity/en/2016 [Accessed 2019 June 6].
16. St-Onge MP, Gallagher D. Body composition changes with aging: the cause or the result of alterations in metabolic rate and macronutrient oxidation? Nutrition. 2010;26(2):152-5.
17. Du H, Bennett D, Li L, Whitlock G, Guo Y, Collins R, et al. Physical activity and sedentary leisure time and their associations with BMI, waist circumference, and percentage body fat in 0.5 million adults: the China Kadoorie Biobank study. The American journal of clinical nutrition. 2013;97(3):487-96.
18. Bradbury KE, Guo W, Cairns BJ, Armstrong ME, Key TJ. Association between physical activity and body fat percentage, with adjustment for BMI: a large cross-sectional analysis of UK Biobank. BMJ Open. 2017;7(3):e011843.
19. Correa-Rodriguez M, Rueda-Medina B, Gonzalez-Jimenez E, Schmidt-RioValle J. Associations between body composition, nutrition, and physical activity in young adults. Am J Hum Biol. 2017;29(1):1-7.
20. Bowen L, Taylor AE, Sullivan R, Ebrahim S, Kinra S, Krishna KV, et al. Associations between diet, physical activity and body fat distribution: a cross sectional study in an Indian population. BMC public health. 2015;15:281.
21. Su C, Jia XF, Wang ZH, Wang HJ, Ouyang YF, Zhang B. Longitudinal association of leisure time physical activity and sedentary behaviors with body weight among Chinese adults from China Health and Nutrition Survey 2004–2011. European Journal of Clinical Nutrition. 2017;71(3):383-8.
22. Su C, Jia X, Wang Z, Wang H, Zhang B. Trends in dietary cholesterol intake among Chinese adults: a longitudinal study from the China Health and Nutrition Survey, 1991-2011. BMJ Open. 2015;5(6):e007532.
23. Su C, Zhang B, Wang YF, Jia XF, Xue H, Wang HJ. Epidemics of overweight and obesity among growing childhood in China between 1997 and 2009: Impact of Family Income, Dietary Intake, and Physical Activity Dynamics. Chinese medical journal. 2015;128(14):1879-86.
24. Ng SW, Norton EC, Popkin BM. Why have physical activity levels declined among Chinese adults? Findings from the 1991-2006 China Health and Nutrition Surveys. Soc

Sci Med. 2009;68(7):1305-14.

25. Ng SW, Howard AG, Wang HJ, Su C, Zhang B. The physical activity transition among adults in China: 1991-2011. Obes Rev. 2014;15 Suppl 1:27-36.
26. Ng SW, Popkin BM. Time use and physical activity: a shift away from movement across the globe. Obes Rev. 2012;13(8):659-80.
27. Jones-Smith JC, Popkin BM. Understanding community context and adult health changes in China: development of an urbanicity scale. Soc Sci Med. 2010;71(8):1436-46.
28. Zhang B, Zhai FY, Du SF, Popkin BM. The China Health and Nutrition Survey, 1989-2011. Obesity Reviews. 2014;15:2-7.
29. Nutrition CSo. Dietary guidelines for Chinese residents (2016). Beijing: People's Medical Publishing House 2016.
30. Bureau of disease control and prevention mohotPsRoC. Chinese Adult Physical Activity Guide. Beijing: People's Medical Publishing House 2011. 14 p.
31. Bottai M, Frongillo EA, Sui X, O'Neill JR, McKeown RE, Burns TL, et al. Use of quantile regression to investigate the longitudinal association between physical activity and body mass index. Obesity (Silver Spring). 2014;22(5):E149-56.
32. Ouyang Y, Wang H, Su C, Wang Z, Song Y, Xiao Y, et al. Use of quantile regression to investigate changes in the body mass index distribution of Chinese adults aged 18-60 years: a longitudinal study. BMC public health. 2015;15:278.
33. Bottai M, Cai B, McKeown RE. Logistic quantile regression for bounded outcomes. Stat Med. 2010;29(2):309-17.
34. World Health Organ Tch Rep Ser 1995. Physical status: the use and interpretation of anthropometry. Report of a WHO expert committee1995. p.854.
35. Romero-Corral A, Somers VK, Sierra-Johnson J, Korenfeld Y, Boarin S, Korinek J, et al. Normal weight obesity: a risk factor for cardiometabolic dysregulation and cardiovascular mortality. Eur Heart J. 2010;31(6):737-46.
36. Foong YC, Aitken D, Winzenberg T, Otahal P, Scott D, Jones G. The association between physical activity and reduced body fat lessens with age - results from a cross-sectional study in community-dwelling older adults. Exp Gerontol. 2014;55:107-12.
37. Xiao S-M, Lei S-F, Chen X-D, Liu M-Y, Jian W-X, Xu H, et al. Correlation and prediction of trunk fat mass with four anthropometric indices in Chinese males. British Journal of Nutrition. 2007;96(5):949-55.
38. Min KB, Min JY. Android and gynoid fat percentages and serum lipid levels in United States adults. Clin Endocrinol (Oxf). 2015;82(3):377-87.
39. Kim M, Shinkai S, Murayama H, Mori S. Comparison of segmental multifrequency bioelectrical impedance analysis with dual-energy X-ray absorptiometry for the

assessment of body composition in a community-dwelling older population. Geriatr Gerontol Int. 2015;15(8):1013-22.

40. Beeson WL, Batech M, Schultz E, Salto L, Firek A, DeLeon M, et al. Comparison of body composition by bioelectrical impedance analysis and dual-energy X-ray absorptiometry in Hispanic diabetics. International Journal of Body Composition Research. 2010;8:45-50.
41. Madeira FB, Silva AA, Veloso HF, Goldani MZ, Kac G, Cardoso VC, et al. Normal weight obesity is associated with metabolic syndrome and insulin resistance in young adults from a middle-income country. PLoS One. 2013;8(3):e60673.
42. Marques-Vidal P, Pe´coud A, Hayoz D, Paccaud F, Mooser V, Waeber Gr, et al. Prevalence of normal weight obesity in Switzerland_ effect of various definitions. European Journal of Nutrition. 2008;47(5):251-7.
43. Shea JL, King MT, Yi Y, Gulliver W, Sun G. Body fat percentage is associated with cardiometabolic dysregulation in BMI-defined normal weight subjects. Nutr Metab Cardiovasc Dis. 2012;22(9):741-7.
44. Popkin BM, Du S, Zhai F, Zhang B. Cohort Profile: The China Health and Nutrition Survey--monitoring and understanding socio-economic and health change in China, 1989-2011. Int J Epidemiol. 2010;39(6):1435-40.
45. Zhang J, Chaaban J. The economic cost of physical inactivity in China. Prev Med. 2013;56(1):75-8.
46. Nutrition CSo. Dietary guidelines for Chinese residents. Beijing: People's Medical Publishing House; 2016. p. 32-55.

Figures

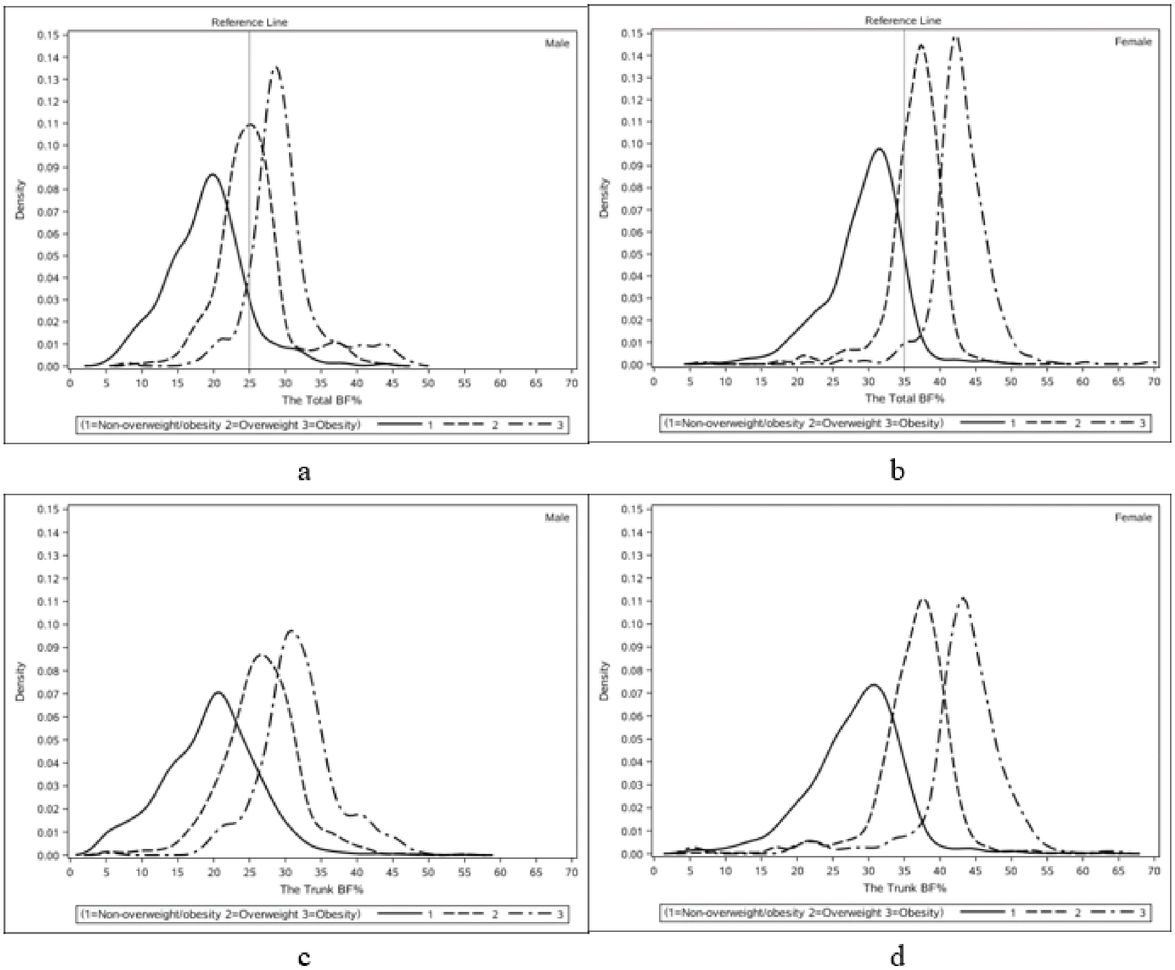

Figure 1

Density diagram for BF% in BMI groups

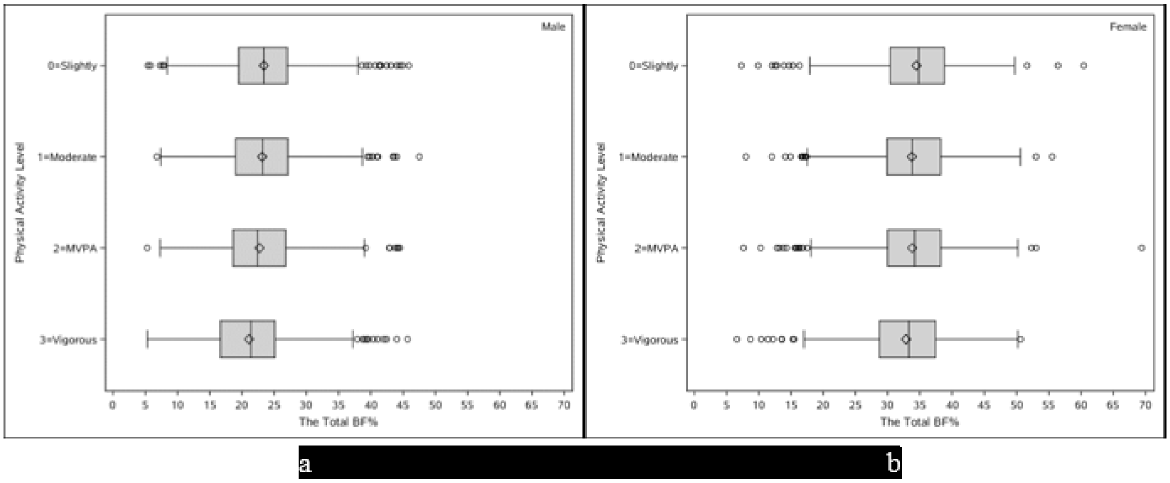

Figure 2

Box plots of the total BF% by levels of PA

Supplementary Files

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