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ORIGINAL CONTRIBUTION

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Cardiovascular risk factors in overweight and obese Chinese children

A comparison of weight-for-height index and BMI as the screening criterion

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Abstract *Background* Childhood obesity is a widespread and growing problem in the world. Body mass index (BMI) and weight-for-height criterion have been used to determine childhood obesity. No data was available to evaluate cardiovascular risk factors in overweight and obese Chinese children screened by weight-for-height index and Chinese newly developed BMI criterion. *Aim of the study* To evaluate cardiovascular risk factors in overweight and obese Chinese children by using Chinese BMI and weight-for-height index as screening criterion. *Methods* A total of 215 children aged 7.5–13 years were recruited from 3 primary schools in Guangzhou, PR China. Measurements included body weight, height, waist and hip circumference, fasting serum glucose, insulin, total triglyceride (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), apolipoprotein A (apo A), apolipoprotein B (apo B). Chinese BMI and weight-for- height criterion were used to classify overweight and obesity. *Results* According to Chinese BMI criterion, 65 from 108 obese children originally identified by weight-for-height were reclassified as obese and other 41 children were classified as overweight. Compared with non-obese children, obese children screened by Chinese BMI and weight-for-height index had increased levels of TG, LDL-C, apo B, insulin; decreased levels of HDL-C, apo A; and significantly higher prevalence of hypertriglyceridemia and high LDL-C. Children identified as overweight by Chinese BMI criterion had also shown high TG, LDL-C, apo B, insulin levels, low HDL-C, apo A levels, and significantly higher prevalence of hypertriglyceridemia than the normal weight children. *Conclusions* Our study reveals that overweight and/or obesity screened by both Chinese new BMI and weight-for-height criterion are associated with increased levels of cardiovascular risk factors (e.g., elevated serum TG, LDL, apo B, and reduced HDL-C, apo A levels). Using Chinese BMI criterion may underestimate the prevalence of childhood obesity but it could be adopted as a unique tool for screening children's overweight in population-based screening programs.

Key words cardiovascular risk factors – childhood – obesity – overweight – screening criterion

Introduction

Obesity is a widespread and growing problem in the world with significant medical and public health consequences. In China, the prevalence of childhood obesity has increased dramatically from 0.2% in 1985 to 12.9% in 2000 for boys and from 0.1% to 9.1% for girls; such figure has already reached the average level seen in the medium-developed countries [19]. The increasing trend will continue and could be largely attributable to the rapid socioeconomic progress in China over the last two decades.

Childhood obesity is a serious public health concern because it is a recognized risk factor associated with increased mortality and morbidity from cardiovascular diseases (CVD) and other chronic conditions in adult life. Identifying and controlling obesity during childhood is thus envisaged as an effective way to prevent disease occurrences at the early stages. The weight-for-height index and body mass index (BMI) are the most frequent approaches used to determine obesity in children and adolescents worldwide [15, 25, 36, 38]. The world health organization (WHO) recommends using the weight-for-height index as a screening criterion to identify children obesity [38]. According to this screening criterion, obesity was defined as Z-score ± 2 SD. from the median as cut-off points [38]. BMI approach was first introduced by *Must et al* in 1991 who used BMI reference data to evaluate nutritional status of children and adolescents [25, 26], and it becomes very popular and is accepted as a screening tool for children obesity around the world then [6, 23, 24, 31, 32]. Based on the growing evidence that childhood/adolescence BMI might be an important predictor for risk factors or morbidity/mortality in adulthood, Cole et al. [5] in 2000 (under the auspices of the international obesity task force (IOTF)) proposed BMI cut-off values of childhood as the important threshold values to predict diseases occurrences or mortality in their adult life.

However, these international criteria are unsuitable for Chinese children and adolescents because there are differences in body composition between Chinese children and other ethnic groups. In 2004, the working group on obesity in China (WGOC) established a national BMI reference for screening overweight and obesity in Chinese children and adolescents aged 7–18 years [14, 18]. Serum lipids and lipoproteins had been studied in Chinese adult population, while few have been performed on childhood obesity and the cardiovascular risk factors in Chinese population [2–4, 22]. No data are available to evaluate cardiovascular risk factors in overweight and obese Chinese children screened by using both the weight-for-height index and BMI approaches. The objective of this study is to compare the levels of cardiovascular risk factors in overweight and obese Chinese children screened by these two methods. Better understanding on different screening criteria for children's obese/overweight in various ethnic populations would guide future health promotion efforts and effective disease prevention.

Methods

Study population

The potential subjects in grade three to six were recruited from three primary schools in Guangzhou city, Guangdong province of PR China. Children with diabetes diagnosed by medical doctors and those using medication potentially altering glucose or lipid metabolism were excluded from the study. All study subjects were first screened for the eligibility and then invited to participate in the study. Each eligible child was face-to-face interviewed by our trained research staff according to a standard questionnaire including information on demographics (age and gender), physical examination, and routine laboratory tests. According to WHO standard on child weight-for-height criterion [39] (Appendix A), obesity was defined as body weight 120% or more above the expected weight for height. Non-obese was defined as weight ranging from 90 to 110% of that predicted for height. Non-obese children were frequency matched by gender and age to obese ones. We finally recruited 108 obese children (boys 61, girls 47) and 107 non-obese children (boys 63, girls 44) into the study based on WHO criterion. On the other hand, we used the gender- and age- specific BMI cutoffs newly developed by WGOC to define overweight and obesity of all these 215 eligible subjects [14, 18], and eventually identified much lower proportion of obesity (65 children), leaving other 150 children being classified as overweight (41 children) and normal (109 children) respectively (Table 1). Physical examination and routine laboratory

Table 1 Distribution of 215 school children screened by weight-for-height index and BMI for obese/overweight status

	Weight-for-height		Total
	Obese	Nonobese	
BMI			
Obese	65	0	65
Overweight	41	0	41
Non-obese	2	107	109
Total	108	107	215

tests were performed to obtain anthropometric and biochemical measurements, while students' past medical histories were extracted from the annual health examination records kept by the schools. The study was conducted following the Declaration of Helsinki, and the study protocol was approved by Ethical Committee of Sun Yat-sen University. Written informed consent was obtained from children and their parents before the start of the study.

Anthropometric measurements

Measurements of height, weight, waist and hip circumferences were carried out under fasting conditions. Body weight was determined to the nearest 0.1 kg on standard physician's beam scales with the children wearing only the underwear and no shoes. Height was measured to the nearest 0.1 cm on standardized, wall-mounted height boards according to the following protocol: no shoes, heels together, and child's heels, buttocks, shoulders, and head touching the vertical wall surface with line of- sight aligned horizontally. Each of the standard physician's beam scales and wall-mounted height boards used to measure were calibrated previously, using three different weights and one reference tape. Body Mass Index (BMI) was calculated by dividing weight (kg) by height squared (m^2). Waist circumference was measured by means of a flexible non-elastic tape with subjects standing at the smallest abdominal position between the lower rib margin and the iliac crest. Hip circumference was measured as the maximum circumference of the buttocks. Waist to hip ratio (WHR) was calculated by dividing hip circumference by the waist circumference.

Biochemical measurements

Blood samples were collected from all eligible subjects in the morning after an overnight fast at least 12 h, with the use of an indwelling venous line for the measurements of the levels of glucose, insulin, total triglyceride (TG), total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C), apolipoprotein A (apo A) , and apolipoprotein B (apo B). Blood glucose was determined by using a glucose oxidase method on an automated autoanalyzer. Serum insulin was measured by radioimmunoassay (Beijing North Biotechnology Company). Serum TC and TG were measured by the routine enzymatic methods. HDL-C and LDL-C were detected by radioimmunity approach. Lipid and lipoprotein values were expressed as mmol/l. Apo A and apo B were measured by nephelometric immunoassay. As there is no reference for Chinese children, high blood lipid concentrations were defined according to the National Cholesterol Education Program NCE [27, 28]. Hypercholesterolemia was defined as blood cholesterol ≥ 5.2 mmol/l. Hypo-HDL was defined as HDL ≤0.9 mmol/l. High LDL was defined as LDL ≥ 3.4 mmol/l. Hypertrigyceridemis was defined as values higher than 1.69 mmol/l. According to the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus [35], fasting plasma glucose higher than 6.1 mmol/l was considered as impaired fasting glucose.

Statistical analyses

Statistical analyses were conducted by using SPSS software (version 13.0). The data were expressed as mean ± SD. Normality of distribution of the compared variables was tested. Student's independent *t* test or ANOVA was performed to compare the mean differences of continuous variables between obese and non-obese groups or among obese, overweight, and normal groups. Comparisons of categorical variables between groups were carried out by the x^2 test. Unconditional logistic regression was used to estimate the odds ratios for cardiovascular risk factors of obese and overweight children with the reference of non-obese children. Two-sided $P < 0.05$ was considered as statistically significant.

Results

Table 2 presents the anthropometric characteristics of the 215 children stratified for the obese/overweight status using both weight-for-height index and BMI criterion. Among 108 children originally identified as obese by weight-for-height index approach, 65 were eventually classified as obese and 41 were overweight based on Chinese BMI method, and two obese children screened by weight-for-height were considered to be normal accordingly. Using weight-for-height index criterion, the values of body weight, height, BMI, waist circumference, hip circumference, and WHR among obese children were all significantly higher than those in non-obese children. There was no significant age difference between obese and non-obese children. Using BMI method, we found body weight, BMI, waist circumference, hip circumference, and WHR in overweight and obese children were also significantly higher than those in non-obese ones. The average age in children with obese and overweight (height also) did not differ significantly from that in non-obese children for both genders.

According to weight-for-height criterion, the mean concentrations of serum triglyceride, LDL-C, apo B,

Table 2 Characteristics of the 215 study subjects

	Weight-for-height†		BMI‡		
	Obese (*n* = 108)	Non-obese (*n* = 107)	Obese (*n* = 65)	Overweight (*n* = 41)	Non-obese (*n* = 109)
Age (years)	11.10 ± 1.06	11.03 ± 0.65	10.98 ± 1.15	11.29 ± 0.91	11.03 ± 0.65
Height (cm)	147.70 ± 8.31†*	144.11 ± 6.79	149.01 ± 8.80‡**	145.82 ± 7.15	144.08 ± 6.77
Weight (kg)	53.70 ± 11.27†**	34.67 ± 5.02	57.67 ± 11.93‡**	47.74 ± 6.48#**	34.72 ± 5.02
BMI (kg/m^2)	24.37 ± 3.12†**	16.59 ± 1.09	25.72 ± 3.24‡**	22.33 ± 1.14#**	16.63 ± 1.14
Waist circumference (cm)	79.37 ± 9.51†**	58.94 ± 3.79	82.78 ± 10.15‡**	74.31 ± 4.93#**	58.99 ± 3.82
Hip circumference (cm)	88.07 ± 7.58†**	73.20 ± 4.80	90.62 ± 7.91‡**	84.30 ± 4.92#**	73.24 ± 4.80
Waist to hip ratio	0.90 ± 0.07†**	0.81 ± 0.04	0.91 ± 0.07‡**	0.88 ± 0.06 #**	0.81 ± 0.04

*$P < 0.05$; **$P < 0.001$; †obese vs. non-obese children by weight-for height index; ‡obese vs. non-obese by BMI criterion; #overweight vs. non-obese children by BMI criterion

glucose, and insulin were significantly higher among obese children than those among non-obese children; while the levels of HDL-C and apo A were significantly higher in the non-obese group. No significant difference in serum TC level was detected between the obese and non-obese children. Using BMI criterion, the mean concentrations of serum triglyceride, LDL-C, apo B, and insulin were also significantly higher in obese and overweight children. Nevertheless, levels of HDL-C and apo A were significantly higher in the non-obese group relative to obese/overweight groups. We did not observe significant differences in serum TC and glucose values among obese, overweight, and non-obese children (Table 3).

The distributions of high level of cardiovascular risk factors of 215 study subjects are presented separately according to weight-for-height index and BMI criterion, as shown in Table 4. Using the weight-for-height index criterion, the most striking difference between obese (16.8%) and non-obese (2.8%) children was for TG ($P = 0.001$). High LDL-C was more prevalent in obese children (29.9%) than non-obese (15.7%) children ($P = 0.013$). The differences for other risk factors were not statistically significant. Using BMI criterion, the prevalence of high TG ($P = 0.003$) and LDL-C ($P = 0.028$) in obese children was higher than those in non-obese ones. There was no significant difference for other risk factors.

Table 3 Serum lipids, insulin and glucose in 215 study subjects

	Weight-for-height †		BMI‡		
	Obese (*n* = 108)	Non-obese (n = 107)	Obese (*n* = 65)	Overweight (*n* = 41)	Non-obese (*n* = 109)
Glucose (mmol/l)	4.26 ± 0.44†*	4.11 ± 0.44	4.24 ± 0.41	4.27 ± 0.48	4.12 ± 0.44
Insulin (μIU/ml)	20.19 ± 10.43†**	12.26 ± 3.86	21.41 ± 12.57‡**	18.31 ± 5.57#**	12.33 ± 3.90
TC (mmol/l)	4.33 ± 0.71	4.18 ± 0.78	4.28 ± 0.75	4.39 ± 0.66	4.19 ± 0.78
TG (mmol/l)	1.15 ± 0.60†**	0.75 ± 0.36	1.16 ± 0.58‡**	1.09 ± 0.57#*	0.77 ± 0.42
HDL-C (mmol/l)	1.28 ± 0.25†**	1.50 ± 0.31	1.26 ± 0.25‡**	1.31 ± 0.26#**	1.50 ± 0.31
LDL-C (mmol/l)	3.03 ± 0.77†**	2.66 ± 0.78	2.99 ± 0.78‡*	3.08 ± 0.75#*	2.67 ± 0.78
apo AI (g/l)	1.13 ± 0.22†*	1.23 ± 0.25	1.13 ± 0.22‡*	1.12 ± 0.22#*	1.23 ± 0.25
apo B_{100} (g/l)	0.91 ± 0.19 †*	0.83 ± 0.18	0.91 ± 0.20‡*	0.92 ± 0.19#*	0.83 ± 0.18

*$P < 0.05$; **$P < 0.001$; †obese vs. non-obese children by weight-for height index; ‡obese vs. non-obese by BMI criterion; #overweight vs. non-obese children by BMI criterion

Table 4 Numbers of children with high level of cardiovascular risk factors among 215 study subjects according to weight-for-height and BMI criteria

	Weight-for-height†		BMI‡		
	Obese (*n* = 108)	Non-obese (*n* = 107)	Obese (*n* = 65)	Overweight (*n* = 41)	Non-obese (*n* = 109)
Hyperglycemiae (%)	0	0	0	0	0
Hypertriglyceridemia	18 (16.8%)†**	3 (2.8%)	11 (16.9%)‡*	6 (14.6%)#*	4 (3.7%)
Hypercholesterolemia	15 (14.0%)	9 (8.4%)	9 (13.8%)	6 (14.6%)	9 (8.3%)
Low HDL-C	2 (1.9%)	1 (0.9%)	2 (3.1%)	0 (0%)	1 (0.9%)
High LDL-C	32 (29.9%)†*	17 (15.7%)	20 (30.8%)‡*	11 (26.8%)	18 (16.5%)

*$P < 0.05$; **$P < 0.001$; †obese vs. non-obese children by weight-for height index; ‡obese vs. non-obese by BMI criterion; #overweight vs. non-obese children by BMI criterion

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Table 5 Estimated odds ratios (ORs) between obesity and adverse risk factor level among 215 children

Risk factor	Weight-for-height		BMI			
	Obese		Overweight		Obese	
	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value
Glucose ≥ 6.1						
TC ≥ 5.2	1.79 (0.75–4.30)	0.190			1.79 (0.67–4.76)	0.246
TG ≥ 1.69	6.68 (1.90–23.56)	0.003	3.75 (0.95–14.75)	0.059	5.35 (1.63–17.59)	0.006
HDL-C ≤ 0.9	2.04 (0.18–22.82)	0.563			3.43 (0.31–38.58)	0.318
LDL-C ≥ 3.4	2.28 (1.18–4.43)	0.015	1.85 (0.79–4.36)	0.158	2.25 (1.08–4.66)	0.030

Compared to non-obese children, the percentage of high TG was significantly higher in overweight children (14.6% vs. 3.7%, $P = 0.016$), but the prevalence of other risk factors did not reach significant difference.

The relationships between obesity and the CVD risk factors are summarized in Table 5 and stratified by weight-for-height criterion and Chinese BMI criterion. Based on weight-for-height criterion and using non-obese children as reference, obese children was 6.68 times as likely to have a high TG level and 2.28 times to have a high LDL-C level. According to BMI criterion, obese children were 5.35 times as likely to have a high TG levels and 2.25 times to have a high LDL-C level using non-obese children as the reference, but there was no significant difference compared to the overweight children.

Discussion

This study compared Chinese newly developed BMI criterion with weight-for-height index criterion to determine the status of obesity and evaluate the levels of cardiovascular risk factors in overweight and obese Chinese children compared with the non-obese children. The current study reveals that obese children, screened by both weight-for-height criterion and Chinese BMI criterion, consistently presented higher levels of CVD risk factors including serum TG, LDL-C, apo B, insulin, hypertriglyceridemia, and LDL-C, but lower levels of HDL-C and apo A than the non-obese group. Overweight children screened by Chinese BMI also showed higher levels of these CVD risk factors compared to those with normal weight group.

Since weight and body composition are continually changing for children and adolescents, it is very complicated to classify obesity in such a dynamic situation [8, 15]. Both BMI and weight-for-height criterion are recognized as the most frequently used methods to classify obesity, but the relative complexity in the estimation of weight-for-height limits its broad usage in population-based screening programs. BMI, which relates body weight to height, has been recommended as the simple and reliable measure of overweight and obesity in childhood for population-based survey purposes. The present study used newly established BMI criterion in China to define obesity and overweight for children which was originally classified by weight-for-height index as obese. Our results showed that using Chinese BMI criterion would have only identified 65 obese children (about 60% of those originally identified as obese by the method of weight-for-height index criterion). In other words, more than one-third of obese children (43 subjects) screened by weight-for-height index were eventually re-defined as overweight (41 subjects) or non-obese (2 subjects) if Chinese BMI criterion was adopted. Therefore, using this Chinese BMI criterion to classify obesity in Chinese children/adolescence populations may have underestimated the prevalence rate of childhood obesity by 40% compared to weight-for-height criterion.

Abnormal levels of serum lipids, lipoproteins, and apolipoproteins (especially decreased levels of HDL-C, apo A and elevated levels of LDL-C, TG and apo B) are generally recognized as independent risk factors for cardiovascular disease (CVD) [13, 29]. LDL cholesterol has long been known to be probably the most important risk factor in atherosclerosis etiology [17]. High levels of apo A–I and apoB were strongly correlated with the development of atheroma [37]. High fasting insulin concentration has been documented as an independent CVD risk factor [7]. Considerable evidence has demonstrated a link between hyperinsulinaemia and children obesity [10, 12, 30, 34]. The present study indicates that the combination of elevated TG, LDL-C, apo B, insulin and low HDL-C and apo A levels would place obese children at greater risks of cardiovascular disease than their counterparts. Our findings are consistent with most of the previous studies that examined the relationships between obesity and cardiovascular risk factors among children and adolescents in other ethnic groups [1, 9–11, 16, 20, 21, 30, 33, 34]. However, we did not find significant differences in TC levels between our obese and non-obese children. Evidence from existing literature shows that the presence of obesity was more strongly related to high level of TG and low level of HDL-C [1, 9, 34]; results from our study are in consistent with those findings. Our study indicates that the significant differences in serum TG and LDL-C concentrations would first be examined out when looking at the relationship between cardiovascular risk factors and childhood obesity. However, given a relatively weak association between obesity and serum TC level, we expect that it is hard to determine a significant difference in serum TC level between children with obesity and those without unless the sample size is large enough [1, 9, 34].

The most striking finding of this study is that the overweight children screened by Chinese BMI (they were originally defined as obese by using weight-for-height index criterion) have actually suffered from metabolic abnormalities, such as higher levels of TG, LDL-C, apo B, and insulin, lower levels of HDL-C and apo A, and the higher prevalence of the hypertriglyceridemia. Using Chinese BMI criterion have shown somewhat lower detection rate of children obesity compared with those introduced by Cole et al. [5] and Must et al. [25, 26], while the group of overweight Chinese children identified using Chinese BMI criterion have still presented abnormal levels of serum lipids. These overweight children may usually be ignored by their parents and/or the health facilitators of local schools, while the adverse health consequences would be significant if the presence of overweight and/or relevant CVD risk factors are not well controlled in their earlier courses of life. Using Chinese BMI criterion would be able to screen out the overweight children timely. We treat this as one of the advantages of our study. Based on our findings and the results from the literature, we recommend that efforts should be made in the initial step of a screening program to identify childhood with overweight. Preventive strategies and measures should be taken not only to control cardiovascular risk factors in obese children, but also in overweight ones.

The major limitation of this study is that the blood pressure was not measured, which avoided us determining the association with obesity and the metabolic syndromes, the latter has been recognized as a cluster of potent risk factors for atherosclerotic cardiovascular disease and type 2 diabetes mellitus. Another potential limitation is that the levels of CVD risk factors and obesity status at whole pubertal stage could not be determined by this cross-sectional study, which hampered us from assessing the changes of lipid profile at different stages of puberty. Pinhas-Hamiel et al found that lipid profiles change substantially during puberty period [30]. The third limitation is related to our small sample size which may provide inadequate statistical power and increases the variability seen in the studied comparisons. Well designed follow-up study with more study subjects are recommended in future research.

In conclusion, our study reveals that overweight and/or obese Chinese children screened by both Chinese new BMI and weight-for-height criterion are associated with increased levels of CVD risk factors (e.g., elevated serum TG, LDL, apo B, and reduced HDL-C, apo A levels). Chinese new BMI criterion may not act as a good screening tool for children obesity since it may have underestimated obesity prevalence compared with the weight-for-height criterion. However, giving relatively less complexity in practice, Chinese new BMI criterion could be adopted as a unique tool for screening children's overweight in population-based screening programs.

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Appendix A

Expected weight for height standard for the observed ages

Height (cm)	Weight (kg)		Height (cm)	Weight (kg)	
	Normal	Obesity		Normal	Obesity
127.0–127.9	23.0–27.8	≥30.5	148.0–148.9	35.0–42.6	≥46.6
128.0–128.9	23.5–28.5	≥31.2	149.0–149.9	35.7–43.5	≥47.5
129.0–129.9	24.0–29.1	≥31.8	150.0–150.9	36.5–44.3	≥48.5
130.0–130.9	24.4–29.6	≥32.4	151.0–151.9	37.4–45.4	≥49.7
131.0–131.9	25.0–30.4	≥33.2	152.0–152.9	38.2–46.4	≥50.8
132.0–132.9	25.4–30.8	≥33.7	153.0–153.9	38.8–47.2	≥51.6
133.0–133.9	25.8–31.3	≥34.2	154.0–154.9	39.5–48.1	≥52.6
134.0–134.9	26.4–32.0	≥35.0	155.0–155.9	40.4–49.2	≥53.8
135.0–135.9	27.0–32.8	≥35.9	156.0–156.9	41.1–50.1	≥54.7
136.0–136.9	27.4–33.2	≥36.4	157.0–157.9	41.5–50.5	≥55.2
137.0–137.9	28.1–34.1	≥37.3	158.0–158.9	42.1–51.3	≥56.0
138.0–138.9	28.8–35.0	≥38.3	159.0–159.9	43.0–52.4	≥57.2
139.0–139.9	29.4–35.7	≥39.0	160.0–160.9	43.9–53.5	≥58.4
140.0–140.9	29.8–36.2	≥39.6	161.0–161.9	44.7–54.4	≥59.4
141.0–141.9	30.3–37.1	≥40.3	162.0–162.9	45.5–55.3	≥60.5
142.0–142.9	31.1–37.7	≥41.3	163.0–163.9	46.0–56.0	≥61.2
143.0–143.9	31.7–38.5	≥42.1	164.0–164.9	47.2–57.4	≥62.8
144.0–144.9	32.1–39.1	≥42.7	165.0–165.9	47.8–58.2	≥63.6
145.0–145.9	32.9–39.9	≥43.7	166.0–166.9	48.3–58.8	≥64.2
146.0–146.9	33.3–40.5	≥44.3	167.0–167.9	49.4–60.2	≥65.8
147.0–147.9	34.3–41.7	≥45.6			

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