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Optimal Cut-off Points of BMI WC and WHR for Screening of Pre-Diabetes and Diabetes Over 35 Years Old People

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Abstract: Using BMI, WC and WHR to investigate and compare these screening tool for IFG, IGT and diabetes subjects in Shanghai China; and to identify the optimal cut-off points of BMI, WC and WHR for screening pre-diabetes (Pre-DM) and diabetes (DM) over 35 years old people. Totally 3,195 aged 35 years old and above people who attended community epidemiological survey of diabetes mellitus. Using ADA criteria (2010), the participants were classified as normal, Pre-DM or DM according to test results of blood glucose. The area under ROC curve (AUROC) for BMI, WC and WHR were calculated; as well as the sensitivity, specificity and Youden index under different BMI or WHR cut-off points. Among these people, age is (61.07±10.08), and BMI and WHR are respectively (25.12±3.29) and (0.87±0.06). The positive rate of screening of DM is 11.36% and that of Pre-DM is 38.57%. There are correlation between blood glucose and BMI or WHR ($p<0.05$). With the increase of BMI or WHR cut-off point, the screening sensitivity (YI, Sp and Se) for DM or pre-DM are decreasing; but the area under ROC (AUROC) increases firstly and then decreases (inflection point: WHR≥0.8~0.9 and BMI≥23 for pre-DM, WHR≥0.9 and BMI≥24 for DM). The combined screening efficacy of BMI merged WHR is the best combination choice (cut-off point of BMI and WHR are respectively 23 and 0.8), and YI is the highest. Using HbA1C as standard of judgment seems to be better than blood glucose in screening for DM. BMI≥23, WC≥90 cm or WHR≥0.8 is the optimal cut-off point for screening DM and pre-DM, and the screening efficacy of BMI is better than WC and WHR. BMI merged WHR is the best combination choice (cut-off point of BMI and WHR are respectively 23 and 0.8). HbA1C is better than FBG and OGTT as standard of judgment in screening.

Keywords: Diabetes, Pre-Diabetes, Cut-off Points, Body Mass Index, Waist to Hip Ratio, Screening

1. Introduction

Central obesity is closely related to diabetes and other chronic diseases [1]. The Chinese Guidelines for the Prevention and Treatment of Type 2 Diabetes (2013 edition) lists central obesity as a high-risk factor for diabetes, and waist circumference as an indicator of central obesity [2]. Recent studies have shown that waist-to-height ratio (WHR) is superior to waist circumference in predicting diabetes risk [3-4]. China has become the country with the largest number of diabetes mellitus (DM) patients in the world, the treatment and control of DM have progressed with the development of medicine [5]. The national survey data in 2010 showed that Pre-diabetes (50.1%) is much higher than DM (11.3%), more than half of DM patients are undiagnosed (62%) [6]. Asian populations have a higher risk of DM at lower body mass index (BMI) levels [7-8]. American diabetes association (ADA) issued a standard for diabetes treatment that lowered the BMI cut-off point for Asian Americans screening for DM from 25 kg/m^2 to 23 kg/m^2 in 2015 [9]. The Chinese guidelines for the prevention and treatment of diabetes (2013 edition) recommended that the BMI cut-off points for overweight and obesity were 24 kg/m^2 and 28 kg/m^2 in screening for people over 40 years of age or with other risk factors of DM. and on the basis of chronic disease aggregation factors, these points were determined by the China Obesity Working Group in 2002. But more than 40% of DM was missed found under this cut-off point [10]. It is worth discussing whether we should reduce this cut point to early detect DM patients and high-risk people. Some studies suggested that the optimal BMI cut-off point for screening DM in Chinese population was from 22 kg/m^2 to 26 kg/m^2 [11-14]. These research was based on the accuracy of diagnosis (Youden index, YI) to determine the optimal cut-off point. When BMI is used as a screening marker rather than a specific clinical diagnostic marker, especially further confirmatory tests, It not only pays attention to the economical and convenient, but also emphasizes the accuracy of diagnosis, especially the ability of early detection of patients (sensitivity). The purpose of this study is to integrate sensitivity and Youden index, using the diabetes screening data of community residents in 2017, to identify the optimal cut-off points of BMI and WHR for screening pre-diabetes (Pre-DM) and diabetes (DM) over 35 years old people.

2. Methods

2.1. Objects Source

The objects in this study were residents of the community aged 35 years old and above (including permanent residents with household registration and non-residents with residence of more than 6 months). A multi-stage stratified random sampling method was used; the first phase was a complete random sampling method to extract three streets/townships from total district area. In the second stage, one residential committee/village was selected from street according to the sampling method proportional to the size of the population. In the third stage, three residents group were selected from every committee by random sampling. In the fourth stage, the residents aged 35 years and over were randomly selected from the sampling group. All screening objects gave verbal and written informed consent to participate in the study, they would like to participate in investigation and answer all the related questions in the questionnaire.

2.2. Investigation and Measurement

All questionnaires and physical examinations were performed by trained medical professionals. Waist circumference (WC) was measured at a level midway between the lower rib margin and the iliac crest. Hip circumference (HC) was measured at the maximum circumference around the buttocks. WC and HC were measured with the accuracy of ±0.5 cm using a flexible measuring tape. Height and weight of the participants (wearing only light clothing and barefooted) were measured with the accuracy of ±0.1 cm and ±0.1 kg, respectively, by using a portable stadiometer and a balance beam scale (SECA measuring equipment).

All study objects were tested for fasting peripheral blood glucose, 12 ml fasting venous blood was collected; Oral 75 g glucose for whose fasting blood glucose levels were below 10 mmol/L, and 2 ml venous blood was collected after 2 hours. Serum total cholesterol (TC), triglyceride (TG), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), oral glucose tolerance test (OGTT) and glycosylated hemoglobin (HbA1c) were measured.

Blood glucose diagnostic criteria: FPG<6.1 mmol/L and OGTT<7.8 mmol/L is normal; 5.6 mmol/L≤FPG<7.0 mmol/L and OGTT<7.8 mmol/L is impaired fasting glucose (IFG); 7.8 mmol/L≤OGTT<11.1 mmol/L but FPG<7.0 mmol/L is impaired glucose tolerance (IGT); FPG≥7.0 mmol/L or OGTT≥11.1 mmol/L or HbA1c ≥6.5% is diabetes [15-16]. Pre-DM includes IFG and IGT. Body mass index (BMI) = body weight (kg) / height squared (m^2), waist to hip ratio (WHR) = Waist circumference (WC) / Hip circumference (HC); Youden Index (YI) = sensitivity (Se) + specificity (Sp) -1. The optimal cut-off point of BMI and WHR is defined based on Youden index reaches its maximum, and sensitivity of nearly is not too small.

2.3. Statistical Analysis

Statistical analyses were performed using the statistical software package (IBM SPSS statistics version 21). When P values <0.05, the difference is considered statistically significant. Descriptive statistics (mean and standard deviation (SD)) were computed for the quantitative variables (age, height, weight, WC, HC, BMI and WHR), Comparisons between groups were performed by t-test. Number (n) and percentage (%)) were computed for the categorical data, Comparisons between groups were performed by the chi-square (χ^2) test. Drawing the receiver operator characteristic curve (ROC) of BMI and WHR for diagnosing Pre-DM/DM, and calculate the area under the ROC (AUROC). Sensitivity (Se), specificity (Sp) and Youden index (YI) in diagnosis of pre-DM and DM among cut-off point of BMI (19~28 kg/m^2) and WHR (0.7~1.1) were calculated respectively. Optimal BMI cut-off point was obtained according to YI.

3. Results

3.1. Basic Characteristics

A total of 3195 people were investigated in this study, and 369 people with diabetes were excluded, the actual effective screening people were 2,826. Among these effective screened objects, male was 1188 (42.04%) and female 1638 (57.96%). The mean age is (60.73±10.18), and the mean BMI and WHR are (24.99±3.26) kg/m^2 and (0.87±0.06). 580 (48.82%) male are WC≥90 cm; 723 (44.14%) female are WC≥85 cm. Among them, they are all over 35 years old, and 35~44 years old is 8.49% (n=240); 45~54 is 19.25% (n=544); 55~64 is 41.44% (n=1171); 65~74 is 24.35% (n=688); aged 75 or above is 6.48% (n=183). There are 171 people FPG≥7.0 mmol/L, 1021 people 5.6 mmol/L≤FPG<7.0 mmol/L; and 511 people 7.8 mmol/L≤OGTT< 11.1 mmol/L, 216 people OGTT≥11.1 mmol/L; 156 people HbA1c ≥6.5%. Others see table 1.

According to diabetes diagnostic criteria, there are 321 cases of diabetes mellitus and 1090 cases of pre-DM (IFG 1021; IGT 511), the screening positive rate of DM and pre-DM are respectively 11.36% and 38.57%.

3.2. Partial Correlation Analysis

After age adjustment, the partial correlation coefficients between body shape index (height, weight, WC, HC, BMI and WHR) and blood glucose test index (FBG, VBG, OGTT and HbA1c) were calculated respectively. The results show that there are correlation between body shape and blood glucose, and the partial correlation coefficients are significant ($p<0.05$), except for the correlation between height and OGTT. See table 2.

Table 1. *The basic characteristics of male and female in measured data.*

	male (n=1188)				female (n=1638)			
	Min	Max	mean	SD	Min	Max	mean	SD
Age(y)	35	90	61.08	10.48	35	92	60.47	9.95
height(cm)	146.1	187.5	165.54	5.98	132.0	187.0	154.41	5.84
weight(kg)	45.0	112.1	69.68	10.22	29.8	102.1	58.93	8.62
WC(mm)	62.1	122.1	89.11	9.16	57.1	113.0	83.63	8.67
HC(mm)	81.0	124.7	99.17	6.37	74.3	123.3	97.40	6.65
BMI	17.21	41.08	25.40	3.30	15.32	37.01	24.70	3.21
WHR	0.73	1.09	0.90	0.05	0.59	1.11	0.86	0.06
FBG(mmol/L)	3.12	18.79	5.72	1.12	4.06	14.76	5.61	0.85
OGTT(mmol/L)	1.67	29.40	6.86	3.12	1.90	31.84	7.01	2.77
HbA1c(%)	4.00	11.90	5.77	0.63	4.00	12.10	5.78	0.53

Table 2. *The result of partial correlation coefficients (* R is partial correlation coefficient).*

	height		weight		WC		HC		BMI		WHR	
	R	p	R	p	R	p	R	p	R	p	R	p
VBG	0.067	<0.001	0.160	<0.001	0.166	<0.001	0.084	<0.001	0.154	<0.001	0.185	<0.001
OGTT	-0.001	0.933	0.151	<0.001	0.179	<0.001	0.083	<0.001	0.198	<0.001	0.208	<0.001
HbA1c	0.036	0.043	0.151	<0.001	0.179	<0.001	0.082	<0.001	0.168	<0.001	0.208	<0.001

3.3. BMI Cut-Off Points Analysis

With the increase of BMI cut-off point, the screening sensitivity (Se) for DM is decreasing, but the specificity (Sp) for DM is increasing; the YI for DM and the area under ROC (AUROC) are increasing firstly and then decreasing (inflection point in BMI≥24). WC is better than WHR in the screening effect of DM. See table 3.

The same as above, with the increase of BMI cut-off point, the screening sensitivity (Se) for pre-DM is decreasing; the specificity (Sp) for pre-DM is increasing; the YI for pre-DM and the area under ROC (AUROC) increases firstly and then decreases (inflection point in BMI≥23). WC is better than WHR in the screening effect of pre-DM. See table 4.

Figure 1 shows the movement of Youden index (YI) and sensitivity (Se) of sex (male, female and total) in screening for DM among different BMI cut-off points (19~28 kg/m^2), and the movement track of Se between male and female is very similar. When BMI≥19, Se is in the maximum; When BMI≥28, Se is in the minimum. But the change of YI is different from Se, Yi is increasing firstly and then decreasing (inflection point in BMI≥24), the same male as female. Therefore, the results of comprehensive table 3 and figure 1 shows that BMI≥23 or BMI≥24 is the optimal cut-off point for screening DM (YI=21.37% or 21.51%, Se=91.59% or 79.75%).

Figures 2 shows the movement of YI and Se of sex (male, female and total) in screening for pre-DM among different BMI cut-off points (19~28 kg/m^2), and the movement track of Se between male and female is very similar. When BMI≥19, Se is in the maximum; When BMI≥28, Se is in the minimum. But the change of YI is different from Se, Yi is increasing firstly and then decreasing (inflection point in BMI≥23), the same male as female. Therefore, the results of comprehensive table 4 and figure 2 shows that BMI≥23 is the optimal cut-off point for screening pre-DM (YI=13.25%, Se=77.71%).

Table 3. *BMI and WHR cut-off points and screening sensitivity for DM.*

	YI	Se	Sp	AUROC	95%CI	P
BMI≥19	1.97	99.38	2.59	0.610	0.577 ~ 0.643	0.565
BMI≥20	3.92	98.13	5.79	0.620	0.587 ~ 0.652	0.252
BMI≥21	8.35	96.57	11.78	0.642	0.610 ~ 0.673	0.015
BMI≥22	13.76	94.08	19.68	0.669	0.638 ~ 0.699	<0.001
BMI≥23	21.37	91.59	29.78	0.707	0.678 ~ 0.736	<0.001
BMI≥24	21.51	79.75	41.76	0.708	0.677 ~ 0.738	<0.001
BMI≥25	21.25	66.04	55.21	0.706	0.674 ~ 0.738	<0.001
BMI≥26	20.16	53.89	66.27	0.701	0.667 ~ 0.734	<0.001
BMI≥27	18.70	42.06	76.65	0.694	0.659 ~ 0.728	<0.001

	YI	Se	Sp	AUROC	95%CI	P
BMI≥28	14.03	29.60	84.43	0.670	0.635 ~ 0.705	<0.001
WHR≥0.7	0.08	100.0	0.08	0.600	0.567 ~ 0.634	0.981
WHR≥0.8	7.29	95.95	11.34	0.636	0.605 ~ 0.668	0.033
WHR≥0.9	15.88	47.98	67.90	0.679	0.645 ~ 0.713	<0.001
WHR≥1.0	1.37	2.80	98.56	0.607	0.573 ~ 0.641	0.690
WHR≥1.1	0.04	0.00	99.96	0.600	0.566 ~ 0.633	0.991
WC≥80	14.94	86.92	28.02	0.675	0.644 ~ 0.705	<0.001
WC≥90	18.39	49.84	68.54	0.692	0.658 ~ 0.726	<0.001
WC≥100	9.03	94.17	3.21	0.616	0.582 ~ 0.650	0.349

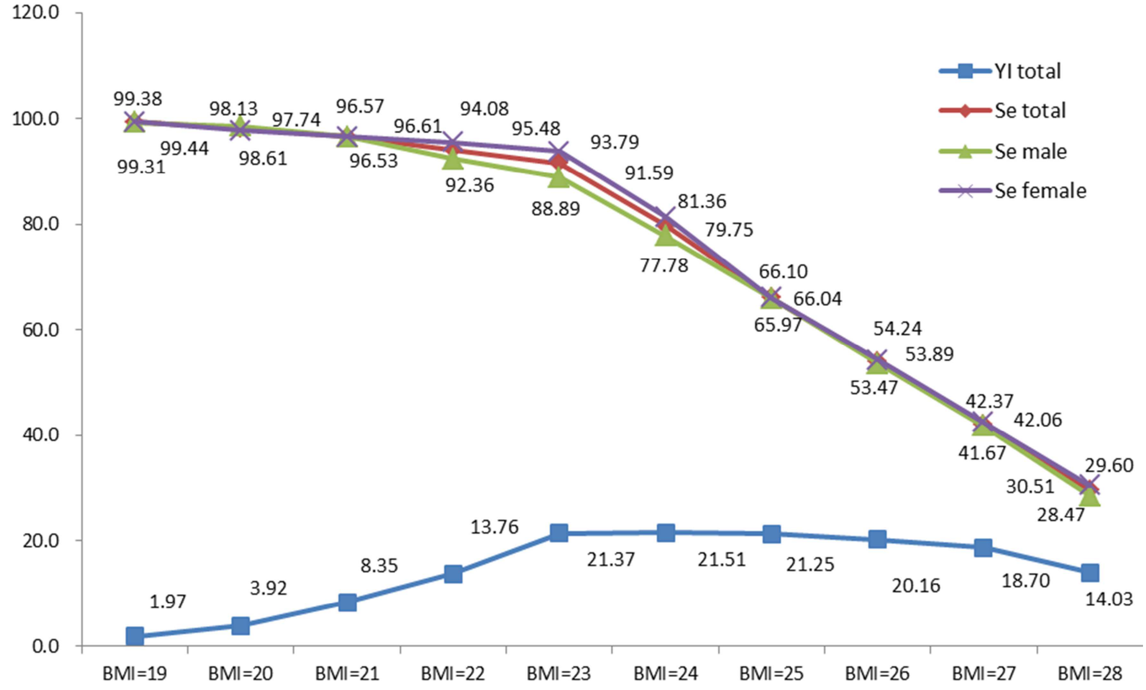

Figure 1. *The change of Se and YI of DM with BMI.*

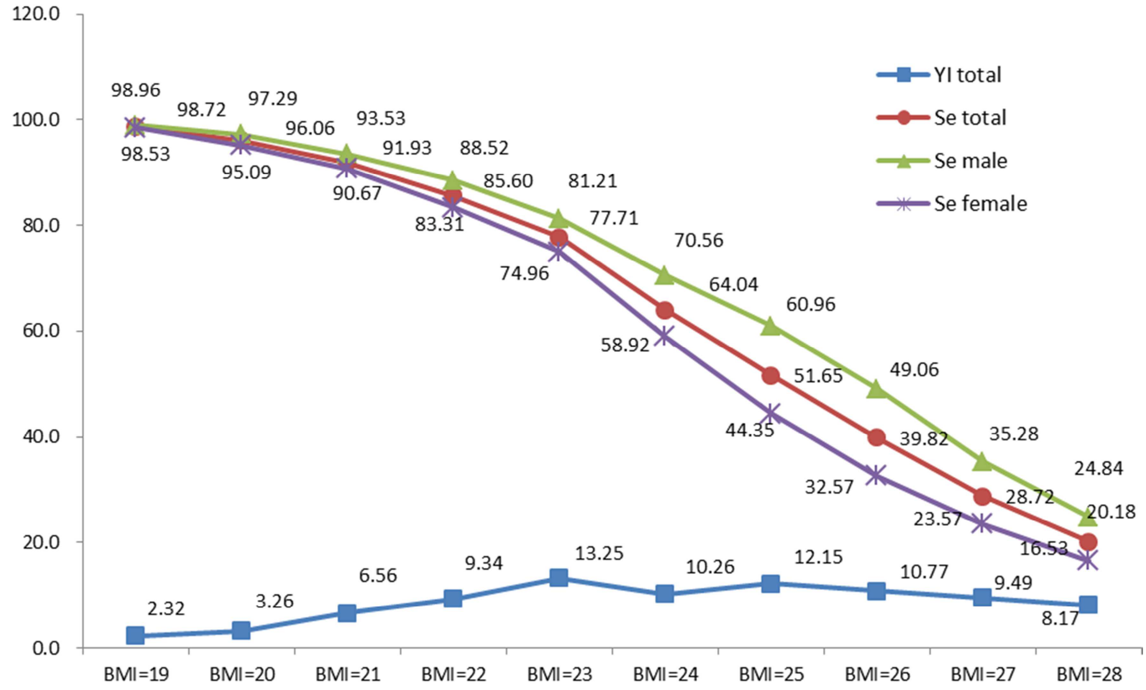

Figure 2. *The change of Se and YI of pre-DM with BMI.*

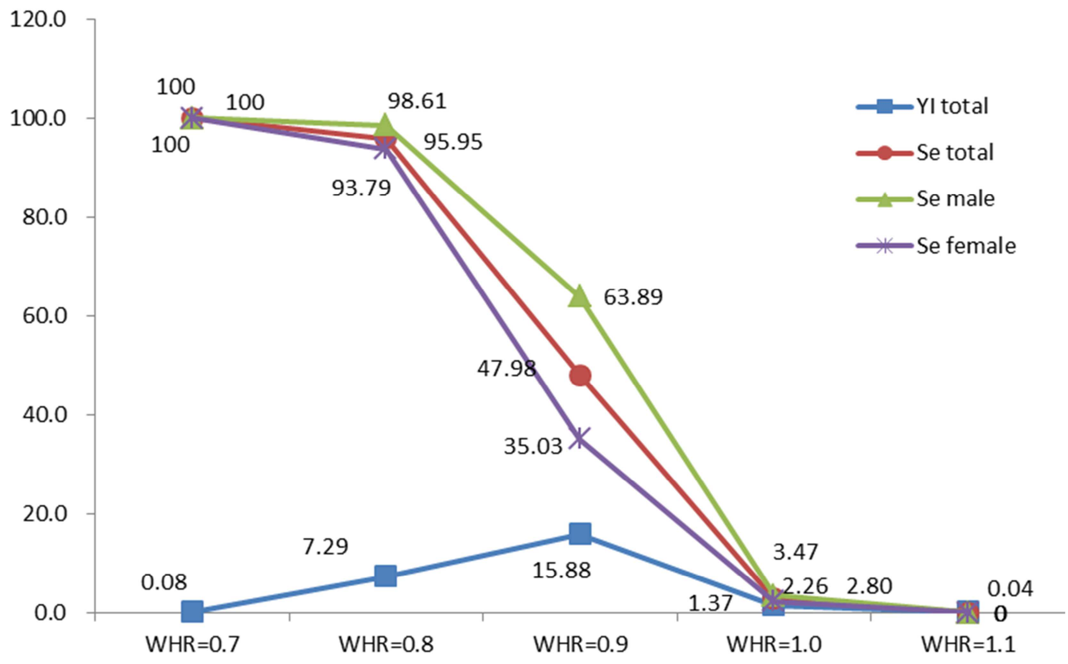

Figure 3. *The change of Se and YI of DM with WHR.*

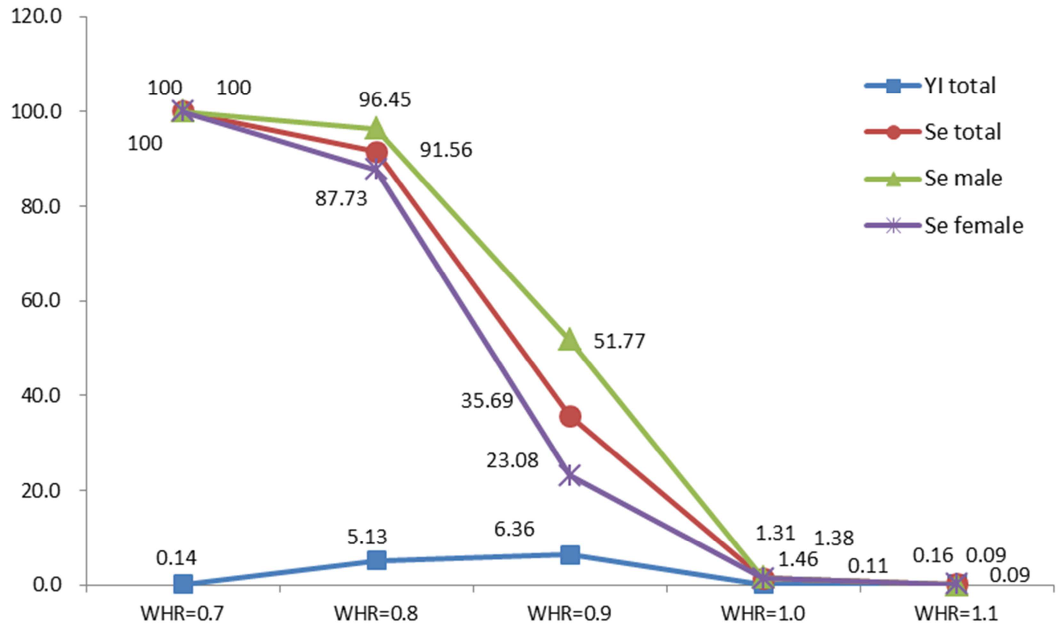

Figure 4. *The change of Se and YI of pre-DM with WHR.*

Table 4. *BMI and WHR cut-off points and screening sensitivity for pre-DM.*

	YI	Se	Sp	AUROC	95%CI	P
BMI≥19	2.32	98.72	3.60	0.612	0.589 ~ 0.634	0.319
BMI≥20	3.26	96.06	7.21	0.616	0.594 ~ 0.639	0.161
BMI≥21	6.56	91.93	14.63	0.633	0.610 ~ 0.655	0.005
BMI≥22	9.34	85.60	23.75	0.647	0.624 ~ 0.669	<0.001
BMI≥23	13.25	77.71	35.55	0.666	0.644 ~ 0.689	<0.001
BMI≥24	10.26	64.04	46.22	0.651	0.629 ~ 0.674	<0.001
BMI≥25	12.15	51.65	60.49	0.661	0.638 ~ 0.683	<0.001
BMI≥26	10.77	39.82	70.95	0.654	0.631 ~ 0.677	<0.001
BMI≥27	9.49	28.72	80.78	0.647	0.625 ~ 0.670	<0.001
BMI≥28	8.17	20.18	87.99	0.641	0.618 ~ 0.664	<0.001

	YI	Se	Sp	AUROC	95%CI	P
WHR≥0.7	0.14	100.0	0.14	0.601	0.578 ~ 0.624	0.952
WHR≥0.8	5.13	91.56	13.57	0.626	0.603 ~ 0.648	0.028
WHR≥0.9	6.36	35.69	70.67	0.632	0.609 ~ 0.655	0.006
WHR≥1.0	0.11	1.38	98.52	0.599	0.577 ~ 0.622	0.963
WHR≥1.1	0.09	0.09	100.00	0.600	0.578 ~ 0.623	0.969
WC≥80	8.52	76.79	31.73	0.643	0.620 ~ 0.665	<0.001
WC≥90	9.44	36.79	72.65	0.647	0.624 ~ 0.670	<0.001
WC≥100	8.07	95.90	3.97	0.620	0.597 ~ 0.643	0.088

3.4. WC and WHR Cut-Off Points Analysis

With the increase of WC and WHR cut-off point, the screening sensitivity (Se) for DM is decreasing; but the specificity (Sp) for DM is increasing; the YI for DM and the area under ROC (AUROC) are increasing firstly and then decreases (inflection point in WC≥90, WHR≥0.9). See table 3.

The same as above, With the increase of WC and WHR cut-off point, the screening sensitivity (Se) for pre-DM is decreasing; the specificity (Sp) for pre-DM is increasing; the YI for pre-DM and the area under ROC (AUROC) increases firstly and then decreases (inflection point in WC≥90, WHR≥0.9). See table 4.

Figure 3 shows the movement of YI and Se of sex (male, female and total) in screening for DM among different WHR cut-off points (0.7~1.1), and the movement track of Se between male and female is very similar. When WHR≥0.7, Se is in the maximum; When WHR≥1.1, Se is in the minimum. But the change of YI is different from Se, Yi is increasing firstly and then decreasing (inflection point in WHR≥0.9), the same male as female. Therefore, the results of comprehensive table 3 and figure 3 shows that WHR≥0.8 or WHR≥0.9 is the optimal cut-off point for screening DM (YI=7.29% or 15.88%, Se=95.95% or 47.98%).

Figures 4 shows the movement of YI and Se of sex (male, female and total) in screening for pre-DM among different WHR cut-off points (0.7~1.1), and the movement track of Se between male and female is very similar. When WHR≥0.7, Se is in the maximum; When WHR≥1.1, Se is in the minimum. But the change of YI is different from Se, Yi is increasing firstly and then decreasing (inflection point in WHR≥0.9), the same male as female. Therefore, the results of comprehensive table 4 and figure 4 shows that WHR≥0.8 or WHR≥0.9 is the optimal cut-off point for screening pre-DM (YI=5.13% or 6.36%, Se=91.56% or 35.69%).

3.5. Screen Efficacy Comparison

Table 5. *The single and merged efficacy of BMI and WHR in DM and pre-DM screening.*

	pre-DM						DM					
	Se	Sp	AI	AUROC	95%CI	p	Se	Sp	AI	AUROC	95%CI	p
BMI≥23	77.71	35.55	13.25	0.666	0.644~0.689	<0.001	91.59	29.78	21.37	0.707	0.678~0.736	<0.001
BMI≥24	64.04	46.22	10.26	0.651	0.629~0.674	<0.001	79.75	41.76	21.51	0.708	0.677~0.738	<0.001
WHR≥0.8	91.56	13.57	5.13	0.626	0.603~0.648	0.028	95.95	11.34	7.29	0.636	0.605~0.668	0.033
WHR≥0.9	35.69	70.67	6.36	0.632	0.609~0.655	0.006	47.98	67.90	15.88	0.679	0.645~0.713	<0.001
WC≥90	72.65	36.79	9.44	0.647	0.624~0.670	<0.001	68.54	49.84	18.39	0.692	0.658~0.726	<0.001
B23+W0.8	74.40	39.15	13.26	0.668	0.645~0.690	<0.001	88.79	33.25	22.04	0.710	0.681~0.739	<0.001
B23+W0.9	33.30	74.91	8.21	0.641	0.618~0.664	<0.001	47.35	71.34	18.69	0.693	0.659~0.728	<0.001
B24+W0.8	61.74	48.48	10.22	0.651	0.628~0.674	<0.001	78.19	44.03	22.23	0.711	0.681~0.742	<0.001
B24+W0.9	30.92	76.54	7.45	0.637	0.614~0.660	0.001	43.93	73.29	17.22	0.686	0.652~0.720	<0.001
B23+WC	48.72	63.96	12.67	0.663	0.641~0.686	<0.001	63.24	58.44	21.68	0.708	0.676~0.741	<0.001
B24+WC	45.87	66.22	12.09	0.660	0.638~0.683	<0.001	60.75	60.96	21.71	0.709	0.676~0.741	<0.001

(B23: BMI≥23; B24: BMI≥24; W0.8: WHR≥0.8; W0.9: WHR≥0.9; WC: WC≥90)

The result shows that the independent screening efficacy (judged by YI) of BMI is relatively highest in DM and pre-DM screening, WC is relatively next, and WHR is lowest (See Table 5); and the combination screening efficacy of BMI merged WHR is not significantly improved than the single screening efficacy of BMI, the same as BMI merged WC. From the combination screening efficacy of DM or pre-DM, the combination screening efficacy of BMI≥23 merged WHR≥0.8 is relatively better.

To further explore the efficacy of standard of judgment with blood glucose (FBG and OGTT) or HbA1C in screening for DM at different cut-off points of BMI (BMI≥23), WC (WC≥90 cm) and WHR (WHR≥0.9). The result shows that the screening sensitivity (Se), specificity (Sp) and YI of HbA1C are better than blood glucose (FBG and OGTT). See table 6.

Table 6. *The screening efficacy of DM in blood glucose and HbA1c.*

	FBG+OGTT						HbA1C					
	Se	Sp	AI	AUROC	95%CI	p	Se	Sp	AI	AUROC	95%CI	p
BMI≥23	80.86	35.55	16.41	0.682	0.661~0.703	<0.001	94.23	28.68	22.91	0.715	0.676~0.753	<0.001
WHR≥0.9	38.34	70.53	8.87	0.644	0.623~0.666	<0.001	51.92	67.19	19.12	0.696	0.649~0.743	<0.001
WC≥90	39.69	72.58	12.27	0.661	0.640~0.682	<0.001	56.41	67.83	24.24	0.721	0.675~0.768	<0.001
B23+W0.9	82.85	31.31	14.16	0.671	0.650~0.692	<0.001	94.23	25.38	19.61	0.698	0.658~0.738	<0.001
B23+WC	52.02	63.96	15.98	0.680	0.659~0.701	<0.001	69.87	57.55	27.42	0.737	0.694~0.780	<0.001

(B23: BMI≥23; W0.9: WHR≥0.9; WC: WC≥90)

4. Discussion

In the guidelines for the prevention and treatment of type 2 diabetes mellitus in China (2013 edition), Diabetes Sciences of Chinese Medical Association recommended BMI≥24 kg/m^2 as a criterion for judging high-risk group of diabetes[2]. American diabetes association (ADA) issued a standard for diabetes treatment that lowered the BMI cut-off point for Asian Americans screening for DM from 23 kg/m^2 to 25 kg/m^2 in 2015 [9]. Some study suggested that it was most optimal cut-off point for male and female BMI cut-off points were 23 kg/m^2 and 22 kg/m^2 respectively when screen pre-diabetes (Pre-DM) and DM in middle -aged and older adults [17-18]. In this study, the results show that the sensitivity in screening for DM is respectively 94.08%, 91.59%, 79.75% and 66.04% when BMI take 22, 23, 24 or 25; and YI is respectively 13.76%, 21.37%, 21.51% and 21.25%. And the sensitivity in screening for pre-DM is respectively 85.60%, 77.71%, 64.04% and 51.65%; YI is respectively 9.34%, 13.25%, 10.26% and 12.15%. If BMI take 23, both of the sensitivity and YI in screening DM or pre-DM are relatively better. When BMI is used as a screening indicator rather than a specific clinical diagnostic indicator, especially when further confirmatory tests are economical and convenient, not only the diagnostic accuracy is concerned, but also the ability to detect patient early (sensitivity) is emphasized. Accordingly, this study suggest that it was optimal cut-off point for male and female BMI cut-off points is 23 kg/m^2 when screening Pre-DM and DM in community for over 35 years old people.

Waist circumference (WC) is a body surface measure for evaluating central obesity. It has been recommended by the International Diabetes Federation (IDF) [19] and the Chinese Medical Association for Diabetes Sciences (CDS) [2] to determine the high risk group of diabetes. However, there are some studies have shown that WC has some limitations, for example, when the height difference was large; the evaluation efficiency is reduced [20-21]. In this study, the results show that the sensitivity in screening for DM is respectively 86.92%, 49.84% and 94.17% when BMI take 80, 90 or 100 cm; and YI is respectively 14.94%, 18.39% and 9.03%. And the sensitivity in screening for pre-DM is respectively 76.79%, 36.79% and 95.90%; YI is respectively 8.52%, 9.44% and 8.07%. this study suggest that it was optimal cut-off point for male and female WC cut-off points is 90 cm when screening Pre-DM and DM in community for over 35 years old people.

Waist-to-height ratio (WHR) reflects the degree of intra-abdominal fat accumulation and eliminates the impact of height, it is not affected by height, gender and race. It is more convenient and applicable to a wide range of people. Some researcher suggested that WHR was superior to WC in screening IGT in women, and there was little difference between men and women in the best cut-off point for screening IFG, IGT and undiagnosed diabetes mellitus [22]. In this study, the result show that the sensitivity in screening for DM is respectively 95.95% and 47.98% when WHR take 0.8 or 0.9; and YI is respectively 7.29% or 15.88%. And the sensitivity in screening for pre-DM is respectively 91.56% and 35.69%; YI is respectively 5.13% and 6.36%. If WHR take 0.8, both of the sensitivity and YI in screening DM or pre-DM are also relatively better. It was optimal cut-off point for male and female that WHR cut-off points is 0.8 when screening in community Pre-DM and DM over 35 years old people. There is not obvious difference between male and female in the best cut-off point for screening DM and pre-DM, similar to those mentioned above.

From a single indicator of DM screening efficacy comparison, BMI (YI=21.37) >WC (YI=18.39) > WHR (YI=15.88); and pre-DM screening efficacy comparison, BMI (YI=13.25) >WC (YI=9.44) > WHR (YI=6.36). Among three indicators, the screening efficacy of BMI is the best, WC is the next, and WHR is relatively lowest. Compared the combination screening efficacy of DM, the order of YI from high to low is respectively: BMI≥24 merged WHR≥0.8 (YI=22.23), BMI≥23 merged WHR≥0.8 (YI=22.04), BMI≥24 merged WC≥90 (YI=21.71), BMI≥23 merged WC≥90 (YI=21.68), BMI≥23 merged WHR≥0.9 (YI=18.69), BMI≥24 merged WHR≥0.9 (YI=17.22). Compared the combination screening efficacy of pre-DM, the order of YI from high to low is respectively: BMI≥23 merged WHR≥0.8 (YI=13.26), BMI≥23 merged WC≥90 (YI=12.67), BMI≥24 merged WC≥90 (YI=12.09), BMI≥24 merged WHR≥0.9 (YI=10.22), BMI≥23 merged WHR≥0.9 (YI=8.21), BMI≥24 merged WHR≥0.9 (YI=7.45). This result suggests, if use single indicator to screen diabetes in community, BMI is the best choice (cut-off point of BMI is 23); If use combinatorial indicators to screen diabetes in community, BMI merged WHR is the best choice (cut-off point of BMI and WHR is respectively 23 and 0.8).

Compared the efficacy of standard of judgment with blood glucose (FBG and OGTT) or HbA1C in screening for DM, the efficiency of HbA1C is higher than that of blood glucose for the same cut-off point of BMI or WHR or WC. This result suggests that using HbA1C as standard of judgment seems to be better than blood glucose in screening for DM.

5. Conclusions

This study compared the screening ability of BMI, WC and WHR at different cut points, and used the maximum of Yoden index to calculate the optimal cut point, and this method takes into account both sensitivity and specificity. The result showed that BMI≥23, WC≥90 cm or WHR≥0.8 is the optimal cut-off point for screening DM and pre-DM in people over 35 years old, and the screening efficacy of BMI is better than WC and WHR.

This study compared the screening ability of different combinations of indicators at different cut points, and found that BMI merged WHR is the best combination choice (cut-off point of BMI and WHR are respectively 23 and 0.8).

Compared the efficacy of standard of judgment with FBG, OGTT or HbA1C in screening for DM, and found that HbA1C is better than FBG and OGTT as standard of judgment in screening.

Abbreviations

BMI: body mass index; DM: diabetes; pre-DM: pre-diabetes; WC: waist circumference; HC: Hip circumference; WHR: waist to hip ratio; YI: Youden Index; Se: sensitivity ; Sp: specificity;

Ethics Approval and Consent to Participate

Ethical approval was granted by Shanghai center for disease control and prevention research ethics committee. All subjects gave verbal and written informed consent to participate in the study, they would like to participate in investigation and answer all the related questions in the questionnaire. The survey was conducted by a full-time investigator using a questionnaire and face-to-face inquiries.

Consent for Publication

Not applicable.

Availability of Data and Material

The questionnaire and database supporting the conclusions of this article are available, through contact with anle_li@aliyun.com.

Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

An-le Li is responsible for the design and implementation of the project, analysis of data and materials, and writing of manuscript; Heng-yun Li is responsible for support of project funds, seeks administrative support for projects and assists in the implementation of investigations; Fang Xiang, Yi-ying Zhang and Zhi-hao Hu participates in the project and assists in the investigation; Qin-ping Yang and Qian Peng participates in project investigation and quality control. All authors contributed to subsequent drafts and approved the final manuscript, and approved it for publication.

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