

# Optimal cut-off levels of obesity indices by different definitions of metabolic syndrome in a southeast rural Chinese population

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## Keywords

Body mass index, Metabolic syndrome, Waist-to-hip ratio

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## ABSTRACT

**Aims/Introduction:** The aim of the present study was to compare the cut-off values and prediction effect of different obesity indices by different definitions of metabolic syndrome (MetS) in Zhejiang Province of China.

**Materials and Methods:** We carried out a cross-sectional survey of 10,100 individuals (age 40 years and older) in Jiashan, Zhejiang Province. Receiver operating characteristic analysis was used to examine discrimination and find optimal cut off values of waist circumference (WC), body mass index (BMI), waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) to predict two or more non-adipose components of MetS by The National Cholesterol Education Program Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III) definition modified by the Asia–Pacific region criteria, International Diabetes Federation definition for the Chinese population and Chinese Diabetes Society definitions of MetS.

**Results:** The age-standardized prevalence of MetS was 23.78% vs 28.76% vs 19.37% by The National Cholesterol Education Program Expert Panel on Detection, Evaluation, And Treatment of High Blood Cholesterol In Adults (Adult Treatment Panel III), International Diabetes Federation and Chinese Diabetes Society definitions, respectively. Cut-off values of BMI were approximately 24 kg/m<sup>2</sup> both in men and women by three definitions; the average cut-off values of WC, WHR and WHtR were 83 cm in men vs 81 cm in women, 0.89 in men vs 0.86 in women and 0.50 in men vs 0.51 in women, respectively. The area under receiver operating characteristic curve of BMI was larger than WC both in men and women ( $P < 0.05$ ); in women, the area under receiver operating characteristic curve of WHtR was larger than WC, and WHR was smaller.

**Conclusions:** MetS is prevalent in Zhejiang Province of China, especially in the female population. BMI and WHtR might be more useful than WC and WHR for predicting two or more non-adipose components of MetS.

## INTRODUCTION

Metabolic syndrome (MetS) is the name given to a clustering of metabolic and cardiovascular risk factors that have been widely discussed for at least 20 years. Since the first official definition of MetS put forward by a working group of the World Health Organization (WHO) in 1999<sup>1</sup>, a number of different

definitions have been proposed. The most widely accepted of these definitions is the original WHO definition and alternatives proposed by the European Group for the Study of Insulin Resistance (EGIR)<sup>2</sup>, and the US National Cholesterol Education Program Adult Treatment Panel III (NCEA-ATPIII)<sup>3</sup>. In 1999, the WHO definition included a measure of obesity and defined obesity in terms of either body mass index (BMI) or waist-to-hip ratio (WHR). The EGIR (1999) and ATPIII (2001)

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definitions also introduced waist circumference (WC) as a measurement of adiposity. The Chinese Diabetes Society (CDS) also introduced a MetS definition in 2004, and it defined BMI as a measurement of obesity<sup>4</sup>. The latest definition is the one of the International Diabetes Federation (IDF), which takes into account evidence that abdominal obesity is an important component of MetS<sup>5</sup>, and proposed WC as an indication of abdominal obesity<sup>6,7</sup>.

Various alternative methods of the indices of obesity, such as WC, BMI, WHR and waist-to-height ratio (WHtR), have been proposed, but their role in defining MetS has not been fully evaluated. The aim of the present study was to carry out a comparative validation of WC, BMI, WHR and WHtR for defining MetS under different definitions in a Chinese population aged 40 years and older in the southeast of China. We used the ATP III, IDF and CDS definitions of MetS, excluding the measure of obesity, to evaluate which of the WC, BMI, WHR and WHtR obesity measures, and an appropriate cut-off, is most closely predictive of the non-adipose components of each MetS definition.

## METHODS

### Study population

The present study was a community-based, cross-sectional survey that was funded by the Chinese Society of Endocrinology (CSE), and carried out during March to September of 2011 in Jiashan of Zhejiang, China. A total of 10,100 participants aged 40 years and older were selected by the cluster random sample method. The procedure of the study was designed by Ruijin Hospital, Shanghai Jiaotong University School of Medicine, and approved by the ethics committee. Written informed consent was obtained from all participants.

We excluded 21 observations, because data were missing for fasting glycemia, 2-h glycemia or glycated hemoglobin. The final sample size was 10,079.

### Data collection

Trained investigators completed questionnaires, measured anthropometric variables including height, weight, WC and hip circumference (HC), and carried out the oral glucose tolerance test (OGTT). The questionnaires included questions related to the diagnosis and treatment of diabetes. If participants had a history of diabetes or were taking drugs to treat diabetes, 75-g oral dextrose tests were carried out. If not, an OGTT was carried out to diagnose diabetes.

### Anthropometric measurements

Anthropometric measurements included height, weight, WC and HC. BMI was calculated as weight (kg) divided by height squared (m<sup>2</sup>). WHtR was calculated as height (cm) divided by WC (cm). WHR was calculated as HC (cm) divided by WC (cm). Two nurses completed each of these measurements; one took the measurements, the other recording the readings. Height was measured to the nearest 0.1 cm with an Iowa Height Board,

and weight to the nearest 0.1 kg using a balance beam metric scale. No adjustments were made for the weight of the gown, underwear or socks that were worn during the examination. Circumferences were measured using a non-stretchable tape. WC was measured midway between the inferior margin of the last rib and the crest of the ileum in a horizontal plane, and HC was measured at the greater trochanters.

### OGTT

After an overnight fasting for at least 10 h, a standard 75-g glucose solution was given, and venous blood samples were drawn at 0 min and 120 min (2 h) to identify diabetes and prediabetes (impaired glucose tolerance and/or impaired fasting glucose). Venous blood samples collected from the antecubital vein were put into vacuum tubes containing sodium fluoride in 4°C ice boxes and were analyzed within 3 h. Plasma glucose was measured using the glucose oxidase method, and serum lipids were measured using an automated biochemical instrument (Beckman CX-7 Biochemical Autoanalyzer; Beckman, Brea, CA, USA).

### Blood pressure measurements

Physicians carried out blood pressure measurements using an American Heart Association protocol<sup>1</sup>. After 5 min of rest in a sitting position, systolic and diastolic pressures were measured from the participant's right arm using a standard mercury sphygmomanometer. Two successive measurements were carried out with at least 1-min interval in between. The mean measurements were put in the records.

### Diagnostic criteria

According to the modified ATP III definition for MetS<sup>3</sup>, patients must be diagnosed as having at least three of the following five factors: (i) obesity (defined as WC  $\geq 90$  cm in men or  $\geq 80$  cm in women in the Asia-Pacific region); (ii) triglycerides  $\geq 1.7$  mmol/L (150 mg/dL); (iii) high density lipoprotein (HDL)  $\leq 1.03$  mmol/L (40 mg/dL) in men or  $\leq 1.29$  mmol/L in women; (iv) systolic blood pressure (SBP)  $\geq 130$  mm Hg, or diastolic blood pressure (DBP)  $\geq 85$  mmHg; and (v) fasting plasma glucose  $\geq 5.6$  mmol/L (100 mg/dL). According to the new IDF definition<sup>8</sup> for the Chinese population, for a person to be defined as having MetS, he/she must be diagnosed as having central obesity (defined as WC  $\geq 90$  cm in men or  $\geq 80$  cm in women) plus any two of the following four factors: (i) triglycerides  $\geq 1.7$  mmol/L (150 mg/dL), or specific treatment for this lipid abnormality; (ii) HDL  $\leq 1.03$  mmol/L (40 mg/dL) in men or  $\leq 1.29$  mmol/L in women, or specific treatment for this lipid abnormality; (iii) SBP  $\geq 130$  mmHg or DBP  $\geq 85$  mmHg, or treatment for previously diagnosed hypertension; and (iv) fasting plasma glucose  $\geq 5.6$  mmol/L (100 mg/dL) or previously diagnosed type 2 diabetes<sup>2</sup>. According to the CDS definition for MetS, patients must be diagnosed as having at least three of the following four factors: (i) BMI  $\geq 25.0$  kg/m<sup>2</sup>; (ii) fasting plasma glucose  $\geq 6.1$  mmol/L, 2-h post-loading plasma glucose

≥7.8 mmol/L or previously diagnosed type 2 diabetes; (iii) SBP ≥140 mmHg or DBP ≥90 mmHg, or treatment for previously diagnosed hypertension; (iv) triglycerides ≥1.7 mmol/L or HDL ≤0.9 mmol/L in men or ≤1.0 mmol/L in women<sup>9</sup>.

### Statistical analysis

Descriptive analysis was used to show distributive features of the study population. Continuous variables are presented as 'mean (standard deviation),' categorical variables are given as 'point estimate (95% confidence interval).' Intersex and inter-subgroup differences were examined by *t*-test or  $\chi^2$ -test, as appropriate to variables.

To obtain the optimal cut-off point for WC, BMI and WHR in predicting the presence of two or more risk factors for MetS (excluding WC to avoid self-correlation), we chose the point on the receiver operating characteristic (ROC) curve that represented the largest sum of sensitivity and specificity<sup>10</sup>, or equivalently, of the Youden index: sensitivity + specificity – 1. The area under the ROC curve (AUC) was used as a general measure of discrimination of a predictor. To assess whether the difference in the areas under two ROC curves is of statistical significance, we used the *Z*-test described in basic principles of ROC analysis<sup>11</sup>.

All analyses were carried out separately for men and women. The level for statistical significance was set at 0.05 (two-sided). The Statistical Analysis System, version 9.2 (SAS Institute Inc., Raleigh, NC, USA) was used for all statistical analyses.

## RESULTS

### Study population characteristics

The mean age of the study population was 52.9 ± 8.1 years. Participants aged >60 years made up 19.08% of the study population. Compared with women, men had a significantly higher height, weight, WC, WHR, SBP and DBP, and FPG and TG

concentration, but smaller WHtR, lower 2-h post-loading plasma glucose, total cholesterol and HDL cholesterol concentrations (*P* < 0.05 for all comparisons; Table 1).

### Prevalence of different definitions of mets and the components

Based on different criteria, the prevalence of MetS in the study population was 22.36%, 28.53% and 18.67% (23.78%, 28.76% and 19.37% adjusted for age), respectively, for ATPIII, IDF and CDS. For almost all age groups, the prevalence of MetS was significantly higher in women than in men according to the ATPIII and IDF definitions, and showed no difference between men and women according to the CDS criteria. The components could be classified into four groups (Table 2). In group 1, ATPIII and IDF had the same definitions for obesity. The prevalence showed no significant difference between ATPIII/IDF and CDS ( $\chi^2 = 0.8035$ , *P* = 0.3701). There were more women diagnosed with obesity (central obesity) than men under the ATPIII and IDF criteria. However, except for CDS, there was no significant difference found by sex. In groups 2–4, there was no significant difference between ATPIII and IDF criteria, because the two definitions have the same cut-offs, but the participants diagnosed and treated were included. Compared with ATPIII and IDF criteria, the prevalence under the CDS definition was much lower in groups 2–4. The prevalence of low HDL cholesterol levels in women were higher than men, whereas high fasting glucose and hypertriglyceride prevalence were much lower in women.

### Optimal cut-off levels of obesity indices for three MetS definitions

The AUCs, cut-off points, sensitivity, and specificity of BMI, WC, WHR and WHtR in different definitions of MetS by sex are presented in Table 3 for comparison. Because WC and

**Table 1** | Mean levels of various characteristics by sex

Variables	Men ( <i>n</i> = 4,194)	Women ( <i>n</i> = 5,885)	<i>t</i>	<i>P</i>
Age (years)	53.22 ± 8.04	52.6 ± 8.11	3.75	0.0002
Weight (kg)	67.18 ± 9.93	58.98 ± 8.79	42.79	<0.0001
Height (cm)	166.23 ± 6.26	155.74 ± 5.73	85.81	<0.0001
BMI (kg/m <sup>2</sup> )	24.31 ± 3.93	24.32 ± 3.86	0.13	0.8998
Waist circumference (cm)	82.84 ± 9.23	79.95 ± 8.7	15.86	<0.0001
Hip circumference (cm)	93.2 ± 6.51	93.16 ± 6.59	0.33	0.7397
WHR	0.89 ± 0.07	0.86 ± 0.06	22.77	<0.0001
WHtR	0.50 ± 0.06	0.51 ± 0.06	12.89	<0.0001
Systolic blood pressure (mmHg)	129.29 ± 18.04	128.15 ± 18.74	3.09	0.002
Diastolic blood pressure (mmHg)	79.35 ± 10.38	77.36 ± 9.85	9.71	<0.0001
FPG (mmol/L)	5.97 ± 1.48	5.83 ± 1.35	4.62	<0.0001
2hPPG (mmol/L)	7.46 ± 3.43	7.87 ± 3.17	6.16	<0.0001
Total cholesterol	4.25 ± 1.03	4.33 ± 1.01	3.65	0.0003
Triglycerides	1.68 ± 1.44	1.51 ± 1.1	6.18	<0.0001
HDL-C	1.17 ± 0.32	1.23 ± 0.3	9.64	<0.0001

Normal data are given as the mean ± standard deviation; skewed data are given as the geometric mean with 95% confidence intervals in parentheses. 2hPPG, 2-h post-loading plasma glucose; BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; SBP, systolic blood pressure; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

**Table 2** | Prevalence of components of metabolic syndrome in men and women

	Male	Female	Total	$\chi^2$	P
Group 1:					
Central obesity (ATPIII and IDF)	966 (23.03)	2,970 (50.47)	3,936 (39.05)	774.3677	<0.0001
BMI $\geq 25$ kg/m <sup>2</sup> (CDS)	1,619 (38.60)	2,255 (38.32)	3,874 (38.44)	0.0841	0.7719
Group 2:					
Hypertriglyceride (ATPIII)	1,345 (32.07)	1,616 (27.46)	2,961 (29.38)	25.0838	<0.0001
Low HDL-C (ATPIII)	1,480 (35.29)	3,512 (59.68)	4,992 (49.53)	582.6813	<0.0001
Hypertriglyceride or under treatment (IDF)	1,364 (32.52)	1,642 (27.90)	3,006 (29.82)	24.9868	<0.0001
Low HDL-C or under treatment (IDF)	1,506 (35.91)	3,533 (60.03)	5,039 (50.00)	570.1271	<0.0001
Dyslipidemia (CDS)	1,817 (43.32)	2,431 (41.31)	4,248 (42.15)	4.0793	0.0434
Group 3:					
High fasting glucose (ATPIII)	2,107 (50.24)	2,650 (45.03)	4,757 (47.20)	26.6589	<0.0001
High fasting glucose or under treatment (IDF)	2,130 (50.79)	2,682 (45.57)	4,812 (47.74)	26.6770	<0.0001
High blood glucose or under treatment (CDS)	1,682 (40.10)	2,448 (41.60)	4,130 (40.98)	2.2550	0.1332
Group 4:					
High blood pressure (ATPIII)	2,068 (49.31)	2,738 (46.53)	4,806 (47.68)	7.6054	0.0058
High blood pressure or under treatment (IDF)	2,292 (54.65)	3,002 (51.01)	5,294 (52.53)	13.0005	0.0003
High blood pressure or under treatment (CDS)	1,721 (41.03)	2,238 (38.03)	3,959 (39.28)	9.2771	0.0023
Metabolic syndrome					
Defined by ATPIII	632 (15.07)	1,622 (27.56)	2,254 (22.36)	220.1149	<0.0001
Defined by IDF	754 (17.98)	2,122 (36.06)	2,876 (28.53)	392.5301	<0.0001
Defined by CDS	772 (18.41)	1,110 (18.86)	1,882 (18.67)	0.3328	0.564

Data show the number of participants in each group, with percentages given in parentheses. ATPIII, National Cholesterol Education Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults with definition for Asia-Pacific region; BMI, body mass index; CDS, Chinese Diabetes Society; IDF, International Diabetes Federation.

BMI are the key factors for ATPIII, IDF and CDS, respectively, we set them as the references by different definitions, respectively. In the ATPIII definition, the AUC of BMI was significantly larger than WC in both the men and women, AUC of WHR and WHtR in women were larger and smaller than WC, respectively. In the IDF definition, AUC of BMI in men and WHtR in women were larger than WC, and WHR in women was smaller than the reference. In the CDS definition, only AUC of WC and WHR in men were smaller than BMI, and the other indices had no significant difference with the reference.

Under three different definitions, there was a very small variation found in men and women for the cut-off points of BMI (range 23.7–23.9). In contrast, the cut-off points of the other obesity indices had relatively significant sex differences, and cut-off levels of those indices for men were higher than women, except for WHtR.

## DISCUSSION

There has been a rapid urbanization in China during the past two decades. The transition to urbanized lifestyles, especially in terms of dietary habits, have inevitably led to an increase in the prevalence of obesity-related diseases, such as diabetes, hypertension and MetS. A cross-sectional survey carried out in 2005 in east China showed that 12.7% of men and 10.1% of women in an urban area, compared with 1.7% of men and 9.7% of women in a rural area, had MetS<sup>12</sup>. Another survey carried out

in 2010 in Zhejiang Province of China showed that the prevalence of MetS was 21.48% (18.03% for men and 25.13% for women), defined by modified ATPIII criteria<sup>13</sup>. In the present study, the prevalence in men (15.07%) was lower than the average level of the whole province, but prevalence in women (27.56%) was higher using the same criteria, and they were both higher than the prevalence reported from Qingpu, Shanghai<sup>14</sup>. According to the IDF definition, the prevalence in women (36.06%) was much higher than the research carried out in Taiwan<sup>15</sup>. However, the situation is complicated by there being many criteria for the diagnosis of MetS, which always creates difficulties in comparisons with different definitions. The major difference between definitions is the measures for obesity and their cut-off value. The present study evaluated and compared the extent to which four body stature measures, WC, BMI, WHR and WHtR, are able to predict two or more non-adipose components (without WC or BMI) of MetS when defined by the ATPIII, IDF and CDS definitions, respectively.

The study was a community-based, cross-sectional survey with a large Chinese population. We used ROC analysis to address the issue of predictive ability. BMI and WC are two commonly accepted anthropometric indices for predicting MetS. Our main finding was that BMI is the best indicator to discriminate MetS, with an optimal cut-off of 24 kg/m<sup>2</sup> for both women and men, which is lower than the guidelines provided by WHO<sup>16</sup>. Nguyen *et al.*<sup>17</sup> found that optimal BMI cut-offs were 23–24, 21–22.5, and 20.5–21 for Chinese, Indonesian

**Table 3** | Areas under the receiver operating characteristic curve, 95% confidence interval, optimal cut-off value, sensitivity, specificity, and Youdon Index of body mass index, waist circumference, waist-to-hip ratio and waist-to-height ratio associated with different definitions of metabolic syndrome by sex

	Men						Women					
	AUC	95% CI	Z-score	Cut-off point	Sensitivity	Specificity	AUC	95% CI	Z-score	Cut-off point	Sensitivity	Specificity
ATPIII												
WC	0.645	0.627–0.662	Ref	84	0.583	0.63	0.639	0.625–0.654	Ref	80.2	0.596	0.612
BMI	0.674	0.657–0.691	4.009**	23.7	0.741	0.524	0.652	0.638–0.667	2.193*	23.8	0.683	0.549
WHR	0.633	0.615–0.650	1.706	0.875	0.727	0.469	0.627	0.613–0.642	2.421*	0.867	0.543	0.65
WHtR	0.649	0.631–0.666	1.064	0.493	0.689	0.532	0.647	0.632–0.661	2.808**	0.506	0.679	0.545
IDF												
WC	0.696	0.680–0.712	Ref	83	0.605	0.692	0.666	0.652–0.680	Ref	81	0.521	0.735
BMI	0.715	0.699–0.731	2.874**	23.9	0.666	0.663	0.676	0.662–0.690	1.735	23.8	0.649	0.616
WHR	0.691	0.675–0.707	0.779	0.883	0.657	0.631	0.65	0.636–0.665	3.316**	0.856	0.598	0.632
WHtR	0.702	0.686–0.718	1.758	0.493	0.67	0.641	0.673	0.659–0.687	2.532*	0.511	0.612	0.655
CDS												
BMI	0.677	0.660–0.694	Ref	23.8	0.737	0.535	0.663	0.648–0.678	Ref	23.9	0.691	0.549
WC	0.652	0.634–0.670	3.375**	82	0.725	0.504	0.653	0.638–0.668	1.6	81	0.576	0.651
WHR	0.644	0.626–0.662	3.366**	0.897	0.594	0.621	0.654	0.639–0.669	1.075	0.864	0.61	0.627
WHtR	0.666	0.648–0.684	1.951	0.502	0.646	0.605	0.668	0.653–0.683	0.955	0.527	0.572	0.684

All areas under the receiver operating characteristic curve were statistically significant. \* $P < 0.05$ ; \*\* $P < 0.01$ . ATPIII, US National Cholesterol Education Program Adult Treatment Panel III; AUC, area under receiver operating characteristic curve; BMI, body mass index; CDS, Chinese Diabetes Society; CI, confidence interval; IDF, International Diabetes Federation; ROC, receiver operating characteristic; WC, waist circumference; WHR, waist-to-hip ratio; WHtR, waist-to-height ratio.

and Vietnamese adults, respectively. Another study, carried out using data obtained from more than 220,000 urban adults from mainland China, showed that the optimal cut-off values to discriminating cardiovascular disease risk factors for men and women were approximately 24.0 and 23.0 kg/m<sup>2</sup> for BMI, 85.0 and 75.0 cm for WC, and 0.50 and 0.48 for WHtR, respectively<sup>18</sup>. Thus, the appropriate BMI cut-off values to detect the presence of multiple metabolic risk factors in the Chinese population might be lower than 25 kg/m<sup>2</sup>. The results of the present study were consistent with those results.

A study in a Korean population suggested that the optimal WC values were 84–86 cm for men and 78–80 cm for women to detect multiple cardiovascular risk factors<sup>19</sup>. Ko *et al.*<sup>20</sup> determined that in a Chinese population, WC of 84.6 cm in men and 75.7 cm in women were the optimal cut-off values to predict high mesenteric fat thickness with ROC analysis. The appropriate cut-off values of WC in our study were similar to those of these previous studies.

There is a controversial issue of whether specific values measuring central fat distribution more accurately indicate health risk than BMI or WC<sup>21–23</sup>. Although some studies report that WHR identifies patients with abdominal obesity, we believe WC might be a more practical measure of abdominal fat mass and total body fat, and is more closely correlated with abdominal adipose tissue than WHR. Yang *et al.*<sup>24</sup> reported that the AUC of WC and BMI for obesity were high in both sexes and

subjects aged 20–45 years, and those of WHR were a little lower in the central south of China. According to the results of the present study, we consider that WHR in both sexes is a much weaker predictor; our optimal cut-offs (0.89 in men, 0.86 in women) are close to those suggested by the WHO and close to Yang *et al.* (0.86 in men and 0.79 in women)<sup>24</sup>.

WHtR has received considerable interest, and the results suggest keeping one's waist to less than half one's height<sup>25–27</sup>. A Chinese study reported that waist-to-stature ratio (or saying WHtR) is the best simple anthropometric indicator in predicting a wide range of cardiovascular risk factors and related health conditions. The optimal waist-to-stature ratio cut-off value was 0.48 for both men and women<sup>27</sup>. In the present analyses, WHtR cut-off values were 0.50 and 0.52 in men and women, respectively. We found that it is probably that WHtR is a better predictor than WC in women, but for men WHtR and WC have the same predictive ability. There were some studies that found WHtR to be a better indicator to reflect intra-abdominal fat distribution than BMI<sup>28, 29</sup>.

There were some limitations to the present study. First, the study was a cross-sectional study carried out in a population aged 40 years and older, and children and young people were excluded from the study. The results and interpretation of WHR and WHtR for MetS prediction requires further validation in prospective studies. Second, the accuracy of anthropometric variables as indicators of multiple metabolic risk was not

high. Swets<sup>30</sup> suggested that  $0.5 < \text{AUC} < 0.7$  indicates that the diagnostic is less accurate. Further studies are required to evaluate the association between these four values and future occurrence of cardiovascular events to define their appropriate cut-off values in a Chinese population.

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## DISCLOSURE

The authors declare no conflict of interest.

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