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The Factors Responsible for and Solution Strategies to Inconsistencies in Waist Circumference Cut-Off Values for Metabolic Syndrome Screening Established by the International Diabetes Federation and the Japanese Committee

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Abstract

Aim: Waist circumference (WC) cut-off values (WC-COVs) for metabolic syndrome (MetS) screening established by the International Diabetes Federation (IDF-Criteria; men/women 90/80 cm) and Japanese Committee (Japanese-Criteria; 85/90 cm) are inconsistent (the WC issue). The factors responsible for the issue were identified and solution strategies to it were developed.

Methods: According to the two sets of criteria, WC was measured midway between the ribs and iliac crest (MWC) and also at the umbilical level (UWC) in 739 Japanese (381 men and 358 women) subjects aged 40–65 years.

Results: Both WC measurements correlated with various metabolic factors, body mass index (BMI), and with each other. The WC-COVs in IDF- and Japanese-Criteria corresponded to BMI values of 25.8 and 23.8 kg/m^2, inconsistently in men and 24.6 and 25.1 kg/m^2 consistently in women, respectively. Sets of WC values corresponding to BMI values of 25.0 and 24.0 kg/m^2 were established as the loosest and most severe sets of WC-COVs for IDF- and Japanese-Criteria and designated as Combination A (MWC; men/women 87.6/81.1 cm UWC; men/women 88.9/89.9 cm) and B (84.3, 78.1, 85.7, 86.1 cm). Lin's concordance correlation coefficients for the MWC/UWC correlations were 0.9621 and 0.6584 in men and women, respectively.

Conclusion: The acceptances of MWC and UWC by IDF- and Japanese-Criteria, respectively, should be one of the basis of the WC issue. In men, this issue was not resolved despite of coordinating this basis; however, the substantial agreement between MWC and UWC measurements estimated by Lin's concordance correlation coefficients warrants the construction of ideal sets of WC-COVs, whose levels may be set between those of Combinations A and B. In women, coordinating the basis apparently resolve this issue; however, further solutions may be required due to the poor agreement between MWC and UMC measurements.

Keywords: Metabolic Syndrome; Waist Circumference; International Diabetes Federation; Japanese; Umbilical Line; Lin's Concordance Correlation Coefficients

Abbreviations

IDF: International Diabetes Federation;

MetS: Metabolic Syndrome;

COV: Cut-off Value;

WC: Waist Circumference;

RI: Reference Interval;

MWC: Waist Circumference Measured at the Intermediate Point Between the Lowest Border of the Ribs and Iliac Crest;

UWC: Waist Circumference Measured at the Umbilical Line

Introduction

Waist circumference (WC) is reported as an important parameter for the clinical diagnosis of metabolic syndrome (MetS) [1]. The International Diabetes Federation (IDF) has proposed cut-off values (COVs) for this parameter in MetS screening in various areas worldwide [2]. The values recommended for Asians including Japanese are 90 and 80 cm for men and women, respectively (IDF-Criteria). WC-COVs have also been independently established by the Japanese Committee, but differ from IDF-Criteria (85 cm and 90 cm for men and women, respectively; Japanese-Criteria) [3]. These discrepancies, referred to as 'the WC issue' in the present study, has not yet been resolved.

Four points are internationally recognized for WC measurements: (i) WC measured immediately below the lowest rib (WC1); (ii) at the narrowest point (WC2); (iii) at the intermediate point between the lowest border of the ribs and iliac crest (WC3); and (iv) immediately above the iliac crest (WC4). Measurements at WC2 and WC3 are supported by the Anthropometric Standardization Reference Manual (ASRM) and World Health Organization (WHO), respectively, whereas the use of WC4 is supported by the National Institutes of Health (NIH) and National Health and Nutrition Examination Survey (NHANES) [4]. In terms of WC measurements, IDF-Criteria have adopted WC3, tentatively named MWC in the present study, whereas the Japanese-Criteria have adopted that measured at the umbilical line, referred to as UWC in the present study. Although an international definition has not yet been established for UWC, its measurement point is close to WC4 [5]. In previous debates on the WC issue, insufficient attention was paid to the fact that the points of WC measurements used in the two sets of criteria were different from each other. The first aim of the present study was to identify the factors responsible for these inconsistencies while considering the differences in their WC definitions.

Since WC is measured as MWC and UWC in IDF- and Japanese-Criteria, respectively, we recently estimated reference interval (RI)-based COVs for both measurements, specifically, the upper limits of the normal ranges of MWC and UWC. In subjects aged between 40 and 65 years old, the values for MWC were determined as 84.6 and 78.4 cm (practically 85 and 78 cm) for men and women, respectively, whereas those for UWC were 86.4 and 87.9 cm (practically 86 and 88 cm), respectively [6,7]. Values other than MWC for men were practically consistent with the current WC-COVs in IDF- and Japanese-Criteria, respectively, suggesting that the WC issue could be mainly attributed to inconsistencies in the current WC-COVs for men in the two sets of criteria but not in those for women. In the present study, this view was validated.

Furthermore, several sets of COVs were constructed for MetS screening comprising consistent MWC and UWC values from relationships between MWC and BMI, or UWC and BMI yielded in the present study. In addition, the relationships between MWC and UWC were examined in more detail and the validities of the newly designed WC-COVs were investigated.

Methods

The present study is an extension of our previous study [7] and was approved by the Research Committee of the School of Medicine, Keio University, in 2009 (approval no. 2009–95) and conformed to the ethical principles of the World Medical Association's Declaration of Helsinki, as revised in 1983.

Subjects

The database created in our previous study [7], which contained information on 2622 men and 2712 women aged between 20 and 65 years old who were undergoing health examinations in our office, was used. Individuals who were smokers, consumed excessive amounts of alcohol (> 20 g/day ethanol), were pregnant, or had a disease other than MetS were excluded from the study. More specific inclusion and exclusion criteria are shown in our previous study [6]. The present study selectively evaluated data for subjects between 40 and 65 years of age. The final numbers of subjects were 381 men and 358 women.

Measurements

Height, weight, UWC, and MWC were measured in all subjects. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2). An automatic sphygmomanometer (Colin Medical Technology, Tokyo, Japan) was used to determine systolic and diastolic blood pressures (SBP and DBP, respectively) in each subject. In addition, fasting (< 10 h) blood samples were collected from each subject for the determination of triglycerides (TG), high-density lipoprotein–cholesterol (HDL-C), and fasting plasma glucose (FPG) levels. The relationships among these factors were examined.

Agreements in judgements of excessive WC based on MWC and UWC measurements.

The MWC and UWC levels of each subject were determined to be excessive or not based on their tentative WC-COVs established in the present study. Agreement rates in these judgements according to two measurements were determined in both genders.

Statistical analyses

All data were expressed as either median values with ranges or as means with standard deviations. Regressions between two factors were examined using a single regression analysis. Some correlations were further evaluated by drawing Bland-Altman plots [8] and by determining their Pearson's correlation coefficients and Lin's concordance correlation coefficients [9]. Regressions between multiple factors were examined using multiple regression analyses and strengths of correlations between a factor and multiple factors were judged by multiple correlation coefficients assigned to their regressions. Statistical analyses were performed using StatView (ver. 5.0; SAS Institute, Cary, NC, USA) or MedCalc (ver 15.4; MedCalc Software bvba, Ostend, Belguim) on personal computers (Inspiron 1300; Dell Japan, Kawasaki, Kanagawa, Japan or LIFEBOOK A574/H, FUJITSU LIMITED, Tokyo, Japan).

Results

Subjects' characteristics

The characteristics of all subjects in the present study were shown in Table 1.

Table 1. Subject characteristics.

	Men	Women
n	381	358
Age (years)	48 (40-65)	48 (40-65)
Weight (kg)	66.9 (45.3–115.3)	52.1 (37.5–94.5)
BMI (kg/m^2)	23.1 (16.6–41.2)	22.2 (14.7–37.9)
UWC (cm)	83 (63–120)	78 (59–115)
MWC (cm)	82 (62–122)	69 (52–103)
SBP (mmHg)	126 (80–192)	117 (83–191)
DBP (mmHg)	80 (53–119)	71 (40–114)
TG (mg/dL)	96 (36–669)	68 (29–338)
HDL-C (mg/mL)	55 (27–107)	68 (27–132)
FPG (mg/mL)	95 (72–383)	93 (48–172)

Data are median values, with the range given in parentheses.
BMI, body mass index; UWC, waist circumference measured at the umbilical line; MWC, waist circumference measured midway between the inferior margin of the ribs and the superior border of the iliac crest; SBP, systolic blood pressure; DBP, blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein–cholesterol; FPG, fasting plasma glucose.

Relationships between various metabolic factors including BMI and MWC or UWC

MWC and UWC both correlated with various metabolic factors, namely SBP, DBP, HDL-C, FPG, and TG. Correlation coefficients assigned regressions between UWC and these metabolic factors were similar to those for MWC (Table 2). The relationships between MWC or UWC and four metabolic factors; SBP, HDLC, FPG, and TG, were examined by multiple regression analyses in both genders. According to the multiple correlation coefficients assigned to the regressions, UWC and MWC were both judged to correlate well with these factors in both genders (Table 2).

Table 2. Relationship between various metabolic factors and either waist circumference measured midway between the inferior margin of the ribs and the superior border of the iliac crest (MWC) or waist circumference measured at the umbilical line (UWC) in both genders.

	Men		Women	
	MWC (n=381)	UWC (n=358)	MWC (n=381)	UWC (n=358)
SBP	0.297 (< 0.0001)	0.301 (< 0.0001)	0.340 (< 0.0001)	0.287 (< 0.0001)
DBP	0.296 (< 0.0001)	0.316 (< 0.0001)	0.326 (< 0.0001)	0.263 (< 0.0001)
TG	0.347 (0.0059)	0.363 (< 0.0001)	0.501 (< 0.0001)	0.439 (< 0.0001)
HDL-C	0.389 (< 0.0001)	0.376 (< 0.0001)	0.433(< 0.0001)	0.395 (< 0.0001)
FPG	0.192 (0.0002)	0.209 (0.0226)	0.238 (< 0.0001)	0.198 (0.0002)
Versus SBP, TG, HDL-C, FPG	0.509*	0.503*	0.612*	0.539*

Data show correlation coefficients with P-values given in parentheses.

*; Multiple correlation coefficients examined correlations between four metabolic factors and MWC or UWC by multiple regression analyses.

MWC; waist circumference measured midway between the inferior margin of the ribs and the superior border of the iliac crest, UWC; waist circumference measured at the umbilical line, SBP; systolic blood pressure, TG; triglycerides, HDL-C; high-density lipoprotein–cholesterol, FPG; fasting plasma glucose.

MWC and UWC both correlated with BMI, with satisfactory correlation coefficient levels in both genders. These regressions (MWC/BMI in men; Fig 1-a, MWC/BMI in women; Fig 1-b, UWC/BMI in men; Fig 2-a, and UWC/BMI in women; Fig 2-b) were tentatively designated as Regressions 1-4, respectively, in the present study.

Relationships between MWC and UWC

MWC and UWC strongly correlated with each other (Fig. 3) in men (a) as well as in women (b) with satisfactory correlation coefficients. These regressions were tentatively designated as Regressions 5 and 6 in the present study.

In the equation assigned Regression 5 (the male study), a UWC value of 85.0 cm (the current WC cut-off value for men in Japanese-Criteria) corresponded to a MWC value of 83.8 cm, which was markedly different from the current WC-COV for men in

IDF-Criteria (90.0 cm). In the same equation, a MWC value of 90.0 cm (the current WC-COV for men in IDF-Criteria) corresponded to a UWC value of 91.1 cm, which was also markedly different from the current WC-COV for men in Japanese-Criteria (85.0cm).

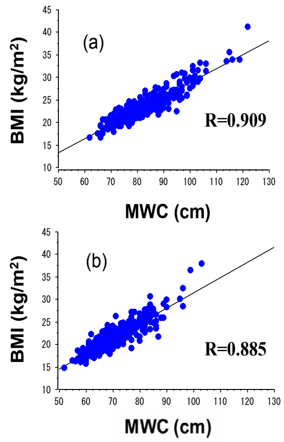

Figure 1. Relationship between body mass index (BMI) and waist circumference measured midway between the lowest border of the ribs and iliac crest (MWC).

Strong correlations were observed between body mass index (BMI) in men (a) and women (b). A single regression analysis of men (n=381) yielded a regression equation of BMI= –2.148 + 0.310xMWC (R=0.909). In women (n=358), this equation was BMI= –2.234 + 0.336xMWC (R=0.885). These linear regressions were tentatively designated as Regressions 1 and 2 in the present study.

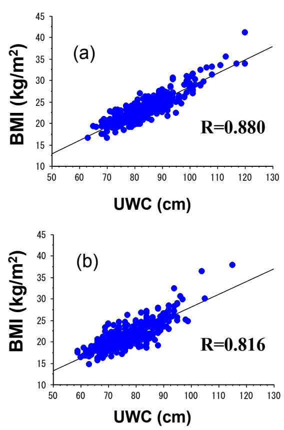

Figure 2. Relationship between body mass index (BMI) and waist circumference measured at the umbilical level (UWC)

Strong correlations between UWC and BMI in men (a) and women (b). A single regression analysis of men (n=381) yielded a regression equation of BMI= –2.644 + 0.311xUWC (R=0.880). In women (n=358), the equation was BMI= –1.403 + 0.295xUWC (R=0.816). These linear regressions were tentatively designated as Regressions 3 and 4 in the present study.

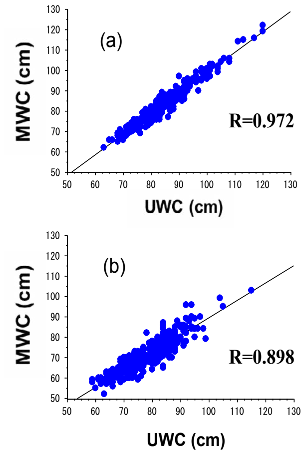

Figure 3. Relationship between waist circumferences measured midway between the lowest border of the ribs and iliac crest (MWC) and at the umbilical level (UWC).

Strong correlations were observed between UWC and MWC in men (a) and women (b). A single regression analysis of men (n=381) yielded a regression equation of MWC= –1.953 + 1.009xUWC (R=0.972). In women (n=358), the equation was MWC= 4.268 + 0.853x UWC (R=0.898). These linear regressions were tentatively designated as Regressions 5 and 6 in the present study.

In the equation assigned Regression 6 (the female study), a UWC value of 90.0 cm (the current WC-COV for women in Japanese-Criteria) corresponded to a MWC value of 81.0 cm, which was similar to the current WC-COV for women in IDF-Criteria (80.0 cm). In the same equation, a MWC value of 80.0 cm (the current WC-COV for women in IDF-Criteria) corresponded to a UWC value of 88.8 cm, which was also similar to the current WC-COV for women in Japanese-Criteria (90.0cm).

BMI values corresponded to the current WC-COVs in IDF and Japanese Criteria.

In the regressions between BMI and MWC (Regressions 1 and 2) or those between BMI and UWC (Regressions 3 and 4), BMI values corresponding to the current WC-COVs in IDF- and Japanese-Criteria were examined in both genders. In men, the current WC-COVs in IDF-Criteria (a MWC value of 90 cm) and Japanese-Criteria (a UWC value of 85 cm) corresponded to BMI values of 25.8 kg/m^2 in Regression 1 and 23.8 kg/m^2 in Regression 3, respectively. They were markedly inconsistent with each other. In women, the current WC-COVs for women in IDF-Criteria (a MWC value of 80 cm) and Japanese-Criteria (a UWC value of 90 cm) corresponded to 24.6 kg/m^2 in Regression 2 and 25.0 kg/m^2 in Regression 4, respectively. They were practically consistent with each other at approximately 25.0 kg/m^2, the conventional border for being overweight in Japanese individuals [10].

Theoretical sets of WC-COVs of MWC and UWC for synchronizing the current WC-COVs in IDF- and Japanese-Criteria

(MWC and UWC values corresponding to BMI values of 25.0 kg/m^2)

Using the equations assigned Regressions 1-4, MWC or UWC values corresponding to a BMI value of 25.0 kg/m^2 were determined in both genders. The MWC values for men and women were 87.6 and 81.1 cm, while their UWC values were 88.9 and 89.9 cm, respectively. A set of these values was collectively named Combination A. UWC values corresponding to a MWC value of 87.6 cm in men and that of 81.1 cm in women were 88.8 and 90.0 cm, respectively in Regressions 5 and 6.

(MWC and UWC values corresponding to BMI values of 24.0 kg/m^2).

Similarly, MWC or UWC values corresponding to a BMI value of 24.0 kg/m^2 were determined in both genders. The MWC values for men and women were 84.3 and 78.1 cm, while their UWC values were 85.7 and 86.1 cm, respectively. A set of these values was collectively named Combination B. UWC values corresponding to a MWC value of 84.3 cm in men and that of 78.1 cm in women were 85.5 and 86.6 cm, respectively in Regressions 5 and 6.

(WC-COVs in the current IDF-Criteria and their corresponding UWCs in regressions between MWC and UWC).

As shown above, UWC values corresponding to WC-COVs in the current IDF-Criteria, namely, MWC values of 90 cm and 80 cm in men and women were 91.1 cm in Regression 5 and 88.8 cm in Regression 6, respectively. A set of these values was correctively designated as Combination C. BMI values corresponding to these MWC and UWC values were determined using Regressions 1, 3, 2, and 4, and were 25.8, 24.6, 25.7 and 24.8 kg/m^2, respectively.

(WC-COVs in the current Japanese-Criteria and their corresponding MWCs in regressions between MWC and UWC)

MWC values corresponding to WC-COVs in the current Japanese-Criteria, namely, UWC values of 85 and 90 cm in men and women were 83.8 cm in Regression 5 and 81.0 cm in Regression 6, respectively. A set of these values was correctively designated as Combination D. BMI values corresponding to these MWC and UWC values were determined using Regressions 1, 3, 2, and 4, and were 23.8, 25.0, 23.8 and 25.1 kg/m^2, respectively.

Likelihood of correlations between MWC and UWC

The likelihood of correlations existing between MWC and UWC were evaluated by drawing Bland-Altman plots [8] (Figure 4). The mean values of differences in the two measurements were shown as 1.2 and 7.1 cm in men and women, respectively, which were consistent with the differences observed in their tentative COVs constituting Combination A as well as those constituting Combination B, in the present study. Although differences in the two measurements varied widely, the number of cases with the difference level being beyond the ranges of their mean +/- 1.96 SD were 16 (4.1%) and 15 (4.2%) in men and women, respectively. Positive and converse regressions between the means of MWC and UWC measurements (MWC/2+UWC/2) and differences in MWC and UWC (MWC-UWC) were observed in men and women, respectively. However, the slopes assigned to the regressions were not so marked.

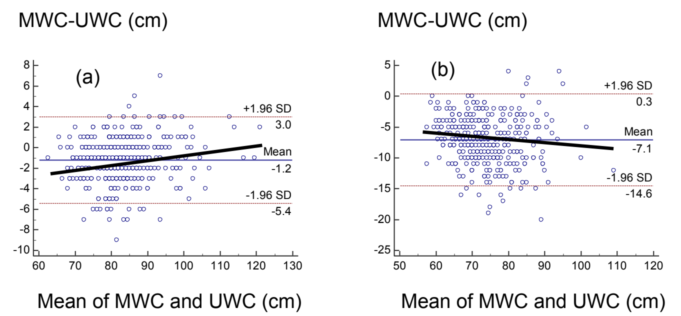

Figure 4. Likelihood of correlations between MWC and UWC evaluated by drawing Bland-Altman plots.

The means of MWC and UWC and differences in MWC and UWC in each subject were arranged in the horizontal and vertical axes, respectively, in men (a) and women (b). The mean values of differences in the two measurements were 1.2 and 7.1 cm in men and women, respectively. Although the level of differences in the two measurements varied widely, they were within mean +/- 1.96 SD in 95.9 and 95.8 % of men and women, respectively. Positive and converse regressions between the two factors were observed in men and women, respectively; however, the slopes assigned to the regressions were not so marked.

Agreements in MWC and UWC measurements in correlations between MWC and UWC.

Agreements in MWC and UWC measurements in their correlations were evaluated by determining the Lin's concordance correlation coefficients [9] associated with Pearson's correlation coefficients (Pearson's ρ) in both genders. In men, the value was 0.9621 (Pearson's ρ=0.9710). According to the descriptive scale proposed by MacBride, [11] two measurements were judged to substantially agree with each other. However, in women, the coefficient was 0.6584 (Pearson's ρ=0.8979), indicating that their agreement was poor.

Agreements in screening for excessive WC based on MWC and UWC measurements.

The concordance rates of screening for excessive WC using MWC and UWC measurements were 91.3 and 94.2% in men and women, respectively, when Combination A was used for the cut-off values, and 92.3 and 92.7 % when Combination B was used.

Discussion

WC may be a significant tool in MetS screening [1]. However, WC-COVs for both genders in IDF- and Japanese-Criteria for MetS screening are inconsistent with each other, [2,3] which has led to confusion in the diagnosis of MetS at least in Japan. Thus, these inconsistencies, namely, the WC issue, which has been the focus of much attention worldwide, must be solved. In the present study, the factors responsible for this issue were identified and solution strategies were developed. One of the advantages of the present study was to recognize that difference in the WC definitions in the two set of criteria underlies the WC issue.

The MWC measurement adopted by IDF-Criteria is an internationally approved index of obesity; therefore, the results that MWC correlated well with BMI in both genders were logical (Regressions 1 and 3). On the other hand, the UWC measurement adopted by Japanese-Criteria has not received such an approval. The findings that UWC also correlated well with BMI with correlation coefficients similar to those assigned to regressions between MWC and BMI in both genders (Regressions 2 and 4) indicate that UWC measurements also work as indexes of obesity in both genders. By considering regressions 1-4 into account, the results that MWC and UWC both correlated well with various metabolic factors in both genders were not surprising. Because the correlation coefficients assigned to these regressions were similar to each other, UWC measurements, as well as, MWC measurements, are considered to work as indexes of MetS screening in both genders. Due to these characteristics, it was rational that MWC and UWC correlated well with each other in both genders (Regressions 5 and 6). The uniqueness of the present study was to attempt to resolve the WC issue by applying these six lines of regressions (Regressions 1-6).

The WC issue comprises two matters, namely, those for men and women. In women, a MWC value of 80 cm and a UWC value of 90 cm, which may represent WC-COVs in IDF- and Japanese-Criteria, respectively, practically agreed with each other in Regression 6. Although WC-COVs for women in the two sets of criteria appeared to differ from each other, they must be substantially consistent with each other. The view is supported by the present results in which BMI values corresponding to both WC values were similar to each other in Regressions 2 and 4. Furthermore, because the BMI values were approximately 25.0 kg/m^2, i.e., a conventional border for being overweight for Japanese individuals, [10] both WC values may be sufficient WC-COVs for MetS screening.

In men, a MWC value of 90 cm and a UWC value of 85 cm, which may represent WC-COVs in IDF- and Japanese-Criteria, respectively, did not agree with each other in Regression 5. Furthermore, BMI values corresponding to the two WC values determined in Regressions 1 and 3 were inconsistent with each other. Even by taking reported errors associated with the measurement of WC into account, [12] they must be judged to have different characteristics. Furthermore, both BMI values were markedly higher and lower than 25.0 kg/m^2, respectively. These inconsistencies may be the root of the WC issue and must be adjusted to settle it.

Combinations C and D were constructed as simple solutions for the WC issue. However, as expected, BMI values assigned to COVs constituting these combinations did not harmonize. Namely, they were not proper solutions to the WC issue.

In order to reach more favorable solutions, a set of MWC and UWC values corresponding to a BMI value of 25.0 kg/m^2 for both genders was constructed using Regressions 1-4 (Combination A). Because the MWC and UWC values constituting this setting were shown to be consistent with each other in Regressions 5 and 6 in both genders, it may be a solution for the WC issue. In order to have this setting, major reforms (2.4 and 3.9 cm) were required to the current WC cut-off values for men in IDF- and Japanese-Criteria; however, only minor reforms (1.1 and 0.5 cm) were needed for those for women.

As another favorable solution, a set of MWC and UWC values corresponding to a BMI value of 24.0 kg/m^2 was constructed using Regressions 1-4 for both genders (Combination B). Because the MWC and UWC values constituting this setting were also consistent with each other in Regressions 5 and 6 in both genders, they may also be a solution for the WC issue. In order to have this setting, major reforms (5.7 and 4.9 cm) were required to the current WC-COV for men in IDF-Criteria and to that for women in Japanese-Criteria; however, only minor reforms (0.7 and 1.9 cm) were necessary for the current WC-COV for men in Japanese-Criteria and for that for women in IDF-Criteria.

In consideration of the current conventional border for being overweight in Japanese individuals, (25.0 kg/m^2), [10] Combination B appeared to be different from WC-COVs for MetS screening. However, the WHO recently stated that the COV of BMI to judge obesity in Japanese individuals may become as low as 24.0 kg/m^2 after adjusting for age, gender, and body fat status [13]. According to this view, WC-COVs composing Combination B may also be acceptable as the most severe WC-COVs for MetS screening. In order to construct Combination B, a major reform, namely, the replacement of the current WC cut-off value in the IDF criteria for men (90 cm) with 84.3 cm, is required. Importantly, multiple lines of evidence from various Asian countries including Korea, China, Hong Kong, and Japan [14-17] support this replacement. Furthermore, the MWC and UWC values composing Combination B are very close to the

RI-based COVs of MWC and UWC in both genders that we estimated previously [7]. Divergences between the corresponding WCs constructing these two sets were just 0.3-1.8 cm.

In the present study, WC-COVs constructing Combinations A and B have been proposed as the loosest and most severe WC-COVs for MetS screening, in which inconsistencies between WC-COVs in IDF- and Japanese-Criteria were settled. Early-life determinants of metabolic risks are considered to be beneficial for the management of MetS [18]; therefore, Combination B, i.e., the more severe COVs, may be more valuable for MetS screening than Combination A. However, screening based on Combination B will result in a higher rate of over-diagnose of MetS than that based on Combination A.

In non-obese women, body circumference typically increases from the narrowest point of WC to the pelvis; however, such a change is not clearly evident in men. Because the measurement points of MWC and UWC are close to the former and latter, respectively, it is not surprising that the WC-COV of UWC, adopted by Japanese-criteria, become larger than that of MWC, adopted by IDF-Criteria, in women, but not in men.

The Bland-Altman plots [8] constructed in the present study suggested the existence of constant and proportional systematic errors in the regressions between MWC and UWC in both genders. However, differences between MWC and UWC measurements in more than 95 % of cases were within their mean +/- 1.96 SD in both genders; therefore, the former errors may be permissive. Furthermore, the slopes assigned to regressions between MWC-UWC and (MWC +UWC)/2 appeared not to be marked; therefore, the later errors may also be tolerant.

Lin's concordance correlation coefficients [9] demonstrated a substantial agreement in MWC and UWC measurements in men, indicating that they were judged to be changeable with each other. Indeed, the concordance rates of screening for excessive WC using MWC and UWC measurements were fully favorable in them. This result warrants the establishment of consistent COVs for MWC and UWC, which work as indexes in MetS screening.

In contrast, such an agreement between MWC and UWC measurements was not observed in women, whereas the concordance rates of screening for excessive WC using MWC and UWC measurements were also satisfied. The reasons for this poor agreement in women currently remain unclear. One plausible explanation is that it is attributed to large individual differences in the body shapes of women, including the positional relationship between the umbilical line and ilium. There appears to be two types of individuals whose umbilical lines are located higher and lower than the iliac crest. The latter type may have larger differences between UWC and MWC than the former type because of the influence of the pelvis, especially in women. Although the WC issue is apparently solved in women as described above, it may be necessary that a level of UWC is separately evaluated according to a positional type of the umbilical line, namely, a new WC-COV for UWC for women is established for each type.

In conclusion, the factors responsible for inconsistencies in WC-COVs between IDF-and Japanese-Criteria for MetS screening (the WC issue) were examined. Inconsistencies in WC definitions, namely, MWC in the former and UWC in the latter (the WC definition problem), may be one of basis for this issue. In men, inconsistency in WC-COVs were still noted in men even after coordinating the WC definition problem. Thus, reform(s) of the current WC-COVs in IDF- or Japanese-Criteria or both are needed. The substantial agreement in UWC and MWC measurements for WC screening demonstrated in the present study warrants the establishment of suitable WC-COVs for the two criteria in older to resolve the WC issue. In women, after adjusting for the WC definition problem, the WC-COVs became consistent with each other. However, since the agreement in UWC and MWC measurements for WC screening was shown to be poor, further designs for UWC-COVs, such as those considering the positional relationship between the umbilical line and iliac in each subject, may be necessary.

Disclosure

The authors have no conflicts of interest to declare.

References

1. Alberti KG, Zimmet P, Shaw J. Metabolic syndrome: a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabet Med. 2006, 23(5): 469-480.

2. Alberti KG, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI et al. Harmonizing the metabolic syndrome: a joint interim statement of the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association; World Heart Federation; International Atherosclerosis Society; and International Association for the Study of Obesity. Circulation. 2009, 120: 1640–1645.

3. Arai H, Yamamoto A, Matsuzawa Y, Saito Y, Yamada N et al. Prevalence of metabolic syndrome in the general Japanese population in 2000. J Atheroscler Thromb. 2006, 13(4): 202–208.

4. Wang J, Thornton JC, Baris S, Willamson B, Gallagher D et al. Comparison of waist circumferences measured at 4 sites. Am J Clin Nutr. 2003, 77(2): 379–384.

5. Formula for life- Body mass index.

6. Yokoyama H, Hirose H, Kawabe H, Saito I: characteristics

of reference intervals of metabolic factors in healthy Japanese: a proposal to set generation- and gender-specific diagnostic criteria for metabolic syndrome. J Atheroscler Thromb. 2009, 16(2): 113–120.

7. Yokoyama H, Hirose H, Kanda T, Kawabe H, Saito I. Relationship between waist circumferences measured at the umbilical Level and midway between the ribs and iliac crest. J Atheroscler Thromb. 2011, 18(9): 735–743.

8. Bland JM, Altman DG. Statistical method for assessing agreement between two methods of clinical measurement. The Lancet. 1986, 1(8476): 307-310.

9. Lin L I. A concordance correlation coefficient to evaluate reproducibility. Biometrics 1989, 45(1): 255-268.

10. Shirai K. Evaluation of obesity and diagnostic criteria of obesity as a disease for Japanese. Nihon Rinsho. 2001, 59(3): 578–585.

11. McBride GB. A proposal for strength-of-agreement criteria for Lin's Concordance Correlation Coefficient. NIWA Client Report. 2005.

12. Agarwal SK, Bardia A, Geol R, Vikram NK, Wasir JS et al. Waist circumference measured by site, posture, respiratory phase, and meal time. Implication for methodology. Obesity. 2009, 17(5): 1056–1061.

13. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet. 2004, 363(9403): 157–163.

14. Park SH, Choi SJ, Lee KS, Park HY. Waist circumference and waist-to height ratio as predictors of cardiovascular disease risk in Korean adult. Circ J, 2009, 73(9): 1643–1650.

15. Wang F, Wu S, Song Y, Tang X, Marshall R. Waist circumference, body mass index and waist to hip ratio for prediction of the metabolic syndrome in Chinese. Nutr Metab Cardiovasc Dis. 2009, 19(8): 542–547.

16. Lee ZS, Critchley JA, Ko GT, Anderson PJ, Thomas GN. Obesity and cardiovascular risk factors in Hong Kong Chinese. Obes Rev. 2002, 3(3): 173–182.

17. Hara K, Matsushita Y, Horikoshi M, Yoshiike N, Yokoyama T. A proposal for the cutoff point of waist circumference for the diagnosis of metabolic syndrome in the Japanese population. Diabetes Care. 2006, 29(5): 1123–1124.

18. Simmons RK, Alberti KGMM, Gale EAM, Colagiuri S, Tuomilehto J. The metabolic syndrome: useful concept or clinical tool? Report of a WHO Expert Consultation. Diabetologia. 2010, 53(4): 600–605.