Abstract

Obesity is defined as a condition of excess body fat accumulation mainly in the adipose tissue. Obesity increases the risk of type 2 diabetes, hypertension, dyslipidemia, cardiovascular disease (CVD) and, ultimately, death. BMI measures general obesity but cannot take into account the distribution of body fat. By contrast, waist circumference is one of the indices of abdominal obesity.

Over the past two decades considerable attention has been paid to the metabolic syndrome. However, partially due to a lack of unified diagnostic criteria for the metabolic syndrome, heated arguments have arisen about the importance of increased waist circumference. These can be summarized as follows. (1) The correlation coefficients between waist circumference and visceral fat area measured by computed tomography are above $r = 0.7$ in both men and women. (2) No single waist circumference measurement is recommended as a protocol for predicting health risks, but we must be aware of the level used to measure waist circumference. (3) Measuring waist circumference provides additional information, beyond that provided by BMI. (4) Increased waist circumference itself is thought to be a simple and useful indicator of an elevated risk of metabolic abnormalities, CVD and death. (5) Independently of arguments over the metabolic syndrome, it is possible that population-specific cut-off points for waist circumference will be established in the near future.

Key words: Waist circumference, body mass index (BMI), abdominal obesity, cardiovascular disease (CVD), metabolic syndrome

Introduction

The prevalence of obesity is rising rapidly in many parts of the world. Obesity is defined as a condition of excessive body fat accumulation mainly in adipose tissue, which increases the risk of type 2 diabetes, hypertension, dyslipidemia and cardiovascular disease (CVD) [1]. Recent data have shown that obesity is associated with the risk of death: average life expectancy has been shown to be reduced in obese subjects [2, 3]. BMI is the best-established index worldwide to assess and classify obesity. BMI cut-off points are 25 kg/m² for overweight (preobese) and 30 kg/m² for obesity, regardless of gender, age and ethnicity (Table I) [4]. However, in Asian populations the risk of developing type 2 diabetes and CVD is substantially higher at a BMI lower than the cut-off point for overweight. Nevertheless, a WHO expert consultation concluded that the WHO BMI cut-off points should be retained for international classifications [5].

**Table I:** Classification of adults according to BMI [4].

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18.5</td>
<td>Underweight</td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>Normal weight</td>
</tr>
<tr>
<td>25.0–29.9</td>
<td>Overweight</td>
</tr>
<tr>
<td>30.0–34.9</td>
<td>Class I obesity</td>
</tr>
<tr>
<td>35.0–39.9</td>
<td>Class II obesity</td>
</tr>
<tr>
<td>≥40.0</td>
<td>Class III obesity</td>
</tr>
</tbody>
</table>

**In Asian populations the risk of developing type 2 diabetes and CVD is substantially higher at a BMI lower than the cut-off point for overweight**

BMI cannot be used to distinguish between excess adipose tissue and high muscle mass. In addition, BMI measures general obesity but cannot take into account the distribution of body fat. Abdominal obesity or visceral obesity is thought to be more closely associated with insulin resistance and the metabolic abnormalities commonly referred to as the metabolic syndrome [6–9]. Although the mechanisms underlying the relationship of abdominal obesity to the metabolic syndrome have yet to be fully elucidated, abdominal obesity is a highly prevalent feature of the metabolic syndrome.
Waist circumference is one of the indices of abdominal obesity, as are waist-hip ratio and waist-height ratio. Current widely used diagnostic criteria for the metabolic syndrome, including the original Japanese criteria, define abdominal obesity by waist circumference (Table II) [10–14]. Considerable attention has been paid to the metabolic syndrome over the past two decades. However, partially due to the lack of unified diagnostic criteria, heated arguments have arisen about the actual existence of a so-called ‘syndrome’, its clinical usefulness and its predictive power for CVD [15]. As a result, there are several controversies about the importance of increased waist circumference in relation to the metabolic syndrome, as discussed in this article.

**Table II: Comparison of various diagnostic criteria for the metabolic syndrome [10–14].**

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Cut-off point</th>
<th>Risk factor</th>
<th>Cut-off point</th>
<th>Risk factor</th>
<th>Cut-off point</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Waist circumference measurement level</td>
<td>Midpoint</td>
<td>1. Waist circumference measurement level</td>
<td>Iliac crest</td>
<td>1. Waist circumference measurement level</td>
<td>Umbilicus</td>
</tr>
<tr>
<td>Men</td>
<td>≥94 cm²</td>
<td>Men</td>
<td>≥102 cm</td>
<td>Men</td>
<td>≥85 cm</td>
</tr>
<tr>
<td>Women</td>
<td>≥80 cm²</td>
<td>Women</td>
<td>≥88 cm</td>
<td>Women</td>
<td>≥90 cm</td>
</tr>
<tr>
<td>2. Triglycerides</td>
<td>≥150 mg/dl</td>
<td>2. Triglycerides</td>
<td>≥150 mg/dl</td>
<td>2. Triglycerides and/or</td>
<td>≥150 mg/dl</td>
</tr>
<tr>
<td>Men</td>
<td>&lt;40 mg/dl</td>
<td>Men</td>
<td>&lt;40 mg/dl</td>
<td>Men</td>
<td>&lt;40 mg/dl</td>
</tr>
<tr>
<td>Women</td>
<td>&lt;50 mg/dl</td>
<td>Women</td>
<td>&lt;50 mg/dl</td>
<td>Women</td>
<td>&lt;40 mg/dl</td>
</tr>
<tr>
<td>3. HDL cholesterol</td>
<td>≥130 mmHg</td>
<td>3. HDL cholesterol</td>
<td>≥130 mmHg</td>
<td>3. HDL cholesterol</td>
<td>&lt;40 mg/dl</td>
</tr>
<tr>
<td>Men</td>
<td>Systolic</td>
<td>≥85 mmHg</td>
<td>Systolic</td>
<td>≥85 mmHg</td>
<td>Systolic</td>
</tr>
<tr>
<td>Women</td>
<td>≥85 mmHg</td>
<td>Women</td>
<td>≥85 mmHg</td>
<td>Women</td>
<td>≥85 mmHg</td>
</tr>
<tr>
<td>5. Fasting blood sugar</td>
<td>≥100 mg/dl</td>
<td>5. Fasting blood sugar</td>
<td>≥100 mg/dl</td>
<td>5. Fasting blood sugar</td>
<td>≥110 mg/dl</td>
</tr>
<tr>
<td>1 is essential</td>
<td>Any two of 2–5</td>
<td>No essential factor</td>
<td>Any three of 1–5</td>
<td>1 is essential</td>
<td>Any two of 2–4</td>
</tr>
</tbody>
</table>

*For Europids.*

Waist circumference is one of the indices of abdominal obesity, as are waist-hip ratio and waist-height ratio. Current widely used diagnostic criteria for the metabolic syndrome, including the original Japanese criteria, define abdominal obesity by waist circumference (Table II) [10–14]. Considerable attention has been paid to the metabolic syndrome over the past two decades. However, partially due to the lack of unified diagnostic criteria, heated arguments have arisen about the actual existence of a so-called ‘syndrome’, its clinical usefulness and its predictive power for CVD [15]. As a result, there are several controversies about the importance of increased waist circumference in relation to the metabolic syndrome, as discussed in this article.

**Does waist circumference reflect visceral obesity?**

According to imaging studies using computed tomography (CT) or magnetic resonance imaging, which can directly measure abdominal adiposity in detail, excess intra-abdominal or visceral adipose tissue, but not the amount of subcutaneous abdominal fat, correlates strongly with the metabolic abnormalities observed in overweight or obese patients [7, 16]. However, such accurate measurements of visceral adipose tissue are expensive and not always available in clinical practice, even in Japan where CT scanners are in abundance.

Waist circumference is weakly related to height [17], correlates closely with BMI [9] and waist-hip ratio [18], and is expected to be an appropriate index of visceral obesity. In theory, waist circumference is a simple index of overall abdominal obesity but is not a specific index of visceral obesity. Therefore the relationship between waist circumference and visceral obesity has become a matter of importance.

A recent Japanese study provides an answer to this fundamental question [19]. Abdominal CT was performed in 1617 subjects (1101 men and 516 women) undergoing general health examinations. Both visceral fat area at the level of the umbilicus and waist circumference anthropometrically measured at the same level in the upright posture were collected. The correlation coefficients between visceral fat area and waist circumference were $r = 0.755$ in men and $r = 0.715$ in women. This result is probably open to a variety of interpretations, though we consider it to be within a reasonable range.

**What is the optimal measurement level of waist circumference?**

At present, no consensus exists on the optimal protocol for measuring waist circumference, and
this gives rise to confusion regarding the waist circumference cut-off point for diagnosing the metabolic syndrome (Table II). Indeed, waist circumference measurement levels are not uniform (Fig. 1). According to the International Diabetes Federation (IDF) criteria published in 2006 [11], waist circumference should be measured in a horizontal plane, midway between the inferior margin of the ribs and the superior border of the iliac crest (the midpoint). In the revised National Cholesterol Education Program–Adult Treatment Panel III (NCEP ATP III) diagnostic criteria published in 2005 [12], however, waist circumference is to be measured in a horizontal plane around the abdomen at the iliac crest level. In addition, the original Japanese criteria published in 2005 clearly noted that waist circumference should be measured in a horizontal plane around the abdomen at the level of the umbilicus except in extremely obese persons with a definite downshift of the umbilicus, in whom waist circumference should be instead measured at the midpoint [14].

Although there may be some differences that cannot be ignored in absolute waist circumference between the selected measurement sites, few studies have directly compared measures at the sites recommended by these diagnostic criteria. Wang et al. [20] compared the three levels of waist circumference measurements, i.e. immediately below the lowest ribs (LR), the midpoint between the lowest ribs and the iliac crest (MP), and immediately above the iliac crest (IC). The mean values of waist circumferences were LR < MP < IC in females, while no differences were seen among LR, MP and IC in males. Thus there are no differences between the iliac crest and midpoint protocols for men, but there is an absolute difference for women, as conceptually illustrated by the cylinder model for men and the hourglass model for women (Fig. 2).

**There are no differences between the iliac crest and midpoint protocols for men, but there is an absolute difference for women.**

The next question is whether the optimal waist circumference measurement level can be determined. A recent systematic review suggested that the waist circumference measurement protocol selected had no substantial influence on the associations of waist circumference with all-cause mortality, CVD mortality, CVD or dia-
Therefore no single waist circumference measurement is recommended as a protocol for predicting health risks, but awareness of the level of waist circumference measurement is essential.

Can measuring waist circumference provide additional information beyond that given by BMI?

From a clinical perspective, abdominal obesity is closely associated with metabolic abnormalities and should therefore be more informative than general obesity, i.e. BMI. As mentioned above, waist circumference correlates closely with BMI and correlation coefficients between the two are reportedly often at or above \( r = 0.80 \) [9].

Because of this high correlation, from a statistical perspective BMI and waist circumference are unlikely to yield different answers. Therefore the clinically important question arises of whether or not, for any given BMI, variation in waist circumference affects metabolic markers, CVD events or death.

One meta-analysis was performed using 32 studies out of 432 publications initially identified [22]. The pooled relative risks (95% CI) for incident diabetes were 1.87 (1.67–2.10), 1.87 (1.58–2.20) and 1.88 (1.61–2.19) per standard deviation of BMI, waist circumference and waist-hip ratio, respectively, demonstrating that these three obesity indicators have similar associations with incident diabetes. By contrast, according to another meta-analysis which included studies that used receiver operating characteristics (ROC) curve analysis and published area under the ROC curves (AUC) for obesity indices with type 2 diabetes, hypertension and dyslipidemia, statistical evidence supported the superiority of measures of abdominal obesity (especially waist-height ratio) over BMI for detecting metabolic abnormalities in both men and women (Table III) [23].

Using data from the INTERHEART study representing several major ethnic groups, a standardized cross-sectional case-control study of acute myocardial infarction with 27,098 participants in 52 countries (12,461 cases and 14,637 controls) was conducted [24]. Waist circumference showed a significant association with myocardial infarction risk after adjustment for BMI (adjusted odds ratio 1.77; 95% CI 1.59–1.97). Strikingly, waist-hip ratio showed a graded and highly significant association with myocardial infarction risk worldwide. Therefore redefinition of obesity based on waist-hip ratio instead of BMI is expected to increase the estimate of myocardial infarction attributable to obesity.

Redefinition of obesity based on waist-hip ratio instead of BMI is expected to increase the estimate of myocardial infarction attributable to obesity

---

**Fig. 2:** Conceptual illustration of abdominal shape and each waist circumference.
Moreover, in a European prospective investigation of 24,508 men and women 45–79 years of age, indices of abdominal obesity were more consistently and strongly predictive of coronary heart disease in comparison with BMI [25]. Hazard ratios (95% CI) of the top vs. the bottom fifth of waist-hip ratio were 1.55 (1.28–1.73) in men and 1.91 (1.44–2.54) in women after adjustment for BMI and other coronary heart disease risk factors. Hazard ratios also increased with waist circumference, but risk estimates for waist circumference without hip circumference adjustment were lower by 10–18%. Overall, measuring waist circumference and hip circumference is anticipated to provide additional information over BMI from both cross-sectional and prospective studies of CVD events. Even among subjects within a normal BMI range, those with an increased waist circumference can have up to double the CVD risk.

A recent study from Europe directly examined the associations of BMI, waist circumference and waist-hip ratio with the risk of death in 359,387 participants from nine countries [3]. After adjustment for BMI, waist circumference and waist-hip ratio were strongly associated with the risk of death. Relative risks (95% CI) among men and women in the highest quintile of waist circumference were 2.05 (1.80–2.33) and 1.78 (1.56–2.04), respectively, and in the highest quintile of waist-hip ratio the relative risks were 1.68 (1.53–1.84) and 1.51 (1.37–1.66), respectively. These data suggested that abdominal obesity as well as general obesity was associated with the risk of death and supported the use of waist circumference or waist-hip ratio in addition to BMI in assessing the risk of death.

How should the appropriate cut-off point for waist circumference be determined?

Although measuring waist circumference must be an independent step in refining the assessment of a patient’s risk, proposing cut-off points to define abdominal obesity based on a scientific or clinical rationale poses another inherent diffi-
but whether visceral fat area can predict future CVD events more reliably than other obesity indices is still under study. Moreover gender differences in fat distribution and cardiovascular morbidity cannot be ignored.

It is also important in the implementation of public health policy to balance the sensitivity and specificity for screening of a disease or ‘pre-disease’ such as the metabolic syndrome. To identify those who are at high risk of future CVD events, cut-off points need to be more sensitive. Previously, we proposed optimal cut-off points for waist circumference (measured at the level of the umbilicus) corresponding to these data were calculated to be 86 cm for men and 77–82 cm for women [19, 29].

**Perspective**

Increased waist circumference itself is thought to be a simple and useful indicator of elevated risk of metabolic abnormalities, CVD and death. Over the past two decades, waist circumference has become the focus of public attention in association with the metabolic syndrome. However, at the same time, this association has given rise to various forms of confusion. Critics of the metabolic syndrome have highlighted scientific shortcomings, inconsistent criteria and uncertain medical value. Controversies regarding the importance of increased waist circumference have thus persisted [31–33]. The minimal requirement for reducing this confusion is one definition and unified criteria for the metabolic syndrome. It is especially necessary to deliberate as to whether increased abdominal circumference is an essential component of the metabolic syndrome or just one component that is occasionally present [15]. A joint interim statement by several major organizations including the IDF and the American Heart Association was recently published, in which it was agreed that there should not be an obligatory component in the diagnosis of the metabolic syndrome, but that waist measurement would continue to be a
useful preliminary screening tool [34]. We are currently conducting a nationwide survey to optimize the Japanese criteria for the metabolic syndrome by integrating 12 cross-sectional and prospective cohort studies performed in Japan, through which some controversies are expected to be resolved [35].

Cut-off points for waist circumference as an index of abdominal obesity vary in the context of diagnostic criteria for the metabolic syndrome, though BMI cut-off points for general obesity are common regardless of gender, age and ethnicity. Independently of arguments over the metabolic syndrome, it is possible that population-specific cut-off points for waist circumference will be established in the near future, as the levels of abdominal obesity at which the risk of other morbidities begins to rise appears to vary among populations [36].

Acknowledgments

We thank T. Yamauchi and K. Hara for their advice and helpful discussions. This study was supported by a grant from the Manpei Suzuki International Prize for Diabetes Research (TK), and Health Science Research Grants (Research on Cardiovascular and Metabolic Diseases) from the Japanese Ministry of Health, Labor and Welfare (TK) and Japan Cardiovascular Research Foundation (IT).

References


