

ACTUALIZACIÓN

Alternative Strategies for Assessing Central Adiposity

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Summary

Chronic diseases are being experienced throughout the globe at higher rates as we approach the new millennium. In particular, central adiposity is being recognized as one aspect of the metabolic syndrome that predisposes individuals for chronic diseases. Accumulation of more adipose tissue in the abdominal region usually involves increasing amounts of deep adipose tissue and visceral adipose tissue. Recognition of the risk of increasing amounts of visceral adipose tissue and central adiposity has led to the evaluation of several methods to detect the amount of abdominal adipose tissue. Regional body composition assessment techniques have

been developed to screen for increasing risk for the metabolic syndrome. These techniques include anthropometric measures, indexes of anthropometric measures, and imaging techniques which permit determination of the amount of subcutaneous and visceral adipose tissue. Waist circumference and abdominal sagittal diameter are the preferred anthropometric techniques for assessing central adiposity in adults. Threshold values for waist circumferences and sagittal diameter require further evaluation to determine what cut-offs represent risk in of chronic disease in different population groups and individuals of differing heights.

KEY WORDS

Visceral adipose tissue
Central adiposity
Waist circumference
Abdominal sagittal diameter

Estrategias Alternativas para evaluación de la Adipocidad Central

Resumen

A medida que nos aproximamos al nuevo milenio, se observa en todo el mundo un incremento en las tasas de incidencia de las enfermedades crónicas. Específicamente, la adipocidad central,

se reconoce como un aspecto del Síndrome Metabólico, que predispone a los individuos a las enfermedades crónicas. de tejido adiposo en la región abdominal, usualmente involucra un au-

PALABRAS CLAVE

Tejido adiposo central
Adiposidad Central
Circunferencia de cintura
Diámetro sagital abdominal

mento en el tejido adiposo profundo y visceral.

La determinación del riesgo que conlleva tener un incremento en el tejido adiposo visceral y la adiposidad central, ha llevado a evaluar diversos métodos para detectar la cantidad de adiposidad abdominal.

Las técnicas de evaluación de la composición corporal regional han sido desarrolladas para tamizar el incremento de riesgo para el Síndrome Metabólico. Estas técnicas incluyen mediciones antropométricas, índices de medición antropométrica y técnicas de imagen, que permiten

la determinación de la cantidad de tejido adiposo subcutáneo y visceral.

La circunferencia de la cintura y el diámetro sagital abdominal, son las técnicas antropométricas preferidas para evaluar adiposidad central en los adultos.

El umbral de los valores para la circunferencia de la cintura y el diámetro sagital, requiere evaluación posterior para determinar cuáles puntos de corte representan riesgo de sufrir enfermedades crónicas en diferentes grupos de población e individuos con estaturas diferentes.

INTRODUCTION

Higher incidences of chronic diseases are being experienced throughout the globe as we approach the new millennium. Health professionals are seeking to understand the causes and to develop diagnostic criteria, screening strategies, treatment regimens, and prevention guidelines. In particular, central adiposity is being recognized as one aspect of the metabolic syndrome (syndrome X) (1-3) that places persons at risk for the development of cardiovascular disease (4-16), hypertension (17), non-insulin dependent diabetes mellitus (NIDDM) (16, 18-21) and other conditions. High levels of centrally deposited adipose tissue affect a persons quality of life and increase the burden of illhealth (22).

Several factors probably influence the development of excessive central adiposity. Central deposition of adipose tissue may involve a redistribution of adipose tissue for

peripheral depots in the thighs and hips to the abdominal region. Increasing obesity also results in greater amounts of central adiposity in men and in postmenopausal women. Aberrations in the endocrine system resulting in elevated levels of cortisol and insulin along with inhibition of gonadotropin favor accumulation of visceral fat (18). Factors such as diet (23-26), habitual exercise (12, 13, 27- 29), psychological stress (4, 18), smoking and alcohol consumption (30), age (31), gender (18), low birth weight (3), residence in a deprived neighborhood (32) and lack of employment (30) have roles to play in the development of central adiposity. Interventions to reduce the amount of central adiposity generally focus on changing behaviors (24-27, 29) and pharmacotherapy (33). Avoiding the development of central obesity is not a simple endeavor for some individuals.

Accumulation of more adipose tissue in the abdominal region usually involves increasing amounts of deep adipose tissue and visceral adipose tissue (VAT). As the abdominal accumulation increases, individuals are at greater risk for adverse changes in blood lipid profiles (7, 8, 10, 12), insulin resistance (9, 18, 21), elevated blood pressure (17) and other complications associated with the metabolic syndrome. Some studies have questioned the link between increased total body fat and greater waist circumferences and hypertriglyceridemia (34) and the association between anthropometric measures and cardiovascular disease in men on anti-hypertensive medication (14). However, because of the association of visceral adipose tissue with the metabolic syndrome, central adiposity continues to be of concern as populations become more vulnerable when faced with an abundant supply of food and fewer requirements to maintain an active lifestyle.

Recognition of the risk of increasing amounts of visceral adipose tissue and central adiposity has led to the evaluation of several methods to detect the amount of abdominal adipose tissue. Assessment techniques for regional body composition have been developed to screen for increasing risk for the metabolic syndrome. These techniques involve both anthropometric measures, indexes of anthropometric measures, and imaging techniques that permit determination of the amount of subcutaneous and visceral adipose tissue.

Each of the approaches will be reviewed, and some current research in this area will be described.

IMAGING OF ABDOMINAL ADIPOSE TISSUE

Technological developments in medical instrumentation have resulted in new options for making direct assessments of the amounts of various tissues. These methods include computed tomography, magnetic resonance imaging, ultrasound and dual energy X-ray absorptiometry. The technical details of each of these methods have been reviewed previously (35). The following discussion of each of these imaging methods is focused on the benefits of these methods relative to assessment of central adiposity.

COMPUTED TOMOGRAPHY

Scanning of the central torso with computed tomography (CT) produces crosssectional images which can be evaluated for the amounts of tissue present (7, 35-37). The images are acquired with instrument settings that make adipose tissue prominent. Evaluation of the images with specialized computer software permits determination of the quantities of subcutaneous and visceral adipose tissue (VAT). This technique involves X-ray exposure and is not suitable for assessment of VAT in children or women of childbearing age. The high quality of a CT image makes computed tomography the "gold standard" or reference method (37) for soft tissue assessment. A computed tomography image at the level of the umbilicus for a post-

menopausal woman is shown in figure 1.

Assessment of the amounts of adipose tissue can be in terms of either areas or volumes. The areas (cm^2) of subcutaneous and visceral adipose tissue are determined in each cross-sectional image. If multiple images are made, the volume of adipose tissue depots can be estimated using conical mathematics that treats the distance between each image as a truncated cone shape (36). Previous research has shown in both men and women that the amount of VAT a single CT image at the positions of L3-L4 and L4-L5 vertebrae corresponds more highly with the total volume of visceral adipose tissue than other locations along the lumbar spine (38).

MAGNETIC RESONANCE IMAGING (MRI)

An alternative technique for assessing central adiposity is magnetic resonance imaging with an instrument that utilizes radio frequency pulses and a strong magnetic field to produce images of soft tissue (35). When examined with this procedure, an individual is not exposed to ionizing radiation, as is the case with computed tomography. Hence, the procedure is usually regarded as safe for most persons. When images are acquired, the instrument is set to make adipose tissue visually prominent on the images. This method of imaging is subject to some motion artifacts due to blood flow in the aorta and motion due to breathing. Those artifacts can be minimized by asking a subject to hold his/her breath for

about 20 seconds while the image is captured using a fast acquisition method (39). A cross-sectional magnetic resonance image at the level of the umbilicus on a postmenopausal woman is shown in figure 2.

With magnetic resonance imaging, the areas (cm^2) and volumes (cm^3) of subcutaneous and visceral adipose tissue depots can be quantified using specialized image analysis computer software. In a study comparing the amounts of subcutaneous and visceral adipose tissue from CT and MR images made at the L4-L5 level, most of the differences occurred for the VAT with MRI being slightly less accurate (40). In recent research, the amount of VAT in a single MRI image at the level of L2-L3 correlated more highly with total VAT than that in an image is made at L4-L5 (41) and contained higher amounts of intraperitoneal and retroperitoneal adipose tissue (42). The process of analyzing the tissue amounts in the visceral depot is rather tedious because of the dispersion of VAT into several small regions.

ULTRASOUND

Determination of the thickness of subcutaneous and visceral depots can be measured by ultrasound (35, 37). While placing a transducer against a person's skin, an image is displayed on the monitor of the instrument showing the tissues below the transducer. B-mode ultrasound provides a two-dimensional image permitting visualization of the layers of tissue (35). Electronic calipers are used to measure distances

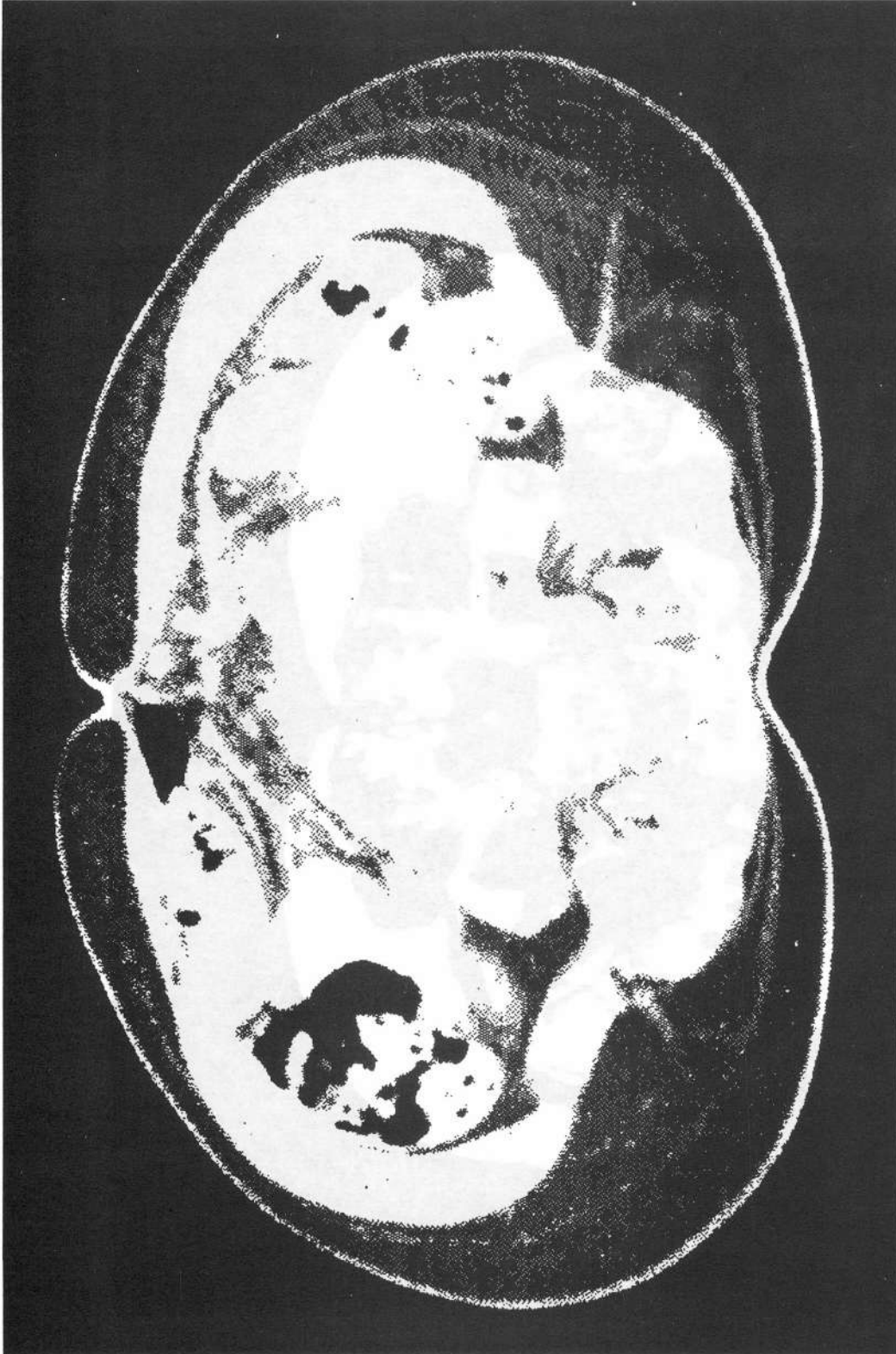


Figure 1
A computed tomography (CT) image at the level
of the umbilicus of a postmenopausal female

10000
10000
10000



Figure 2
A magnetic resonance image (MRI) at the level
of the umbilicus of a postmenopausal female

while viewing tissue interfaces on a frozen image on the monitors screen (37). Measures can be made in a few seconds and some models of the equipment are portable (35). Ultrasound offers an alternative to anthropometric techniques and permits non-invasive measurements of tissue thicknesses within the body.

In a study comparing CT and ultrasound assessment of intra-abdominal fat, ultrasound was evaluated for its ability to distinguish between groups with differing amounts of VAT (37). The groups were defined as tertiles of VAT (< 114, 114-170, > 170 cm²) determined from CT images at L4-L5 in females of differing transverse diameter measures. The ultrasound intra-abdominal measurements correlated better with VAT from CT than either sagittal diameter or WHR. The intra-abdominal thickness, the distance between the rectal muscle and the aorta, was made with a 3.5 MHz transducer (37). When an equation was developed to predict VAT, the ultrasound muscle-aorta thickness was the first of several variables to enter a step-wise regression and was the best predictor of VAT.

DUAL ENERGY X-RAY ABSORPTIOMETRY (DXA)

As the name implies, dual energy X-ray absorptiometry is a method that involves the use of X-ray technology to detect the type of tissue present as a person's body passes across the beam. The low level of radiation of DXA scan is not considered a risky exposure. Thus, DXA is increasingly reported as the analytic method

used in studies of body composition; use of DXA with pregnant women is not permitted. Although it is not possible to distinguish subcutaneous adipose tissue from that in the visceral depot, DXA images can be evaluated to assess the total amount of adipose tissue on the body or in a particular region of interest. At the time the DXA image is analyzed, regional boundaries can be manipulated on the image for various regions of the body; the scan is processed by computer software to provide weights of fat, lean and bone mineral content for the various regions and for the total body.

Dual energy X-ray absorptiometry has been used to assess central adiposity by analyzing DXA scans for the composition of the trunk region of the body (7, 16, 19). In a recent study, DXA-derived trunk fat and CT-derived intra-abdominal fat (IAF) and subcutaneous fat (SAF) were compared with cardiovascular disease (CVD) risk factors; both trunk fat and IAF were positively related to CVD risk factors (7). The DXA-derived trunk fat and IAF had a simple correlation of 0.75; when the trunk fat measure was used in combination with anthropometric measures to develop a predictive equation for IAF, the correlation increased to 0.9 (7). Scientists can rearrange boundaries on DXA scans to create custom regions. For example, abdominal fat was the area between the dome of the diaphragm to the top of the femur (16), upper lumbar fat was the fat between L1 and L4 (16), and central adiposity was the area between the lowest rib and the top of the iliac crest (43). The analysis options available

with DXA provide the flexibility to customize assessment to a specific region of a body for the needs of a particular study.

In summary, computed tomography, magnetic resonance imaging, and dual energy X-ray absorptiometry can reveal the actual amounts of adipose tissue in the central abdominal area of the body with accuracy, and ultrasound can reveal the thickness of tissues or regions. However, the expense of using these instruments (CT, MRI, DXA) and their limited availability often restrict their use to medical or research settings. Despite limited accessibility to these instruments for body composition analysis, each has a valuable role to play in the validation of alternative techniques for screening for excessive central adiposity.

ANTHROPOMETRIC SCREENING FOR CENTRAL ADIPOSIITY

Measures of physical dimensions can be made inexpensively with simple anthropometric tools with little subject burden or discomfort. Circumferences and depths provide direct assessments of a location on a persons body, and larger values of these measures usually reveal increasing accumulations of adipose tissue when taken on the torso of a persons body. Several anthropometric measures have been proposed as strategies for assessing central adiposity. Molarus and Seidell (44) recently reviewed the advantages and disadvantages of waist-thigh ratio, waist-hip ratio, abdominal sagittal diameter,

waist-height ratio, conicity index, abdominal diameter to midhigh girth ratio, and waist circumference for classification of abdominal obesity. The following discussion will be limited to three anthropometric measures related to central adiposity: waist-to-hip ratio (WHR), sagittal diameter, and waist circumference.

WAIST/HIP RATIO (WHR)

For almost two decades, the waist/hip ratio, devised as a screening tool for upper body obesity, has been used to reflect the distribution of body fat and the presence of an android body shape (45). Calculating a ratio of the two circumferences appears to be an obvious way to depict the proportionate amount of central adipose tissue. An increasing waist circumference relative to a hip circumference has been viewed as an undesirable change in body composition. WHR values above specified cut-off values for men (0,95-1,00) and women (0,80-0,90) have been regarded as placing individuals at higher risk for cardiovascular disease and insulin resistance (44).

The research literature contains many reports comparing WHRs with disease risk factors. In many instances a positive relationship has existed between WHR and other measures of disease risk (11,15,45,46); in some instances the relationships have not been supported. The extent to which WHR is associated with cardiovascular disease risk factors has been shown to depend on the locations at which the waist and hip circumferences are mea-

sured (47). Metabolic variables were strongly related to the following circumference combinations: minimal waist/maximal hip, umbilicus/maximal hip, and umbilicus/greater trochanters; other combinations such as umbilicus/superior iliac or 1/3 the distance between the xiphoid process and the umbilicus/4 cm below superior iliac spine had weaker relationships (47). Molarius and Seidell (44) believe that WHR is difficult to interpret biologically; the relative amounts of peripheral muscle may pose a risk for NIDDM more than abdominal obesity, especially when the hip circumference is smaller than expected for body mass index (BMI) (weight (kg)/height (m²) reflecting muscle atrophy (20).

Recently, investigators have begun to question the capability of the WHR to represent central adiposity (37, 48, 49). When compared with BMI and waist circumference, WHR was less sensitive in classifying regional adiposity in healthy women (49). Lifestyle factors such as smoking, alcohol consumption and physical activity levels can independently influence the magnitude of waist and hip circumferences (30). As a predictor of VAT, WHR was a less effective than the ultrasound muscle-aorta thickness or sagittal diameter (37). In a study of weight loss in obese men and women, WHR was not highly related to changes in VAT and was regarded as inappropriate for detecting changes in VAT (48).

The sensitivity of the WHR to assess metabolic risk may relate to naturally occurring situations

and lifestyle factors that may be ignored when screening individuals. In one case, a person can have very large circumferences of both the waist and the hips yielding an "acceptable" WHR while in reality the individual is obese and at risk for medical complications. Conversely, another person can have small circumferences of both the waist and hips yielding an "unacceptable" WHR while in reality the individual is very slender with little variation in the two measures and not at risk for medical complications of obesity. Both of these cases illustrate the need for a more robust indicator which will not mis-classify individuals relative to central obesity.

ABDOMINAL SAGITTAL DIAMETER

The thickness of the body from back to front at the level of the abdomen, usually when supine, is referred to as the sagittal diameter. This distance can be measured with calipers or can be determined when analyzing CT or MR images. The sagittal diameter includes the thickness of various tissues and the location of internal organs. This measure does not give any indication of what part is associated with either the subcutaneous or visceral fat depot. Instead, an assumption is made that a greater thickness represents increased quantities of subcutaneous and visceral adipose tissue.

Several investigators (5, 37,50-52) have studied the relationship of sagittal diameter with visceral adipose tissue. Sagittal diameter

The magnitude of a persons waist circumference can be influenced by the location on the body where the measure is made

was found to maintain a significant relationship with VAT after adjusting for BMI in men and women of varying levels of obesity; however, the relationship was stronger in lean and moderately overweight than in obese subjects (50). In men and women of varying BMI levels, sagittal diameter correlated more closely than WHR with metabolic variables (serum lipids, glucose, and insulin); a sagittal diameter >25 cm had a high probability of being associated with metabolic complication (5). After ultrasound intra-abdominal thickness and age, sagittal diameter entered a stepwise regression analysis to develop an equation to predict VAT (37). In a 7-year follow-up study of women, changes in sagittal diameter were more highly associated with changes in VAT than WHR after controlling for changes in body fat mass (51). Sagittal diameter was correlated poorly with VAT, at the level of L4-L5 in men and women with a BMI ≥ 27 . Sagittal diameter was not sufficiently precise to estimate VAT in obese individuals in whom a 2 cm range of sagittal diameter was associated with up to a three-fold variability in total VAT (52). These reports confirm that increases in sagittal diameter are associated with increasing adiposity, but the usefulness of sagittal diameter to reflect VAT appears to be limited at high levels of obesity.

WAIST CIRCUMFERENCE

The health risk associated with a large waist circumference is recognized. Several studies have confirmed the risk for cardiovascular disease or metabolic syndrome in individuals with large waist cir-

cumferences (3, 6, 8, 11, 20, 21, 44, 47). In non-obese, mature men, waist circumferences were found to account for more variance in metabolic variables than hip circumferences or WHR (47). In men and women in the Netherlands, both shortness in stature and a large waist circumference were found to be strong predictors of NIDDM (21), and diabetics had larger waists and smaller hip circumferences than would be expected for their BMI than non-diabetics (20). In an 8-year follow-up study of mature women, a large waist circumference was independently associated with an increased age-adjusted risk for coronary heart disease (11). Also, postmenopausal women of low birth weight who became obese as adults with a large waist circumference had a high prevalence of the metabolic syndrome (3). Living in a deprived neighborhood (32), lifestyle habits (12, 13, 24, 27-31) and intervention programs (25, 26, 33, 53) can influence the size of ones waist circumference. A large waist circumference can predict an excess burden of ill health (22), be an indicator of the need for weight management (54), and serve as a simple alternative to BMI in health promotion (6).

The magnitude of a persons waist circumference can be influenced by the location on the body where the measure is made. Frequently, individuals define their waist as the minimal point on their torso or where they position a belt on their clothing. Obviously, these could be different locations on different persons. To standardize measurement at an anatomic location, the U.S. National

Health and Nutrition Examination Survey (NHANES) defined an abdominal circumference measured parallel to the floor just above the iliac crest (55, 56). That location is likely to yield a larger value than when measured at the narrowest point on a person's torso. The validity of self-reported measures of waist circumference has been examined in several recent studies (57-59); some subjects underestimated waist circumferences. Using a specially designed tape (> Waist Watcher) with different color bands corresponding to action levels, individuals made more accurate measurements and placed themselves in the appropriate action level category (59). Thus, with some training, people can themselves make waist circumference measures that are appropriate for epidemiologic studies (57).

Strong relationships between waist circumference and visceral adipose tissue have been reported in several studies (5, 50, 51, 60). Like the abdominal sagittal diameter, the waist circumference does not permit determination of the amounts of subcutaneous and visceral adipose tissue, but increasing measures in mature adults usually indicate increasing amounts of either or both depots. After adjustment for total body fat mass, waist circumference was significantly associated with VAT changes in a 7-year follow-up study of women (51). In African American women, waist circumference was the highly predictive of VAT at L4-L5 and was preferred above WHR as a surrogate for VAT (60). Waist circum-

ferences above 100 cm indicate a greater accumulation of VAT and placed men and women at a higher probability of developing metabolic disturbance (5). These and similar studies have led to increased interest in the utility of a waist circumference measure as an indicator of the need for clinical care and health promotion (61).

Several publications have indicated cut-off points for waist circumference for men and women that reflect risks for health complications (3, 6, 9, 11, 22, 49, 54, 62-64). For a Scottish sample, Lean, *et al.* (54) used a BMI of 25 to identify corresponding waist circumferences indicating that individuals should not gain additional weight (Action Level 1); they were ≥ 94 cm for men and ≥ 80 cm for women. Action Level 2, the point at which a person should lose weight, was defined as ≥ 102 cm for men and ≥ 88 cm for women. Han, *et al.* (6) proposed that the Action Level 1 be adopted as a simpler alternative to BMI for detecting health risk. Individuals with waist circumferences above Action Level 2 were found to have greater risk for NIDDM, cardiovascular disease, low back pain, and difficulties in daily activities than persons below Action Level 1 (22). Obese adult females of low birth weight had a high prevalence of metabolic syndrome at a waist circumference $> 80,7$ cm (3). Waist circumferences of 76,2 cm in female nurses were associated with a higher risk (2-fold) for coronary heart disease after eight years of follow-up in a longitudinal study while a waist circumference of 96,5 cm was associated

with a relative risk of 3,25 for coronary heart disease (11). A waist circumference of 86,9 cm was better than WHR in screening healthy females for regional fat distribution and correctly classifying them as centrally obese (49). In a study of men and women, a waist circumference of 95 cm was determined to correspond to 130 cm² of VAT (62). For persons < 40 years, a waist circumference threshold of 100 cm corresponded to that amount of VAT while it was 90 cm for persons \geq 40 years, indicating the age-specific nature of VAT accumulation (62); gender and degree of obesity did not influence the threshold values. The risk for coronary artery disease in hyperinsulinemic men with familial hypercholesterolemia increased when waist circumference was > 95 cm (9). Waist circumferences of 85 cm for men and 75 cm for women were more effective in identifying Hong Kong Chinese with a high BMI and WHR than the previously mention Action Level 1 cut-off values (64).

Cut-off values for waist circumference assessment for evaluating obesity in U.S. adults were proposed in 1998 by the National Heart, Lung, and Blood Institute (NHLBI) of the National Institutes of Health, Department of Health and Human Services (63). Waist circumferences > 102 cm for men and > 88 cm for women were established as the point of high risk. These cut-off values were proposed for use in conjunction with BMI for evaluating persons for overweight and obesity.

CORRECTING FOR STATURE AND BODY SIZE

Stature and body dimensions were not taken into consideration in the techniques presented above. Height-normalized indexes have been proposed to report lean and adipose compartments in the same manner as the BMI (65). Similarly, investigators have evaluated the relationship of height and waist circumference (6, 54, 66, 67). Han, *et al.* (6,66) reported that height accounts for only a very small amount (0,3-3,5%) of the variance in waist circumference and has only a small impact on the relationship of intra-abdominal fat area and waist circumference (67). However, in cross-sectional study, a large waist circumference, high BMI, high WHR and short stature related to the incidence of NIDDM (21). Skeletal stunting (short stature and limbs) has been associated with diabetes in Scottish men and coronary heart disease in Scottish women (68) and with greater limb and trunkal subcutaneous fat in Colombian women (69). Lean, *et al.* (54) indicated that the action levels for four stature classes were not different although men above Action Level 1 were 2 cm taller than individuals below Action Level 1. For hypertensive men, a waist to height ratio had a stronger linear relationship with the probability of cardiovascular disease development than BMI, but the same was not true for women (14). Also, the ratio of waist to height was shown more effective than waist cir-

cumference alone in both men and women as a predictor of intra-abdominal fat (70) and more effective than BMI to predict death due to cardiovascular disease (71).

Two indexes have been proposed to take height into consideration when assessing central adiposity (72,73). The abdominal circumference index (ACI) was defined as a circumference at the level of the umbilicus (cm^2)/height (cm) (72). In Japanese, higher values of the ACI were associated with elevated blood pressure and serum lipid levels, abnormal ECG changes, and glucose intolerance even when the subjects were an appropriate weight for height. The Conicity Index, developed to screen for abdominal obesity, treats the body shape as two cones with the base of both at the level of a abdominal circumference (73). Values for the Conicity Index vary from 1.0 for a perfect cylinder to 1,73 for a perfect double cone and are calculated by dividing abdominal girth by the product of 0,109 times the square root of weight divided by height. An advantage of the Conicity Index is that height and weight adjustments are inherent in its calculation.

Adjustment for height can be made using either standing height (70,71) or knee height (74). Intuitively, a shorter person would be assumed to be at greater risk with a given waist circumference measure than a tall person; thus, the height adjustment of waist circumference or sagittal diameter seems reasonable. However, Molarius and Seidell (44) regarded the benefit of height ad-

justment as small and not worth the complexity it introduces in interpretation because it is short stature that is related to increased morbidity.

In recent studies, we have addressed the association of height and waist circumference and its relationship with BMI in healthy Caucasian women (75, 76). Both standing height and knee height were both considered as potential ways to adjust for body size and both were found to be significantly correlated ($R^2 = 0,73$, $p < 0,0001$) in pre-menopausal women (75). When waist circumference was expressed as a ratio of both standing height and knee height, the two ratios were significantly related ($R^2 = 0,96$, $p < 0,0006$); thus, knee height was determined to be a suitable basis for a height-adjusted ratio. Similarly, indexing intra-abdominal fat (IAF) to stature with the intra-abdominal fat to knee height ratio (IAKR) was determined to be preferable to expressing IAF as a ratio of subcutaneous adipose tissue (77, 78).

In a study exploring the relationship of waist circumference with standing height and BMI in healthy, non-smoking Caucasian women (35-62 years), three measures of waist circumference were made: the narrowest location and just above the iliac crest both while standing and when supine (76). Waist circumference measured at the most narrow point had the strongest relationship with BMI ($R^2 = 0,83$, $p < 0,0001$). The two waist circumferences measured just above the iliac crest were larger and less strongly re-

lated to BMI. These findings suggest that only one measure is necessary at the narrowest point, similar to a location mid-way between the bony landmarks of the lowest ribs and the iliac crest which was used by Lean, *et al.* (54).

In addition, subjects were assigned to short (< 160,5 cm), average ($\geq 160,5$ and $\leq 168,7$ cm), and tall (> 168,7 cm) stature classes, and BMI was regressed on waist circumference (narrowest) by stature class. Changes in waist circumference were related differently with BMI in the tall stature class where all subjects had normal BMIs. For the short and average classes, the slope was 0,355 and 0,364, respectively; for the tall

class, the slope was 0,237. Thus, for each 1 cm of change in waist circumference, the change in BMI was greater for the short and average than for the tall stature class. These findings suggest that cut-off points for risk assessment may vary according to a person's height. The same increase (e.g. 1" or 1 cm) in waist circumference appears to have a more negative consequence on body composition in short and average stature females than in taller females by being associated with a larger increase in BMI. Because this study was conducted on a small number of subjects, this relationship requires further exploration with a larger sample of subjects.

Conclusions

Central adiposity is highly related to the development of chronic diseases and is appropriately a concern in clinical and public health settings. Several alternatives exist for assessment of central obesity. Imaging techniques, while expensive and not readily available for body composition assessment, represent the most accurate strategy for measurement of specific tissue depots. Waist

circumference and abdominal sagittal diameter are the preferred anthropometric techniques for assessing central adiposity in adults. Threshold values for waist circumferences and sagittal diameter require further evaluation to determine what cut-offs represent risk in of chronic disease in different population groups and individuals of differing heights.

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