The importance and predictive value of BMI and waist circumference in the development of Type 2 Diabetes

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BODY MASS INDEX AND THE DEVELOPMENT OF TYPE 2 DIABETES

The evidence linking high, or increasing, BMI to diabetes is strong and consistent around the world. The most persuasive data come from the Nurses' Health Study.[2] The BMI of nurses at 18 years of age was highly predictive of the occurrence of type 2 diabetes at 30 - 50 years of age, and the BMI at this age (mean 42 years) is even more strikingly predictive of diabetes over the next 14 years (**Table I**.) The study concluded that weight gain of 7.0-10.9kg after the age of 18years was associated with a two-fold increase in the risk for diabetes, and an adult body mass index of 23.0 to 25.0 kg/m2 was associated with a fourfold increased risk for diabetes, compared to women whose body mass index was less than 22kg/m2. Even women with a body mass index of 22.0 to 22.9kg/m2, had a significant three-fold elevation in age-adjusted relative risk compared with those with a BMI of less than 22kg/m2. In practice, this means that weight gain at any age is associated with an increased risk for diabetes. Middle-aged women who lose more than 5.0kg have a significantly reduced risk for diabetes compared with women with stable weight.

The greatest population-attributable risk and absolute number of cases of type 2 diabetes occurs in people with a BMI 25 - 30kg/m^2.

Chan *et al.*[3] have recorded similar data for men. They obtained the reported BMI at 21 years of age in male health professionals. They found a striking correlation between higher BMI levels and the later development of diabetes, which was aggravated by weight gain in adulthood. It is important to note that only a few of these 18-year old men would have qualified as 'obese' and the risk for type 2 diabetes increased substantially as the BMI rose above (tertile) thresholds of 22 and 24 kg/m^2 (i.e., well below BMI 30 kg/m^2). This observation is borne out by the mean BMI at diagnosis of type 2 diabetes of 28 - 29 kg/m^2 in the United Kingdom Prospective Diabetes Study (UKPDS).[4] More than half of all cases of diabetes will present at a BMI 25 - 30kg/m^2. These findings are important for deciding the 'action levels' for tackling obesity in order to prevent the development of diabetes. At a BMI of 34, the chances of developing type 2 diabetes may be 40-fold higher in certain ethnic groups.

Between populations, when adjustments for age and other factors have been made, there are only small differences in the risk of diabetes at a given BMI. It seems that an elevation in BMI is more likely to provoke diabetes in people of Asian and African origin, and this probably relates to differences in body fat distribution and thus genetic tendencies towards the metabolic syndrome.[5]

Table I: Relative risks of diabetes at various levels of BMI

BMI (kg/m^2)	Relative risk (95% CI) for type 2 diabetes at age 30 - 55 years, from a BMI at age 18 years (adjusted for age and subsequent weight change)	Age-adjusted relative risk (95% CI) for type 2 diabetes over 14 years, according to BMI at age 30 - 55 years
22.0	1.0	1.0
25.0 - 26.9	3.3	8.1
31.0 - 32.9	9.6	40.3
>35.0	13.5	93.2

WAIST CIRCUMFERENCE AND DEVELOPMENT OF TYPE 2 DIABETES

The body of evidence linking increased waist circumference to diabetes is less than that for BMI, but this evidence is increasing rapidly as major studies recognise the value of waist circumference measurement. The waist circumference is also the most reproduceable of the anthropometric measures.[6] The measurement should be taken as defined by the WHO[1] according to bony landmarks.

How to measure a waist circumference:

Place the tape midway between the lowest rib and iliac crest. The tape should be horizontal with the subject standing in 'gentle expiration'.

There is strong evidence from cross-sectional studies that high waist circumference can identify people with type 2 diabetes.[7] In fact, it is apparent that waist circumference is the best long-term predictor of type 2 diabetes.[8] Interestingly, although there are differences in prevalence and relative risks between the sexes, a given waist circumference indicates approximately the same absolute risk of disease in men and women and also reflects the same intra-abdominal fat mass.[6]

As with BMI, there are minor variations in body composition that relate to diabetes development, reflected by waist circumference, between ethnic groups. But the same waist circumference leads to comparable incidences of type 2 diabetes within different populations.[5] These differences are, however, relatively small. In the San Antonio Heart Study, high waist circumference predicted the development of diabetes over seven years in Mexican Americans.[8] Research continues to define the absolute and relative risks of high waist circumference in Chinese and Asian populations, where diabetes appears to develop at lower waist circumferences than in Caucasians.

At present it seems safe to adopt 'action levels' for health promotion based on waist circumference measurements that have been agreed upon by bodies such as the National Institutes of Health (NIH), British Diabetic Association (BDA) / Diabetes UK and Health Education Board for Scotland (HEBS) (**Table II**). The value of maintaining waist circumference below action level 1 may be slightly different for ethnic groups, but any difference is unlikely to be of practical importance.

Waist circumference, unlike weight, can for practical purposes be used without any need to adjust for height. Indeed, across populations from around the world, there is no correlation between waist circumference and height. In the past, the waist-to-hip ratio has been proposed as a measure of risk. This complex term without a biological basis, and has subsequently been proven to be inferior to waist circumference alone for most purposes.[5] The waist-to-hip ratio was, however, first popularised in cross-sectional studies for the prediction of diabetes.[9,10] More detailed analysis in larger studies suggests that both high waist circumference and low hip circumference play a part in the development of type 2 diabetes.[11,12]

It is possible that a relatively low hip circumference might indicate reduced gluteal muscle mass, either through muscle catabolism during diabetes development, or through inactivity. A lower hip circumference

Table II: Measures of health risk for use in health promotion

	Waist circumference (cm)	BMI (kg/m2)
Healthy or normal	M < 94 F < 80	18.5 - 25
Increasing risks (avoid further weight gain)	M 94 - 102 F 80 - 88	25 - 30
High risks (seek professional help)	M > 102 F > 88	> 30

Table III: ATP III: Features of the Metabolic Syndrome

TRADITIONAL RISK FACTORS **The presence of > 3 factors would indicate a positive diagnosis.**
1. Abdominal Obesity (Waist circumference) - Men >102 cm - Women >88 cm
2. Elevated Triglycerides (> 1.9mM)
3. Low HDL Cholesterol - Men <0.9mmol/l - Women <1.1mmol/l
4. Elevated Blood Pressure (>130/>85 mmHg)
5. Elevated Fasting Glucose (>6.1mmol/l)

Table IV: Non-traditional factors

NON-TRADITIONAL RISK FACTORS **The presence of one or more risk factors will increase the odds ratio for ischaemic heart disease (IHD) 20 fold.**	
1. Increased insulin **2. Increased** Apo B	≈ Waist ≥ 90cm (over 49 years of age)
3. Increased small dense LDL	≈ TG > 2.0 mmol/l
4. Increased CRP	≈ quintiles waist

is less likely to affect bone growth, and possibly even foetal growth, since the waist-to-hip ratio is not as strongly predictive of diabetes as waist circumference alone in longitudinal studies.[8]

METABOLIC SYNDROME

The earliest clinical clustering of measurable factors that have a predictive value in the development of insulin resistance and diabetes can be grouped under the heading of the Metabolic Syndrome. The ATP III classification can be used in a diagnostic format for this syndrome (**Table III**).[9] Where three or more positive factors are present the addition of 'non-traditional' risk factors **(Table IV)** can increase the sensitivity of predicting an adverse cardiovascular outcome in these patients (**Fig. 1**). Patients with one or more positive factors should be rescreened on an annual basis.

ADDITIONAL RISK FACTORS

The presence of one or more of the following factors should alert the attending physician to screen the patient for type 2 diabetes.

- BMI > 25kg/m^2.
- Waist circumference > 102cm in men.
- Waist circumference > 88cm in women.
- Positive family history of obesity or diabetes or both (also gestational diabetes).
- Age > 40 years.
- Sedentary life-style / stressful life conditions.
- African and Asian ethnicity.
- High saturated fat intake.
- Presence of comorbid conditions (i.e. H.T. / IHD).
- Acanthosis Nigricans; polycystic ovarian disease; non-alcoholic fatty infiltration of the liver.

See CPD Questionnaire p.47

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Figure 1.