Waist Circumference and Waist–Hip Ratio

Report of a WHO Expert Consultation

GENEVA, 8–11 DECEMBER 2008

World Health Organization

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WHO Library Cataloguing-in-Publication Data

Waist circumference and waist–hip ratio: report of a WHO expert consultation, Geneva, 8–11 December 2008.

1.Body mass index. 2.Body constitution. 3.Body composition. 4.Obesity. I.World Health Organization.

ISBN 978 92 4 150149 1 (NLM classification: QU 100)

Printed by the WHO Document Production Services, Geneva, Switzerland.

Acknowledgements

This meeting report was originally prepared by Dr Prakash Shetty, with support from Professor Shiriki Kumanyika (Chairperson of the consultation) and Dr Gary Tin-Choi Ko (Rapporteur of the consultation). It was further developed and finalized with substantial support and inputs from Professor Shiriki Kumanyika, Professor Scott Lear, Professor Thorkild Sørensen and Professor Paul Zimmet, and the members of the WHO Secretariat (Dr Chizuru Nishida and Dr Francesco Branca).

Special acknowledgement is made to all the members of the expert consultation, in particular to those who prepared the background papers for the consultation. WHO is grateful to the European Journal of Clinical Nutrition for accepting and publishing these background papers (EJCN, vol 64, No. 1, pp 2–61, January 2010) for wider dissemination. Acknowledgement is also made to the WHO staff from the departments of Nutrition for Health and Development, and Chronic Diseases and Health Promotion, who provided valuable contributions to the consultation.

WHO expresses deep appreciation to the Ministry of Health, Labour and Welfare of the Government of Japan for their financial support for the commissioning of the background papers, holding of the expert consultation and production of the meeting report.

Technical editing of the report was undertaken by Dr Hilary Cadman from Cadman Editing Services in Australia and cover design was undertaken by Ms Sue Hobbs from Minimum Graphics in New Zealand.

Abbreviations and acronyms

ATP	Adult Treatment Panel
AUC	area under the receiver operating characteristic curve
BMI	body mass index
CARDIA	Coronary Artery Risk Development in Young Adults
CVD	cardiovascular disease
DEXA	dual X-ray absorptiometry
FAO	Food and Agriculture Organization of the United Nations
FPR	false-positive rate
IDF	International Diabetes Federation
MESA	Multi-Ethnic Study of Atherosclerosis
NCD	noncommunicable disease
NCEP	National Cholesterol Education Program
NHANES	National Health and Nutrition Examination Survey
NHLBI	National Heart, Lung and Blood Institute
NIH	National Institutes of Health
ROC	receiver operating characteristic
STEPS	STEPwise Approach to Surveillance (WHO)
SWAN	Study of Women's Health Across the Nation
TPR	true-positive rate
US	United States
WHO	World Health Organization

Contents

1 Introduction

The World Health Organization (WHO) Expert Consultation on Waist Circumference and Waist–Hip Ratio was held in Geneva, Switzerland on 8–11 December 2008. The consultation was organized by WHO's Department of Nutrition for Health and Development, in collaboration with the Department of Chronic Diseases and Health Promotion. It was opened by Dr Ala Alwan, WHO Assistant Director-General for Noncommunicable Diseases and Mental Health. The consultation was convened as part of WHO's:

- efforts in implementing the recommendations made at the WHO Consultation on Appropriate Body Mass Index for Asian Populations (WHO, 2004);
- response to the emerging problem of obesity and related chronic diseases, in particular in low- and middle-income countries.

The 1997 WHO Expert Consultation on Obesity recognized the importance of abdominal fat mass (referred to as abdominal, central or visceral obesity), which can vary considerably within a narrow range of total body fat and body mass index (BMI). It also highlighted the need for other indicators to complement the measurement of BMI, to identify individuals at increased risk of obesity-related morbidity due to accumulation of abdominal fat (WHO, 2000a). Waist–hip ratio (i.e. the waist circumference divided by the hip circumference) was suggested as an additional measure of body fat distribution. The ratio can be measured more precisely than skin folds, and it provides an index of both subcutaneous and intra-abdominal adipose tissue (Bjorntorp, 1987). The suggestion for the use of proxy anthropometric indicators arose from a 12-year follow-up of middle-aged men, which showed that abdominal obesity (measured as waist–hip ratio) was associated with an increased risk of myocardial infarction, stroke and premature death, whereas these diseases were not associated with measures of generalized obesity such as BMI (Larsson et al., 1984). In women, BMI was associated with increased risk of these diseases; however, waist–hip ratio appeared to be a stronger independent risk factor than BMI (Lapidus et al., 1984).

The 2002 WHO Expert Consultation on Appropriate Body Mass Index for Asian Populations and Its Implications for Policy and Intervention Strategies (WHO, 2004) reviewed the issue of ethnic differences in the meaning of BMI cut-off values. In populations with a predisposition to central (i.e. abdominal or visceral) obesity and the related increased risk of developing metabolic syndrome, the consultation recommended that, where possible, waist circumference should be used to refine action levels based on BMI. For example, levels based on BMI might be increased by one level if the waist circumference were elevated above a specified level. The choice of the action level for waist circumference should be based on population-specific data and health considerations. An expert working group was formed by the 2002 consultation, to start examining data on the relation between waist circumference and morbidity, and on any association between BMI, waist circumference and health risk. The aim was to develop recommendations for using waist measurements to further define risks.

WHO's Global Strategy for the Prevention and Control of Noncommunicable Diseases (WHO, 2000b), and the more recent 2008–2013 Action Plan for the Global Strategy for the Prevention and Control of Noncommunicable Diseases (WHO, 2008a), provide the platform for WHO's work on noncommunicable diseases (NCDs). These publications identified the monitoring of NCDs and their determinants as a key component for:

- developing policies;
- evaluating the effectiveness and impact of interventions;
- assessing the progress made.

The Expert Consultation on Waist Circumference and Waist–Hip Ratio contributed to the implementation of the global strategy and NCD action plan. It achieved this by reviewing and updating the waist circumference and waist–hip ratio issues related to diagnostic criteria, classifications and (possibly) management guidelines for major NCDs.

The overall aim of the expert consultation was to review the scientific evidence and make recommendations on the issues related to waist circumference and waist–hip ratio. It focused particularly on issues related to:

- methods of measurement;
- variations by sex, age and ethnicity;
- predicting risks of cardiovascular disease (CVD) and diabetes, and of overall mortality;
- relationship with BMI in predicting disease risks**.**

The specific objectives of the consultation were to:

- review the usefulness of waist circumference and waist–hip ratio measures as predictors of NCD risk;
- assess operational considerations related to measurement protocols and cut-off points for public health action;
- define potential cut-off points for public health action;
- identify future research needs.

To achieve these objectives, six peer-reviewed background papers were prepared by selected experts in the related fields. The selection of experts, both for the preparation of the background documents and for the actual consultation, followed WHO process and guidelines; as part of the process, all expert participants, peer reviewers and temporary advisors signed a declaration of interests.

Where possible, the background papers prepared for the consultation evaluated the strength of the evidence, using modified criteria from the World Cancer Research Fund, as adapted by an earlier joint WHO and Food and Agriculture Organization of the United Nations (FAO) Expert Consultation on Diet, Nutrition and the Prevention of Chronic Disease (WHO/FAO, 2003) (see Table 1.1, below). Much of the data and many of the study designs did not easily lend themselves to rigorous evaluation based on these criteria. Nevertheless, the criteria were useful to the discussions at the expert consultation, in relation to understanding conclusions on the differences among diverse populations derived from examination of associations between BMI and proxy anthropometric indicators of abdominal fat, and different health outcomes.

Table 1.1 Criteria for assessing strength of the evidence of association

Convincing evidence	Probable evidence	Possible evidence
• Based on epidemiological studies showing consistent associations between exposure and disease, with little or no evidence to the contrary • Based on a substantial number of studies including prospective observational studies and, where relevant, randomized controlled trials of sufficient size, duration and quality showing consistent effects • Association should be biologically plausible	• Based on epidemiological studies showing fairly consistent associations, but with perceived shortcomings in available evidence or some evidence to the contrary, precluding a more definite judgement • Shortcomings in the evidence may include insufficient duration of trials/studies, insufficient availability of trials/studies, inadequate sample sizes, and incomplete follow-up • Laboratory evidence is usually supportive • Association should be biologically plausible	• Based mainly from case–control and cross-sectional studies, and data from insufficient randomized control trials, observational studies, non-randomized control trials and evidence from non-epidemiological studies (i.e. clinical and laboratory based) • More trials are required to support tentative associations • Association should be biologically plausible

Adapted from WHO/FAO (2003)

This report provides a summary of the discussions of the expert consultation. It includes:

- discussion of the methods for measuring waist circumference and waist–hip ratio (Chapter 2);
- age, sex and ethnic variations in fat distribution (Chapter 3);
- associations of waist circumference and waist–hip ratio with BMI, and with health outcomes (Chapter 4).

Chapter 5 presents a summary and conclusions on these different aspects, and discusses approaches and research needs for using measurements of waist circumference and waist–hip ratio. Chapter 6 outlines steps that could be taken to arrive at appropriate WHO recommendations. Annex A contains background information (compiled by the WHO Secretariat) on existing cut-off points for waist circumference and waist–hip ratio. These cut-off points are used to variable extents, some for clinical and diagnostic purposes, others for screening and surveillance for public health purposes. Annex B lists the participants in the consultation.

The detailed background papers, together with an overview of the expert consultation, have been published elsewhere (Huxley et al., 2010; Lear et al., 2010; Nishida et al., 2010; Qiao & Nyamdorj, 2010a; Qiao & Nyamdorj, 2010b; Seidell, 2010; Stevens et al., 2010). The main findings and key issues identified from these background papers are included in this report.

Some of the potential uses of the cut-off points for waist circumference and waist–hip ratio include:

- surveillance
- screening
- diagnosis and decision to treat in a clinical situation
- assessing the value of treatment of an individual
- assessing the value of intervention in the community.

To use either or both of these measures, the method for selecting cut-off points to indicate thresholds for risk needs to be specified (WHO, 1995). The basis for identifying these cut-off points may be identical for the different measurements or may differ, depending on the purpose for which the cut-off points are used. The relevance to public health is related to prevention and the prediction of disease burden, rather than the prediction of mortality. As part of an evidence base to inform policy, these measures may be used to assess the need for interventions, and to assess effectiveness of interventions in reducing health risks or associated costs and burdens.

2 Methods for measuring waist and hip circumference

An important issue in using and interpreting waist circumference or waist–hip ratio is the protocol used to obtain the measurements. Also important is the extent to which the measurement protocol varies across studies, and the potential for standardizing these measurements within a study or survey, when taken by different people.

Theoretically, differences in measurements protocols across studies could be responsible for variation in the association of these measures with risk factors, or disease or mortality outcomes. Therefore, the expert consultation considered background information on protocols currently in use, and the impact of differences in measurement approaches on measurement error and associations with health outcomes. The aim was to recommend an appropriate protocol for international use.

Elements of the protocol discussed below include:

- the anatomical placement of the measuring tape, its tightness and the type of tape used;
- the subject's posture, phase of respiration, abdominal tension, stomach contents and clothing.

2.1 Placement, tightness and type of measuring tape

2.1.1 Placement of tape

Waist circumference

The WHO STEPwise Approach to Surveillance (STEPS) provides a simple standardized method for collecting, analysing and disseminating data in WHO Member countries. The WHO STEPS protocol for measuring waist circumference instructs that the measurement be made at the approximate midpoint between the lower margin of the last palpable rib and the top of the iliac crest (WHO, 2008b). The United States (US) National Institutes of Health (NIH) protocol provided in the *NIH Practical guide to obesity* (NHLBI Obesity Education Initiative, 2000) and the protocol used in the US National Health and Nutrition Examination Survey (NHANES) III (Westat Inc, 1998) indicate that the waist circumference measurement should be made at the top of the iliac crest.

The NIH also provided a protocol for the measurement of waist circumference for the Multi-Ethnic Study of Atherosclerosis (MESA) study. This protocol indicates that the waist measurement should be made at the level of the umbilicus or navel. However, published reports indicate that measurements of waist circumference made at the level of the umbilicus may underestimate the true waist circumference (Croft et al., 1995).

Some studies have assessed the waist circumference at the point of the minimal waist (Ross et al., 2008).

Hip circumference

All of the protocols mentioned in Section 2.1.1 indicate that the hip circumference measurement should be taken around the widest portion of the buttocks.

2.1.2 Tightness and type of tape

The accuracy of waist and hip circumference measurements depends on the tightness of the measuring tape, and on its correct positioning (i.e. parallel to the floor at the level at which the measurement is made). The WHO STEPS protocol states that, for both waist and hip, the tape should be snug around the body, but not pulled so tight that it is constricting (WHO, 2008b). The protocol also recommends the use of a stretch-resistant tape that provides a constant 100 g of tension through the use of a special indicator buckle; use of this type of tape reduces differences in tightness.

Both the protocol described in *NIH Practical guide to obesity* (NHLBI Obesity Education Initiative, 2000) and the NHANES III protocol (Westat Inc, 1998) recommend that the measurements be made with the tape held snugly, but not constricting, and at a level parallel to the floor.

2.2 Subject posture and other factors

2.2.1 Posture of the subjects during the measurement

The posture of the subject at the time the measurement is taken influences the accuracy of the measurement. Thus, the WHO STEPS protocol recommends that the subject stands with arms at the sides, feet positioned close together, and weight evenly distributed across the feet (WHO, 2008b). The NHANES III protocol recommends that the subject be standing erect, with the body weight evenly distributed (Westat Inc, 1998).

2.2.2 Phase of respiration at the exact point of measurement

The phase of respiration determines the extent of fullness of the lungs and the position of the diaphragm at the time of measurement; it also influences the accuracy of the waist circumference. The WHO STEPS protocol suggests that the waist circumference should be measured at the end of a normal expiration, when the lungs are at their functional residual capacity (WHO, 2008b). The NHANES III protocol states that the waist circumference should be measured at minimal expiration (Westat Inc, 1998).

2.2.3 Abdominal tension at the point of measurement

The tension of the abdominal wall influences the accuracy of the waist circumference measurement. Lowering the tension of the abdominal wall increases waist circumference, whereas increasing the tension (by sucking in) reduces waist circumference. Many individuals unconsciously react to waist measurements by sucking in the abdominal wall; hence, a relaxed posture is best for taking waist measurements. The WHO STEPS protocol recommends advising the subject to relax and take a few deep, natural breaths before the actual measurement is made, to minimize the inward pull of the abdominal contents during the waist measurement (WHO, 2008b).

2.2.4 Influence of stomach contents at time of measurement

The amount of water, food or gas in the gastrointestinal tract will affect the accuracy of the waist measurement. Gibson (1990) suggests that a waist measurement be made after the subject has fasted overnight or is in a fasted state, to reduce this effect. None of the protocols evaluated address this issue, perhaps because it would entail the subject being notified in advance of the measurement, and being present the morning after an overnight fast.

2.3 Measurement error

Information on the measurement error of the waist circumference and hip circumference has come from studies in adolescents. Lohman et al. (1988) calculated the technical error of waist circumference measurement in adolescents to be 1.31 cm from intrameasurer error and 1.56 cm from intermeasurer error. For hip measurements, the authors calculated the technical error to be 1.23 cm from intrameasurer error and 1.38 from intermeasurer error.

2.4 Implications of differences in methodology

There has been no evaluation of the effects of differences in the methods of measurements of waist and hip circumferences on measurement error and on the prediction or estimation of specific adipose tissue depots (e.g. abdominal fat). However, a systematic review of 120 studies examined whether measurement protocols influenced the relationship of waist circumference with morbidity from CVD and diabetes, and mortality from CVD and all causes (Ross, et al., 2008). The review only focused on the anatomical site of placement of the tape for waist circumference measurement. Most protocols measured at the midpoint (36%), umbilical level (28%) and minimal waist level (25%). Similar patterns of association were observed between health outcomes and all waist circumference protocols across sample size, sex, age, race and ethnicity. The review concluded that waist circumference measurement protocol had no substantial influence on the association between waist circumference, all-cause and CVD-specific mortality, and risk of CVD and diabetes (Ross, et al., 2008).

Even when the same protocol is used, there may be variability within and between measurers when more than one measurement is made. The experts were uncertain whether these and other issues related to measurement are relevant at either the population or the clinical level, and felt that this may be an important area for inclusion in the future research agenda.

2.5 Summary and conclusions

Waist circumference should be measured at the midpoint between the lower margin of the least palpable rib and the top of the iliac crest, using a stretch-resistant tape that provides a constant 100 g tension. Hip circumference should be measured around the widest portion of the buttocks, with the tape parallel to the floor.

For both measurements, the subject should stand with feet close together, arms at the side and body weight evenly distributed, and should wear little clothing. The subject should be relaxed, and the measurements should be taken at the end of a normal expiration. Each measurement should be repeated twice; if the measurements are within 1 cm of one another, the average should be calculated. If the difference between the two measurements exceeds 1 cm, the two measurements should be repeated.

3 Impact of variations in body fat distribution by sex, age and ethnicity

Commonly used cut-off points for waist circumference and waist–hip ratio are based on studies undertaken predominantly in populations of European origin. The importance of taking into account ethnic differences in the amount of body fat associated with waist circumference or waist–hip ratio at different BMI levels was a primary motivation for this expert consultation, based on the findings of the 2002 WHO Expert Consultation on Appropriate Body Mass Index for Asian Populations and Its Implications for Policy and Intervention Strategies (WHO, 2004).

The key issue is whether there are systematic differences in the extent to which a given waist circumference or waist–hip ratio level predicts disease outcomes in different ethnic groups, particularly if such differences could lead to underestimation of risk in certain populations. Systematic differences could relate to one or both of the following:

- differences in body composition – that is, the relative amounts or types of fat reflected in the waist circumference or waist–hip ratio measurement;
- differences in disease risk for a particular body fat profile.

Also of interest were variations in body fat distribution that may affect all populations; for example, variations between men and women, and with ageing. This chapter summarizes the issues related to sex, age and ethnic variations. More detailed discussions were provided in the background paper that examined associations between sex, reproductive status and age, and waist circumference (Stevens, et al., 2010); and the paper that examined associations between ethnicity and waist circumference (Lear, et al., 2010).

3.1 Sex

Sex differences in deposition of body fat are evident even at the foetal stage, but they become much more pronounced during puberty (Wells, 2007). After adjusting for differences in height, men have greater total lean mass and bone mineral mass, and a lower fat mass than women; these differences continue throughout adult life. Women have substantially more total adipose tissue than men, and these whole-body sex differences are complemented by major differences in tissue distribution. Men have greater arm muscle mass, larger and stronger bones, less limb fat and a relatively greater central distribution of fat. Women have a more peripheral distribution of fat in early adulthood. Sex differences in body composition are primarily attributable to the action of sex steroid hormones, which drive the dimorphisms during pubertal development. In men, a reduction in free testosterone levels is associated with an increase in fat mass and reduction in muscle mass, and both total and free testosterone levels are inversely associated with obesity (Derby et al., 2006).

3.2 Reproductive status

Parity is an important contributor to changes in body composition and body shape in women. Pregnancy is associated with gains in visceral and central adiposity postpartum. Cross-sectional analysis of data from NHANES III illustrated how parity is associated with changes in body shape (Lassek & Gaulin, 2006). Data from 16 325 women showed that women who had given birth had less lower body fat and greater waist circumference. After controlling for age and BMI, increasing parity was associated with lower hip and thigh circumferences, and higher waist circumference. These findings are supported by data over 10 years of follow-up from the Coronary Artery Risk Development in Young Adults (CARDIA) study of women aged 18–30 years (Gunderson et al., 2004). Both first and higher order births were associated with increases in waist circumference.

Menopause is also associated with an increase in fat mass, and a redistribution of fat to the abdominal area (Toth et al., 2000). It is not clear whether such changes are due to hormonal changes or to the ageing process. The Study of Women's Health Across the Nation (SWAN) included an ethnically-diverse cohort of 3064 women, with an average age of 45.9 years. SWAN showed no independent effect of menopause on fat distribution (Sternfeld et al., 2004). Over a 3-year follow-up, the study showed a mean weight gain of 2.1 kg (3% increase) and a mean increase in waist circumference of 2.2 cm (2.8% increase); gains that could be attributed to age and physical activity level. Other studies concurred with SWAN, suggesting that, on average, women experience a 0.68 kg per year increase in weight during their 40s and 50s, regardless of menopausal status (Macdonald et al., 2003; Wing et al., 1991).

3.3 Age

To appreciate the effect of ageing on fat distribution, changes in BMI that occur with increasing age need to be considered. Changes in body weight and BMI are strongly related to changes in fat-free mass, and explain 54% of the variance in those changes (Forbes, 1999). While the associations between BMI and body fat are linear, the association with per cent body fat is curvilinear, with the slope steeper at lower BMIs than at higher BMIs (Welch & Sowers, 2000). Per cent body fat may remain constant or increase with age, but ageing is associated with substantial redistribution of fat tissue among depots (Cartwright et al., 2007). From late middle age until the 80s or later, there is a decline in the volume of subcutaneous fat, and a redistribution of fat from subcutaneous to visceral depots. This age-associated decline in the size of adipose depots is accompanied by the accumulation of fat outside adipose tissue (in muscle, liver and bone marrow), and loss of lean body mass.

Data from NHANES show that waist circumference increases with age, and is larger in older than in younger adults of both sexes up to the age of 70 years (Ford et al., 2003). Similarly, in the Baltimore Longitudinal Study of Aging, age-related differences in waist–hip ratio were also reported in all BMI categories examined in both men and women (Shimokata et al., 1989). Changes in waist circumference were followed up in Finnish adults (9025 men and 9950 women aged 25–64 years), and mean waist circumference was seen to increase by 2.7 cm in men and 4.3 cm in women over a 15-year period (Lahti-Koski et al., 2007). BMI also increased over the study period, but the changes were relatively small (1.2% or less per 5-year period) in all but the youngest age category (25–34 years), while increases in waist circumference were seen in every age group.

The Baltimore Longitudinal Study of Aging also examined the effects of weight change on changes in fat distribution (Shimokata, et al., 1989). The study found that changes in waist and hip circumferences correlated directly with changes in weight, but there were differences in the pattern of change by sex. In men, waist changes were larger than hip changes, whereas in women they were similar. This resulted in weight changes in men having a larger effect on waist–hip ratio. On average, with a 4.5 kg weight gain, men had a 4 cm increase in waist circumference and a 2.5 cm increase in hip circumference. Comparable values for women were 3.3 cm and 3.6 cm, respectively.

3.4 Ethnicity

Interpretation of evidence on ethnic differences is complicated by issues related to defining ethnicity, and other methodological issues that are outlined in the background paper prepared by Lear et al. (2010). The background review only considered studies on populations that were not represented in earlier analyses and that led to recommendations about waist circumference or waist–hip ratio cut-offs in Europeans. The potential significance of these differences for identifying cut-off points to predict health outcomes is considered in Chapter 4.

3.4.1 Ethnic groups for which waist circumference or waist–hip ratio may reflect more body fat at a given body mass index level

Studies investigating body composition and the association with health outcomes in Asian populations have focused on study populations defined as Chinese, Japanese and Korean or South Asian (or Indian). However, a number of studies have analysed these ethnic groups as a homogeneous population labelled as "Asians". These studies found a higher percentage of body fat in Asians at lower BMI (Deurenberg-Yap et al., 2001; Deurenberg-Yap et al., 2000), as well as an increased prevalence of truncal fat, compared to Caucasians (Wu et al., 2007).

3.4.2 Populations for which waist circumference or waist–hip ratio may reflect less body fat at a given body mass index level

Chinese and South Asian men and women display a greater amount of visceral adipose tissue for a given waist circumference than Europeans (Lear et al., 2007b). Similarly, a higher percentage of body fat across a range of waist circumference values has been documented in East Asia (Kagawa et al., 2007).

In North America, comparisons of Indigenous people and Caucasians have reported no difference in the relationships between visceral adipose tissue and BMI (Gautier et al., 1999), total body fat (Lear, et al., 2007b) or waist circumference (Lear et al., 2007a). Australian Aboriginals living in a remote area were reported to have higher waist–hip ratios with lower BMIs than urban Australians of European origin (Piers et al., 2003).

Compared to European women, black women in South Africa have a slightly lower BMI at a given percentage body fat, but also have less abdominal adipose tissue – as determined by dual X-ray absorptiometry (DEXA) – at the same waist circumference (Rush et al., 2007). A few small studies report African women as having less visceral adipose tissue than white women (Punyadeera et al., 2001a; Punyadeera et al., 2001b; van der Merwe et al., 2000).

In Hispanics, one study reported that visceral adipose tissue at a given waist circumference was not appreciably different from that of whites (Carroll et al., 2008; Haffner et al., 1996; Nelson et al., 2008).

Some studies have reported that Pacific Islanders have larger muscle masses and lower percentage body fat than Europeans at similar BMIs (Rush et al., 2004; Rush et al., 2009). In women, this has also been reported for similar waist circumferences and waist–hip ratios (Rush, et al., 2007).

3.5 Summary and conclusions

There is substantial evidence of sex and age variations in waist circumference and waist–hip ratio, and some evidence for ethnic differences. Compared to Europeans, Asian populations have greater visceral adipose tissue, and African populations and, possibly, Pacific Islanders have less visceral adipose tissue or percentage of body fat at any given waist circumference. If higher levels of abdominal fat for a waist circumference or waist–hip ratio level are reflected in associations with health outcomes, then lower thresholds for these indicators might be needed for the affected populations than for European or other reference populations. There is relatively consistent evidence that this situation may apply to Asian populations. Data for Africans and Pacific Islanders are examples of possible indications for a need for higher cut-offs than those used for European reference populations. However, given that the objective is to predict disease risk, drawing conclusions about cut-offs solely on the basis of observed risks does not seem appropriate.

4 Relationships of waist circumference and waist–hip ratio to disease risk and mortality

Both generalized and abdominal obesity are associated with increased risk of morbidity and mortality. The main cause of obesity-related deaths is CVD, for which abdominal obesity is a predisposing factor. It is unclear which anthropometric measure is the most important predictor of risk of CVD in adults – BMI, waist circumference, waist–hip ratio or even hip circumference.

BMI has traditionally been the chosen indicator by which to measure body size and composition, and to diagnose underweight and overweight. However, alternative measures that reflect abdominal adiposity, such as waist circumference, waist–hip ratio and waist–height ratio, have been suggested as being superior to BMI in predicting CVD risk. This is based largely on the rationale that increased visceral adipose tissue is associated with a range of metabolic abnormalities, including decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profiles, which are risk factors for type 2 diabetes and CVD.

This chapter summarizes the experts' discussions on the strength of associations between anthropometric measures and health outcomes. More detailed reviews are provided in several of the background papers (Huxley, et al., 2010; Qiao & Nyamdorj, 2010a; Qiao & Nyamdorj, 2010b; Seidell, 2010).

One paper examined how waist circumference, waist–hip ratio and BMI perform in predicting and differentiating risks of hypertension, dyslipidaemia and diabetes (as major risk factors for CVD), and risks of CVD events (Huxley, et al., 2010). The authors reviewed data comparing Asian and Pacific with Caucasian populations, and data on other ethnically diverse study populations. Other studies examined the relative associations of waist circumference, waist–hip ratio and BMI with diabetes risk (Qiao & Nyamdorj, 2010a; Qiao & Nyamdorj, 2010b). Seidell (2010) reviewed data on all-cause mortality, cancer and sleep apnoea in association with waist circumference, waist–hip ratio and BMI, highlighting variations in findings according to choice of indicator, age and BMI status of the population.

4.1 Measures of obesity and abdominal obesity and cardiovascular disease risk

Based on an extensive review, Huxley et al. (2010) concluded that there was convincing evidence that measures of general obesity (e.g. BMI) and measures of abdominal adiposity (e.g. waist circumference, waist–hip ratio and waist–height ratio) are associated with CVD risk factors and incident CVD events. The authors also concluded that there was probable evidence that:

- measures of abdominal obesity are better than BMI as predictors of CVD risk, although combining BMI with these measures may improve their discriminatory capability;
- for any given level of BMI, waist circumference or waist–hip ratio, the absolute risk of diabetes or hypertension (risk factors for CVD incidence) is higher in some population groups than in Caucasian adults;
- universal cut-off points for BMI and waist circumference are not appropriate for use worldwide, given ethnic or population-specific differences in disease risk for any

particular anthropometric measure; however, there may be general consistency in the cut-off points of waist–hip ratio for predicting CVD risk.

4.2 Measures of obesity, abdominal obesity and type 2 diabetes risk

The positive association between obesity and the risk of developing type 2 diabetes has been repeatedly observed, both in cross-sectional studies (Hartz et al., 1983; Shaten et al., 1993; Skarfors et al., 1991) and in prospective studies (Cassano et al., 1992; Colditz et al., 1990; Ohlson et al., 1985). The consistency of the association across populations – despite differences in measures of fatness and diagnostic criteria for diabetes in adults – reflects the strength of this relationship. The risk of type 2 diabetes in adults increases continuously with increasing obesity, and decreases with weight loss. A careful analysis of the relationship between obesity and adult-onset diabetes confirms that abdominal obesity is an important risk factor, even after controlling for age, smoking and family history. Since waist circumference correlates more closely with abdominal adipose tissue than BMI, the association between indicators of such obesity (e.g. waist circumference and waist–hip ratio) has been studied extensively in the last two decades.

Qiao & Nyamdorj (2010b) concluded that, with respect to type 2 diabetes, all anthropometric measures (BMI, waist circumference, waist–hip ratio and waist–height ratio) performed similarly in predicting risk. However, data from most of the cross-sectional studies suggested that waist circumference or waist–hip ratio are better indicators than BMI of the risk of diabetes. The number of prospective studies was limited, and the studies covered only a few ethnic or population groups; thus, the evidence that waist circumference or waist–hip ratio is preferable is neither convincing nor generalizable. The cross-sectional studies provide only possible association, and the strength of evidence may be considered as possible (see Table 1.1). All these studies have provided evidence that either BMI or waist circumference predicted an association with diabetes, and an increased risk of the disease, independent of other factors.

Key methodological issues that affected the ability to draw clear conclusions were emphasized by Qiao & Nyamdorj (2010b). In the reviews undertaken, most studies used the "sensitivity and specificity" approach to determine the optimal cut-off points for anthropometric measures predicting type 2 diabetes risk. Selection of cut-off points using such an approach is arbitrary, because values are based on analysis of the trade-offs between sensitivity and specificity. Although a high sensitivity for the waist circumference measurement may be preferred in health promotion (to increase public awareness of obesity and diabetes), a high specificity in diagnostic criteria is expected in clinical practice.

Thus, the usefulness of waist circumference measurement as a first-step diagnostic tool when assessing an individual's risk of diabetes is unclear. Further investigation based on well-designed prospective studies with incident type 2 diabetes as the outcome would be needed to make recommendations on the use of the waist circumference. Most published studies are cross-sectional, so the interpretation of results is likely to be confounded by other concurrent conditions such as hypertension and dyslipidaemia. However, the literature review and analysis did confirm that the optimal cut-off points for indicators of overweight and obesity, and measures of abdominal obesity, vary across different ethnicities and population groups. The findings also supported the view that there is no optimal cut-off point that can be applied worldwide. The review undertaken by Qiao & Nyamdorj (2010b) suggested that country or region-specific cut-off points may need to be used, taking into consideration the purpose for which the value is required and the availability of resources.

4.3 Measures of obesity and abdominal obesity and all-cause mortality and mortality from specific causes

Due to inconsistencies in the literature, controversy continues about the relationship between obesity and overall mortality (WHO, 2000a). Some studies have found a U or J-shaped association, with higher mortality rates at both the upper and lower weight ranges. Others have shown a gradual and continuous increase in mortality with increasing body weight, or no association at all between body weight and mortality. Many of the studies on obesity and mortality have systemically underestimated the impact of obesity on premature mortality, due to bias in the study design. This bias may be the result of failure to control for smoking, inappropriate control for associated conditions (e.g. hypertension, dyslipidaemia and hyperglycaemia, which are essentially comorbidities of obesity), failure to control for weight loss with illness and failure to standardize for age (Manson et al., 1987; Seidell et al., 1996).

Seidell (2010) concluded that:

- waist circumference and waist–hip ratio are both related to increased risk of all-cause mortality, throughout the range of adult BMIs;
- waist circumference and waist–hip ratio are strongly predictive in young and middle-aged adults compared to older people and those with low BMI;
- waist circumference alone could replace waist–hip ratio and BMI as a single risk factor for all-cause mortality.

However, data are lacking on appropriate cut-offs for measures of abdominal obesity for predicting risk of all-cause mortality in ethnic and population groups other than European, North American and Australian white populations. Evidence for use of waist circumference or waist–hip ratio to replace BMI for predicting morbidity related to cancer risk is less strong than for all-cause mortality.

4.4 Ethnic differences

Numerous studies of populations throughout the world have suggested using cut-off points specific to ethnic groups. This section highlights studies that have evaluated (directly or indirectly) the potential basis for waist circumference or waist–hip ratio cut-off points that differ from those proposed for general use and are based on European or Caucasian reference populations.

When studies in Asian populations are taken together, Asians appear to have an increased metabolic risk at lower waist circumference and waist–hip ratio than Europeans. This is probably due to higher levels of body fat and abdominal adipose tissue. In particular, those studies that included a European or Caucasian comparison group indicated a lower waist circumference for Asians, and some also suggested a lower waist–hip ratio (Diaz et al., 2007; Huxley et al., 2007; 2008). These data indicate a lower waist circumference and waist–hip ratio cut-off point for Asians; for example, waist circumference values of 85 cm and 80 cm, and waist–hip ratio values of 0.90 and 0.80 for men and women, respectively. Studies in populations residing in the Middle East have provided waist circumference and waist–hip ratio cut-off points similar to those suggested for Europeans. Only one analysis reported on waist circumference cut-off points in Africans (none investigated waist–hip ratio cut-off points). That analysis recommended 75.6 cm and 80.5 cm for men, and 71.5 cm and 81.5 cm for women of Nigerian and Cameroon origin, respectively, for the identification of hypertension (Okosun et al., 2000a; Okosun et al., 2000b). Given that no other studies have investigated cut-offs in this population group, there is insufficient evidence for recommending specific cut-offs for sub-Saharan Africans.

Cut-off points for waist circumference of 94 cm and 80 cm (determined for European men and women, respectively) have been associated with a 1.5–2.0 fold increased risk in hypertension, and a 3.9 and 1.6 fold increase in diabetes, in men and women of African origin, respectively (Okosun et al., 1998). Findings that African-Americans tend to be leaner than Europeans are inconsistent with the data indicating that African-Americans are at increased risk for CVD at a given waist circumference (due to higher blood pressure and lipids). Studies investigating specific cut-off points for African-Americans either suggested similar cut-off points to those used for Europeans, based on the limited evidence available, or indicated that there was not enough evidence to set specific cut-off points for African-Americans.

Studies investigating South Americans recommended waist circumference cut-off points of 88–90 cm for men, and 83–84 cm for women (Lear, et al., 2010). Three studies reporting on waist–hip ratio indicated a value ranging from 0.85 to 0.95 in men, and from 0.80 to 1.18 in women. These studies suggested that waist circumference cut-off points should be lower than those for Europeans, but that waist–hip ratio cut-off points should be similar to those for Europeans. Only one study in Hispanics provided a recommendation for cut-off points; it suggested a waist circumference of 90 cm for men and 85 cm for women, and a waist–hip ratio of 0.90–0.91 for men and 0.84–0.86 for women (Berber et al., 2001). Another study suggested that the current waist circumference cut-off points based on Europeans provided low sensitivity with respect to metabolic risk factors for the Hispanic population (Okosun, et al., 2000a).

4.5 Summary and conclusions

The overall results of the evaluation of the associations between waist circumference and waist–hip ratio with measures of metabolic diseases and risk factors are summarized in Table 4.1, and presented below.

4.5.1 Cardiovascular disease

The biological rationale for relating measures of central adiposity to CVD risk is that abdominal adipose tissue (which is positively associated with waist circumference and waist–hip ratio) is related to a range of metabolic abnormalities. These abnormalities include decreased glucose tolerance, reduced insulin sensitivity and adverse lipid profiles, which are risk factors for type 2 diabetes and CVD. Most anthropometric indicators of abdominal obesity have been derived from predominantly European populations. This has raised issues about the applicability of the recommended cut-off points to non-European populations, among whom the problem is currently of much greater concern. Neither is there consensus over which of these measures of central adiposity is most strongly associated with CVD risk, either within or between different ethnic groups.

It has been suggested that waist circumference, waist–hip ratio and waist–height ratio, which reflect abdominal adiposity, are superior to BMI in predicting CVD risk. For example, in the INTERHEART case–control study of myocardial infarction in diverse populations in 52 countries (Yusuf et al., 2005), BMI, waist circumference and waist–hip ratio were all strongly and linearly associated with risk of myocardial infarction. Relationships with BMI were attenuated by adjustment for waist–hip ratio, but relationships with waist measures were relatively unaffected by adjustment for BMI, indicating the independence of measures of abdominal obesity in predicting risk. However, a combined analysis of the Physicians' Health Study and the Women's Health Study found that (Gelber et al., 2008):

- the magnitude of associations of BMI, waist circumference, waist–hip ratio and waist–height ratio with CVD risk were similar;
- these measures were not entirely independent as predictors of risk;
- differences according to the measure used were not likely to be clinically significant.

In the Asia Pacific Cohort Study, none of the anthropometric indices were clearly associated with stroke outcomes (APCSC, 2006). Overall, these measures seem to be comparable in their discriminatory capability – as assessed by the area under the receiver operating characteristic curve (AUC) – at identifying those individuals with the highest risk of CVD (Huxley, et al., 2010).

4.5.2 Diabetes

Data from prospective studies show a wide range of relationships between anthropometric measures and risk of type 2 diabetes; hence, it would be difficult to conclude that measures of abdominal obesity are always superior to BMI in predicting risk. However, most of the cross-sectional studies showed that the AUC was slightly larger for waist circumference or waist–hip ratio than for BMI.

4.5.3 Risk factors

This review suggests that, at any given level of body size, the prevalence of hypertension, diabetes and dyslipidaemia is higher in Asian than in non-Asian populations. It also suggests that no anthropometric measure is more strongly associated with blood pressure, plasma glucose, diabetes and lipid levels than any other measure. However, BMI appears to be less informative than other measures.

4.5.4 Mortality

The evidence with regard to anthropometric measures – in particular waist circumference or waist–hip ratio measures and all-cause mortality – is predominantly from white European and American adults, both in young and middle-aged adults and older people. Few studies have examined African and Asian populations. When waist circumference was adjusted for BMI, the relationship appears J-shaped to almost linear.

4.5.5 Ethnic differences

Overall, the data suggested that, for a given combination of BMI and waist circumference or waist–hip ratio measures, the risk is higher for Asians for all disease outcomes; however, it was not possible to draw definitive conclusions, due to limitations of the data. Only in populations of Asian descent were differences in risk sufficient to warrant consideration of alternative cut-off points. The multiple causality and impact of the nutrition transition may also contribute to the interpretation of apparent ethnic differences. Specifically, the impact of exposure to undernutrition (including gestational exposure to maternal undernutrition) on subsequent weight gain and fat deposition was noted as a possible factor contributing to differences among populations. A rising relative risk of disease along the continuum of waist circumference or waist–hip ratio was also evident. However, the absolute risk currently determined by the multiple risk factors associated with body fat and its distribution may well reflect the phase of disease transition in a population. Hence, the thresholds for risk associated with waist circumference or waist–hip ratio may vary with time. These considerations make it difficult to specify cut-off points on the basis of ethnicity.

Table 4.1 Summary of the associations of body mass index, waist circumference, waist–hip ratio and waist–height ratio with disease risk

	Body mass index		Waist circumference		Waist–hip ratio		Waist–height ratio		Remarks and major references
	Relationship	Strength of evidence[a]	Relationship	Strength of evidence[a]	Relationship	Strength of evidence[a]	Relationship	Strength of evidence[a]	
CVD risk	++	Convincing	++++	Convincing	++++	Convincing	+++	Convincing	de Koning et al. (2007) APCSC (2006) Yusuf et al. (2005) Gelber et al. (2008) Zhu et al. (2005)
Overall CVD risk factors (mainly cross-sectional data)	++	Convincing	+++	Convincing	+++	Convincing	+++	Convincing	Lee et al. (2008)[b]
CVD risk factors (from STEPS analysis presented in the WHO meeting)	/	/	+++	Probable	+++	Probable	/	/	WHO (2008b)
Type 2 diabetes mellitus (prospective studies)	+++	Convincing	+++	Convincing	+++	Convincing	/	/	Vazquez et al. (2007)
Type 2 diabetes mellitus (cross-sectional studies)	+++	Convincing	++++	Convincing	++++	Convincing	++++	Convincing	Huxley et al. (2007) Huxley et al. (2008) Nyamdorj et al. (2008)[b] Qiao & Nyamdorj (2010b)
Hypertension (mainly cross-sectional data)	+++	Convincing	+++	Convincing	+++	Convincing	+++	Convincing	Wolf & Colditz (1998) James et al. (2004) Huxley et al. (2007) Huxley et al. (2008) Nyamdorj et al. (2008)[b]
Overall mortality (without mutual adjustment of the anthropometric parameters)	+++	Convincing	+++	Convincing	+++	Convincing	+++	Convincing	Koster et al. (2008) Zhang et al. (2008) Welborn & Dhaliwal (2007)[b] Remarks: Some studies showed J-shape relationship with BMI, especially elderly people (Dolan et al., 2007; Katzmarzyk et al., 2002) Evidence is less consistent in elderly people (Baik et al., 2000; Price et al., 2006)
Overall mortality (with mutual adjustment of the	0/–	Probable	++++	Convincing	++++	Convincing	/	/	Kalmijn et al. (1999) Pischon et al. (2008)

	Body mass index		Waist circumference		Waist–hip ratio		Waist–height ratio		Remarks and major references
	Relationship	Strength of evidence[a]	Relationship	Strength of evidence[a]	Relationship	Strength of evidence[a]	Relationship	Strength of evidence[a]	
anthropometric parameters)									Bigaard et al. (2003)
Cancer – colorectum, breast (post-menopause)	+++	Convincing	++	Convincing	++	Convincing	NR	NR	Moghaddam et al. (2007) Harvie et al. (2003)
Cancer – pancreas, endometrium, cervix, kidney, gallbladder	+	Possible	+	Possible	+	Possible	NR	NR	AICR (2007)

APCSC, Asia Pacific Cohort Studies Collaboration; BMI, body mass index; CVD, cardiovascular disease; FAO, Food and Agriculture Organization of the United Nations; NR, not reported; STEPS, STEPwise Approach to Surveillance; WHO, World Health Organization

Levels of evidence are based on the report of the joint WHO/FAO expert consultation (WHO/FAO, 2003) (see Table 3.1 of that report)

Relationship: + to ++++ = positive association, mild to strong; 0/– = negative association, nil to mild

[a] Definitions of the strength of evidence are based on those that were used by the 2002 joint WHO/FAO Expert Consultation on diet, nutrition and the prevention of chronic diseases (WHO/FAO, 2003)

[b] References with evidence on waist–height ratio

5 Summary and conclusions

The aim of the expert consultation was to provide guidance that WHO could use to develop recommendations and ultimately provide guidelines for the effective use of specific cut-off points for waist circumference and waist–hip ratio. Making definitive decisions on actual cut-off points was outside the scope of the consultation. However, the expert consultation was asked to advise WHO on how the process of developing actual cut-off points could be moved forward, and to identify any gaps in the data.

This chapter summarizes the potential usefulness and relative advantages of:

- waist circumference versus waist–hip ratio, with or without accompanying BMI measurements;
- measurement protocols for waist circumference and waist–hip ratio;
- methods for selecting cut-off points;
- considerations for determining the need for population-specific cut-off points.

5.1 Usefulness of waist circumference and waist–hip ratio for prediction of disease risk

The fundamental question of whether waist circumference and waist–hip ratio are useful measures for predicting disease risk was answered with convincing evidence. An increase in both of these indices is associated with increased disease risk, and this association is evident in diverse populations, although most of the data were derived from populations of European descent. Waist circumference and waist–hip ratio (as measures of abdominal obesity) were correlated with BMI, but the level of association varied, suggesting that these measures may provide different information and thus may not be interchangeable. Practical considerations appeared to favour the use of waist circumference as an alternative to BMI. For example, waist circumference may be justified when measuring the waist is easier and more accurate than measuring weight and height. Measuring hip circumference may be more difficult than measuring waist circumference alone; this could limit the potential use of waist–hip ratio as an alternative to either waist circumference alone or BMI.

In assessing the complementarity of BMI and waist measures, the main issue was whether there was a substantial gain in information when using both measures, as suggested in the *NIH Practical guide to obesity* (Table 5.1) and the International Diabetes Federation (IDF) guidelines (Table 5.2). This also raised some more general issues:

- the extent to which the range of waist circumference depends on body size;
- whether differences in the waist circumference distribution in populations with different body sizes may create problems in arriving at appropriate cut-off points that would be similarly sensitive to health risk in all populations (e.g. the *NIH Practical guide to obesity* suggests that waist circumference cut-offs are only useful up to a BMI of 35, after which most individuals will exceed the cut-off points).

Due to the relative ease of obtaining waist circumference, its use is favoured over waist–hip ratio. There was insufficient data on other proxy measures (e.g. waist–height ratio), to suggest giving other measures any priority at present. Although BMI and abdominal adiposity measures may be highly correlated, it is desirable to obtain a BMI, where possible, and consider the utility of joint use of the two indicators.

Table 5.1 Combined recommendations of body mass index and waist circumference cut-off points made for overweight or obesity, and association with disease risk

	Body mass index	Obesity class	Disease risk (relative to normal weight and waist circumference)	
			Men < 102 cm Women < 88 cm	Men >102 cm Women >88 cm
Underweight	<18.5			
Normal	18.5–24.9			
Overweight	25.0–29.9		Increased	High
Obesity	30.0–34.9 35.0–39.9	I II	High Very high	Very high Very high
Extreme obesity	>40.0	III	Extremely high	Extremely high

Source: NHLBI Obesity Education Initiative (2000)

Table 5.2 International Diabetes Federation criteria for ethnic or country-specific values for waist circumference

Country or ethnic group	Sex	Waist circumference (cm)
Europid	Men Women	>94 >80
South Asian	Men Women	>90 >80
Chinese	Men Women	>90 >80
Japanese	Men Women	>90 >80

Source: Adapted from Zimmet & Alberti (2006)

5.2 Measurement protocol

It was relatively straightforward to determine the recommended protocol for the standardized measurement of waist circumference and hip circumference, and for the assessment of abdominal obesity. There are many potential points of variation in how these measurements can be taken, and many potential sources of measurement error among and within measurers. Nevertheless, the consultation agreed that the measurement protocol previously approved by WHO should be recommended. This protocol is in extensive use by STEPS, and has been featured in several previous WHO expert meeting reports (WHO, 1995; WHO, 2000a; WHO/FAO, 2003).

This protocol can be summarized as outlined below.

- Measure the ***waist circumference*** at the end of several consecutive natural breaths, at a level parallel to the floor, midpoint between the top of the iliac crest and the lower margin of the last palpable rib in the mid axillary line.
- Measure the ***hip circumference*** at a level parallel to the floor, at the largest circumference of the buttocks.
- Make both measurements with a stretch-resistant tape that is wrapped snugly around the subject, but not to the point that the tape is constricting. Keep the tape level and parallel to the floor at the point of measurement.

- Ensure that the subject is standing upright during the measurement, with arms relaxed at the side, feet evenly spread apart and body weight evenly distributed.

5.3 Selecting cut-off points

The experts generally agreed that the basis for effective use of waist circumference and waist–hip ratio cut-off points in clinical and public health should relate to health outcomes rather than to associations with intra-abdominal fat, because risk prediction is more straightforward if based on health outcomes. Other issues that need to be considered are outlined below:

- *Which health outcome or outcomes should be used?*
- *Should outcome measures from cross-sectional data be used?* – Although use of cross-sectional data is practical, the data may be confounded by effects of existing disease and its diagnosis and treatment on risk status or associations. A clear preference was stated for outcomes from longitudinal data, which avoid the bias associated with relying on prevalent cases.
- *Are relative risks or absolute risks preferable when comparing risk factor or disease levels at different levels of waist circumference or waist–hip ratio? – Relative risks* (the outcome in those with waist circumference or waist–hip ratio above a given cut-off point compared to the outcome in those below the cut-off point) vary, depending on the reference category used to calculate the ratio; thus, they do not necessarily reflect the disease burden on an absolute scale. *Absolute risks* (the difference, by subtraction, in disease burden among those with waist circumference or waist–hip ratio above or below a specified cut-off point) may be more relevant from a policy perspective. This situation may be particularly relevant to the issue of ethnic differences. A high baseline disease rate will decrease ratios relative to populations with lower baseline rates, but will not influence the calculation of risk differences.
- *Would linking waist circumference or waist–hip ratio measures to overall body size or generalized obesity grades (e.g. by using BMI categories) add valuable information within populations, within a given range of body size, or across population subgroups with substantially different BMI distributions?* – This question could be answered by analysing potential differences in the range and distribution of waist circumference or waist–hip ratio in populations with different BMI range and distribution. For example, such analyses might compare waist circumference and waist–hip ratio distributions and health outcomes in Asian populations (in whom mean BMI levels are relatively low) with European or other populations (in whom mean BMI levels are relatively high), to determine whether one set of waist circumference or waist–hip ratio cut-off points would be sufficiently sensitive in both populations. The performance of measures such as waist circumference and waist–hip ratio, used in conjunction with BMI, might contribute to the development of composite indices for use with individuals and the community.
- *Should cut-off points be determined using statistical approaches such as receiver operating characteristic (ROC) curves; if so, how should such approaches be used?* – With respect to the use of ROC curves, questions included whether to choose cut-off points on the basis of the maximum level of sensitivity identified, likelihood ratios or equivalence of sensitivity to specificity, and whether to resort to an arbitrarily designated level of sensitivity (e.g. 85%) as criteria for cut-off values. As indicated in Annex A, all of these measures are currently in use by various countries. The consultation did not identify a basis for giving priority to a particular approach. In addition, potential limitations of the ROC method were noted, including differences in

cut-off points based on differences in population characteristics (e.g. average body size or disease prevalence).

All these questions need to be carefully considered when determining the method and process used to derive cut-off points for waist circumference and waist–hip ratio for recommendation by WHO. The choice of method and the process to be outlined will also depend on the potential uses of the derived cut-off points and health-relevant policy considerations. For example, specific problems of the population group for which the cut-off points are to be used should be taken into account.

5.4 Universal or population-specific cut-off points

The issue of sex-specific cut-off points was not deliberated as such, but the consultation noted that many countries or settings currently specify different cut-off points for men and women (see Annex A). The experts did not identify evidence for discontinuing the use of sex-specific cut-off points.

With respect to ethnicity-specific cut-off points, there was substantial evidence of population-dependent variations in association of disease risk with measures of abdominal obesity. However, other evidence discouraged the development and use of ethnically based cut-off points. The populations of greatest interest in this respect are of Asian descent, because risks of certain diseases (e.g. diabetes) are notably higher in these populations than would be expected from their mean BMI levels. Understanding the basis for this increased risk of diabetes among Asian populations, for instance, would be important to identify the potential environmental variations and the heterogeneity among populations designated as Asian.

The consultation identified the need for a transparent and methodologically sound empirical approach to developing population or geography-specific cut-off points for abdominal obesity. At the same time, the experts recognized the utility of the current recommended cut-off points, which are simple and universally applicable. The background paper by Lear and colleagues (2010) provided examples of how it might be possible to set cut-off points that are generally applicable, but also recognize the differences in risk among populations. However, there were too many unresolved issues for the consultation to determine whether this process would be useful.

The consultation identified many challenges related to the use of surrogate measures of abdominal obesity for the derivation of universally applicable cut-off points for health outcomes. For example, there are inherent challenges related to determination of health outcomes, including sex differences; age-related changes in body composition and conformation; and group, population and geographical differences. Some of these confounders need to be evaluated more carefully, as outlined below:

- In individuals of the same sex and age anywhere in the world, is the same level, proportion or quantity of:
  - total fat or adipose tissue present for a given BMI?
  - intra-abdominal or visceral adipose tissue present for a given waist circumference or waist–hip ratio?
- In individuals of the same sex and age anywhere in the world, is the risk of disease and mortality the same for a given BMI (i.e. level of obesity), or waist circumference or waist–hip ratio (i.e. level of abdominal obesity)?

- Is the relationship between adiposity and the proxy measure, and the association with a given health risk, the same for both sexes?
- Is the relationship between adiposity and the proxy measure, and the association with a given health risk, affected by increasing age for both sexes?

Addressing these issues will be a major challenge. It is clear from the data reviewed at this expert consultation and from previous WHO publications that the current evidence base cannot answer these questions. Further studies are needed to determine whether recommended cut-off points should be specific to sex, age and population.

6 Recommendations

The expert consultation agreed that the anthropometric indicators and measures used previously (i.e. BMI, waist circumference and waist–hip ratio) are predictive of the risk of chronic disease. Hence, any waist circumference and waist–hip ratio cut-off points developed following the process recommended by the consultation could be used alone or in conjunction with BMI.

Ideally, the characteristics associated with the most useful analyses for one or more uses of waist circumference or waist–hip ratio would be that:

- the data are representative of all population groups (with respect to age, sex, social class and concurrent diseases) in countries from all regions;
- data collected include anthropometric measures (of both central adiposity and BMI) and at least three risk factors (e.g. blood pressure, blood glucose and cholesterol);
- standardized methods were used for measurement of waist circumference and other anthropometric indicators;
- measured weight and height were available and were not self-reported data;
- the dataset include information on characteristics such as age, sex and demographics;
- sufficient longitudinal data from appropriate populations be available, with high quality follow-up of disease status along the time course, to permit confirmation of key conclusions about cut-off points derived using cross-sectional data.

Given the data available, the consultation felt that the steps presented below (which are not in any specific order) could be taken to arrive at appropriate WHO recommendations in this critical area:

- Determine whether multiple sets of cut-off points will be needed (e.g. by sex, body size or health-status characteristics of the population).
  This could be accomplished by evaluating similarities or differences in the associations of waist circumference or waist–hip ratio with various health outcomes, across populations or population subgroups. The approach would compare populations that differ in distributions of waist circumference and waist–hip ratio, or in disease profiles. Type 2 diabetes should be considered as a major health risk factor or outcome in evaluating associations with waist circumference and waist–hip ratio. In populations throughout the world, diabetes apparently increases with overall and abdominal fat gain and obesity development. Comparisons based on diabetes would allow identification of the potential variations in the predictive potential of various cut-off points.
- For any set of cut-off points to be developed, choose the most sound and policy-relevant statistical approach to determine cut-off points for waist circumference and waist–hip ratio, and specify the resulting decision rules.
- Develop a schema with different levels of risk and three sets of cut-off points.This could be achieved by linking datasets to diabetes prevalence for countries, and examining whether the recommended cut-off points are appropriate for the reliable identification of disease risk. In addition, it would be helpful to analyse populations with high risk, to ensure that the cut-off points developed are a sensitive measure of risk.

- Alternatively, choose a set of three indicative risk factors (e.g. high blood pressure, elevated cholesterol and elevated blood glucose), whereby a population or group could be identified by waist circumference cut-off points as having one of three levels of risk:
  - *Level I: Minimal risk* – At this cut-off point, less than 10% of people would have any one of the three indicative risk factors; hence, this would be the lowest level of risk. The objective is to identify a value that national governments could use for surveillance and to determine the need for public health interventions.
  - *Level II: Moderate risk* – At this cut-off point, there would be a high probability that 80% of people have at least one of the three indicative risk factors, in which case, giving health advice or other appropriate action would be deemed essential. The suggestion was to examine combined datasets (bearing in mind global variation), to judge whether it was possible to arrive at a universal cut-off point to indicate this level of population risk. Issues to consider would be the effects of using 80% as the basis for Level II classification, and whether this value would have the same utility across population groups. Critical analysis of the data should ultimately enable WHO to create a scheme to derive cut-off points tailored for different purposes.
  - *Level III: Substantial or high risk* – At this cut-off point, everyone in the population group would be almost certain to have at least one of the three indicative risk factors. This determination would be based on national or regional datasets that suggest that the individuals in this group will have a doubling of risk compared to low-risk groups. High-risk groups may include subgroups or populations defined by obesity or diabetes prevalence.
- The question of how to cope with transitions in disease risk also needs to be addressed. Associations of waist circumference or waist–hip ratio with risk factors and diseases may change over time in populations in which incidence of obesity-related diseases is increasing in association with social and economic transitions.

To facilitate the implementation of the proposed next step and carry this process forward, the consultation formed a working group of experts in this area to work closely with WHO.[1] The working group comprises academic researchers, clinicians who have expertise in this field, statisticians and data analysts. The working group will also consider gaps in the available global data and items appropriate for future research.

The consultation recommended that the working group be asked to develop and suggest the appropriate methods and criteria for a process for open and transparent analysis and clarification of the relationships between abdominal fat distribution and its measures, and disease risk and health outcomes.

It was agreed that the working group needs access to a wide range of databases worldwide, including the STEPS data within WHO. The consultation recommended that the working group be assisted to gain access to the available datasets.

The consultation urged WHO to view this matter as being of utmost urgency, and to enable completion of the task within a 2-year period. The ultimate recommendations from WHO will depend on whether WHO can obtain representative datasets to permit systematic

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[1] The recommended follow-up work to be carried out by the working group that was formed by the consultation has been overtaken by the new guideline development process implemented by WHO as of 1 January 2009. During 2011–2012, the WHO Nutrition Guidance Expert Advisory Group (NUGAG) will take forward the follow-up action recommended by the expert consultation, through its subgroup on Diet and Health.

analysis of all the issues raised in the consultation. Ultimate recommendations from WHO need to take into consideration:

- the various waist circumference and waist–hip ratio criteria that are already in use by national governments, and by national and international medical organizations;
- the potential policy and practical implications associated with any attempts to align diverse cut-offs.

On the other hand, timely and authoritative guidance is needed to ensure that measures that can guide appropriate public health and clinical actions on the problems related to NCDs are brought into full use as quickly as possible. NCDs are rapidly increasing worldwide, particularly in low- and middle-income countries.

Annex A: Current uses of waist circumferences and waist–hip ratios, and recommended cut-off points

A1 Recommendations from different organizations

World Health Organization

A number of WHO publications make recommendations for waist circumference and waist–hip ratio.

Recommendations about abdominal obesity and waist circumference have been made as one of the components of metabolic syndrome in a report on diabetes mellitus (WHO, 1999), under the definition of metabolic syndrome. According to this report, the working definition of metabolic syndrome is a condition characterized by “glucose intolerance, IGT [impaired glucose tolerance] or diabetes mellitus, and/or insulin resistance together with two or more components listed below”, which includes abdominal obesity in addition to raised arterial pressure, raised plasma triglycerides and microalbuminuria. Abdominal obesity is further defined as waist–hip ratio above 0.90 for males and above 0.85 for females, or a BMI above 30.0.

The more recent report of the WHO Expert Consultation on Obesity (2000a) stated the “need to develop sex-specific waist circumference cut-off points appropriate for different populations”. That report provides a table as an example of sex-specific waist circumference and risk of metabolic complications associated with obesity in Caucasians. The table is based on the increased relative risk observed in the Netherlands from a random sample of 2183 men and 2698 women aged 20–59 years (Han et al., 1995). The recommended sex-specific cut-off points are 94 cm (men) and 80 cm (women) for increased risk, and 102 cm (men) and 88 cm (women) for substantially increased risk.

Based on these two WHO reports, the recommendations often attributed to WHO are shown in Table A1 although those sex-specific cut-off points cited in the report of the WHO Expert Consultation on Obesity (2000b) were an example only and not WHO recommendations.

Table A1 World Health Organization cut-off points and risk of metabolic complications

Indicator	Cut-off points	Risk of metabolic complications
Waist circumference	>94 cm (M); >80 cm (W)	Increased
Waist circumference	>102 cm (M); >88 cm (W)	Substantially increased
Waist–hip ratio	≥0.90 cm (M); ≥0.85 cm (W)	Substantially increased

M, men; W, women

International Diabetes Federation

The International Diabetes Federation (IDF) has also provided recommendations for cut-offs for waist circumference and waist–hip ratio (IDF, 2006; Zimmet & Alberti, 2006). The recommendations of IDF for waist circumference are not only sex specific, but are also population and geography specific. Values are shown in Table A2.

Table A2 International Diabetes Federation cut-off points for different ethnic groups

	Men	Women
Europids	>94 cm	>80 cm
South Asians, Chinese and Japanese	>90 cm	>80 cm

United States National Cholesterol Education Program

Another set of recommendations widely used are the ones recommended by the experts of the Adult Treatment Panel (ATP) (APT III, 2001) under the aegis of the National Cholesterol Education Program (NCEP) of the NIH's National Heart, Lung, and Blood Institute. The NCEP recommends a single set of sex-specific cut-offs, of above 102 cm for men and above 88 cm for women.

Other countries

An analysis conducted by WHO as part of the preparations for the expert consultation showed that some countries adhered to one or the other of the three recommendations mentioned above, whereas others had their own specific recommendations. For example, many countries use the WHO cut-off points; South Africa uses the IDF recommendations; and the Republic of Korea, Saudi Arabia, Singapore, Slovakia and Turkey use the IDF recommendations plus other specified sources. The NCEP recommendations are used by Ecuador, Greece, Italy, Jordan, Thailand, Turkey and the US, with several of these countries also using other sources of recommendations. Saudi Arabia, Singapore and Slovakia,use both the IDF and the NCEP recommendations.

There is little information on the endorsement of waist circumference and waist–hip ratio cut-off points at national level by national ministries of health. However, the most popular cut-off points used worldwide were the ones attributed to two reports from WHO (WHO, 1999; WHO, 2000a). The IDF recommendations and the NCEP cut-off points were frequently used in research or national surveys in many countries. However, the rationale for the choice and use of a specific recommendation was often unknown and unclear.

Several other countries have developed their own recommendations and cut-off points. However, some of these are simply suggested or used in specific populations in published studies, rather than being national recommendations. Some examples are provided in the following section.

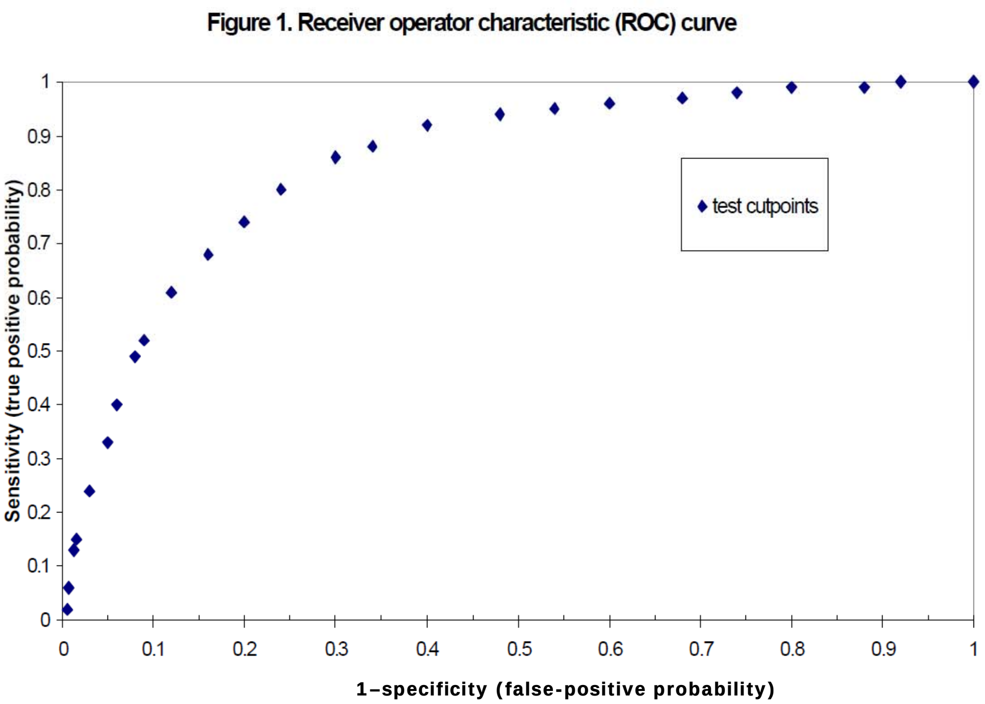
A2 Rationale for selection of cut-off points

The most common approach to determining cut-off points is based on the use of sensitivity and specificity as interpreted from receiver operating characteristic (ROC) curves. Sensitivity measures the proportion of actual positives correctly identified as such, and specificity measures the proportion of actual negatives correctly identified as such.

In any test, there is usually a trade-off between optimizing sensitivity and optimizing specificity. This can be represented graphically using a ROC curve (see Figure A1) (WHO, 2003), which is a plot of the true-positive rate (TPR, or sensitivity) against the false-positive rate (FPR, or 1 – specificity). Useful cut-off points are those that provide for a high proportion of true positives while giving a low proportion of false positives. A ROC curve is also known as a “relative operating characteristic” curve, because it compares two operating characteristics (TPR and FPR) as the criterion changes. Thus, ROC is directly related to diagnostic decision-making.

There are limitations to using a ROC approach for choosing a single cut-off point (e.g. to designate a “high waist circumference”), particularly if the intent is to choose a single cut-off point that is applicable across difference populations and survey conditions. The ROC approach should take into account the validity, reliability and reproducibility of the test or criterion measure (e.g. the waist measurement), and the prevalence of the condition of interest (e.g. high blood pressure or diabetes) in the population to be screened. Population prevalence is important because the predictive value (e.g. the probability of having a disease given a positive test result) is higher in populations with a high prevalence of the disease compared to populations with a low prevalence. This would apply to differences in disease prevalence both across and within populations (e.g. if only high-risk individuals are selected for screening, as opposed to the population at large). Measurement errors also reduce the utility of ROC curves.

Figure A1 Example of a ROC curve



Source: WHO (2003: p 40)

Below are examples of how these concepts have been used as the rationale for waist circumference and waist–hip ratio cut-off points in different countries.

Sensitivity is equal to specificity

Table A3 shows examples of studies from different countries that have set cut-off points based on sensitivity being equal to specificity.

Table A3 Cut-off points based on sensitivity being equal to specificity

Country	Cut-off point	Men	Women	Reference	Notes
Barbados	Waist circumference for general risk	87.3 cm	87.5 cm	(Okosun, et al., 2000b)	
China	Waist circumference for obesity, diabetes, and CVD risk	80–85 cm	75–80 cm	(Wildman et al., 2004)	In this range, the sensitivity equaled the specificity
Islamic Republic of Iran	Waist circumference for CVD for those at risk of CVD but requiring only life style change	90 cm	90 cm	(Delavari et al., 2009; Esteghamati et al., 2009; Mirmiran et al., 2004)	
Islamic Republic of Iran	Waist circumference for CVD for those at high risk for CVD events, requiring immediate intervention for CVD prevention	95 cm	95 cm		
Mexico	Diabetes and CVD	90	85	(Berber, et al., 2001)	
Mexico	Waist–hip ratio	0.90	0.85	(Berber, et al., 2001)	Sensitivity equals specificity (based on the ROC technique), from a study in a hospital population in Mexico City
Mexico	Waist circumference for diabetes	93–98 cm	94–99 cm	(Sanchez-Castillo et al., 2003)	These national recommendations are based on the intersection of lines of specificity and sensitivity
Mexico	Waist circumference for hypertension	92–96 cm	93–96 cm		

CVD, cardiovascular disease; ROC, receiver operating characteristic

Maximum sensitivity

A study from France provided cut-off points for the most corpulent 30% of the population (Balkau et al., 2006):

- waist circumference for obesity, diabetes, and CVD: 96 cm for men and 83 cm for women;
- waist–hip ratio for general risk and obesity: 0.96 for men and 0.83 for women.

Sensitivity was of paramount importance, with waist circumference sensitivities of 74% for men and 82% for women, and for waist–hip ratio of 66% for men and 77% for women.

Optimal sensitivity and specificity

A study from Chile, for example, provided cut-off points for CVD and metabolic risk for women: a waist circumference of at least 87.7 cm and a waist–hip ratio of at least 0.84 (Koch et al., 2008). Specific cut-off points were based on optimal sensitivity and specificity for detecting one or more cardiovascular and metabolic risk factors in the population under study.

Shortest distance between any point on the ROC curve and top-left corner on the y-axis

A study from Oman provided cut-off points for CVD as follows (Al-Lawati & Jousilahti, 2008):

- waist circumference: 80 cm for men and 84.5 cm for women;
- waist–hip ratio: 0.91 for both men and women.

Separate ROC curves were plotted for waist circumference and waist–hip ratio.

Range of values and best cut-off points for multiple indicators

A study from Tunisia provided a cut-off point for waist circumference (for obesity, diabetes, and CVD) of 85 cm for both men and women, based on sensitivity being equal to specificity (Bouguerra et al., 2007).

However, the study also provided individual cut-off points for each disease risk, and would clearly be applicable for clinical use (whereas the single value given above would be useful for public health purposes):

- for men: 82 cm (hypertension); 83 cm (glycaemia); 87 cm (diabetes); 85 cm (total cholesterol and triglycerides);
- for women: 81 cm (hypertension); 82 cm (glycaemia); 87 cm (diabetes); 83 cm (total cholesterol and triglycerides).

A3 Summary

Cut-off points chosen vary considerably between countries; also, the variation is greater for waist circumference than for waist–hip ratio. The cut-off points appear to be chosen based on disease risk (e.g. CVD, type 2 diabetes and risk factors of CVD) and on hard outcomes such as mortality. Rationales vary, but are generally based on indices of sensitivity and specificity. In some cases, there are multiple specific cut-off points for different diseases or risk factors. In addition to the above examples, some countries (e.g. Japan) have based their cut-off points on assessment of visceral adipose tissue from computerized tomography – that is, the extent to which measurements predict intra-abdominal fat rather than disease risk (JSSO, 2002) – and DEXA (Ito et al., 2003).

Annex B: List of participants

This annex lists the participants at the WHO Expert Consultation on Waist Circumference and Waist–Hip Ratio, Geneva, Switzerland, 8–11 December 2008.

B1 Members[2]

Professor Sir George Alberti, SCMS (Diabetes Research Group), The Medical School, University of Newcastle upon Tyne, Newcastle upon Tyne, United Kingdom

Professor Fereidoun Azizi, Director, Research Institute for Endocrinology and Metabolism, Shaheed Beheshti University of Medical Sciences, Tehran, Islamic Republic of Iran

Professor Juliana CN Chan, Director, Hong Kong Institute of Diabetes and Obesity, The Chinese University of Hong Kong, Department of Medicine and Therapeutics, The Prince of Wales Hospital, Shatin, Hong Kong SAR, People's Republic of China

Professor Rachel Huxley, Director, Nutrition & Lifestyle Division, The George Institute for Global Health, Camperdown, Sydney, New South Wales, Australia

Professor Philip James, International Obesity Task Force, London, United Kingdom

Professor Takashi Kadowaki, Department of Metabolic Diseases, Graduate School of Medicine, University of Tokyo, Tokyo, Japan

Professor Kay-Tee Khaw, Department of Clinical Gerontology, University of Cambridge, Addenbrooke's Hospital, Cambridge, United Kingdom

Dr Gary Tin-Choi Ko, Hong Kong Institute of Diabetes and Obesity, The Chinese University of Hong Kong, The Prince of Wales Hospital, Shatin, Hong Kong SAR, People's Republic of China (*Rapporteur*)

Professor Shiriki Kumanyika, Center for Clinical Epidemiology & Biostatistics, University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, US (*Chairperson*)

Professor Scott Lear, School of Kinesiology, Simon Fraser University, Vancouver, British Columbia, Canada

Professor Jean Claude Mbanya, Vice Dean/Professor of Medicine and Endocrinology, Faculty of Medicine and Biomedical Sciences, University of Yaoundé, Yaoundé, Cameroon

Dr Qing Qiao, Academy Research Fellow, Department of Public Health, University of Helsinki, Helsinki, Finland

Professor K. Srinath Reddy, President, Public Health Foundation of India, New Delhi, India

Professor Jaap Seidell, Head, Department of Nutrition & Health, Faculty of Earth and Life Sciences, Free University of Amsterdam, Amsterdam, The Netherlands

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[2] Unable to attend: Dr Viswanathan Mohan, President & Chief of Diabetes Research, Madras Diabetes Research Foundation, Indian Council of Medical Research (ICMR) Advanced Centre for Genomics of Diabetes, Chennai, India

Professor Thorkild IA Sørensen, Institute Director and Professor of Clinical Epidemiology, Institute of Preventive Medicine, Centre for Health and Society, Copenhagen, Denmark

Professor June Stevens, Chair, Department of Nutrition, Schools of Public Health and Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina, US

Professor Paul Zimmet, Emeritus Director and Director of International Research, Baker IDI Heart and Diabetes Institute, Caulfield, Victoria, Australia

B2 Secretariat

Dr Ala Alwan, Assistant Director-General, Noncommunicable Diseases and Mental Health, WHO, Geneva, Switzerland

Dr Francesco Branca, Director, Nutrition for Health and Development, WHO, Geneva, Switzerland

Dr Chizuru Nishida, Scientist, Country focused nutrition policies and programmes, Nutrition for Health and Development, WHO, Geneva, Switzerland

Dr Jonathan Siekmann, Technical Officer, Country focused nutrition policies and programmes, Nutrition for Health and Development, WHO, Geneva, Switzerland

Dr Prakash Shetty, Temporary Advisor, Country focused nutrition policies and programmes, Nutrition for Health and Development, WHO, Geneva, Switzerland

Dr Elaine Rush, Consultant, Country focused nutrition policies and programmes, Nutrition for Health and Development, WHO, Geneva, Switzerland

Ms Ying Liu, Technical Assistant, Country focused nutrition policies and programmes, Nutrition for Health and Development, WHO, Geneva, Switzerland

Dr Fiona Adshead, Director, Chronic Diseases and Health Promotion, WHO, Geneva, Switzerland

Dr Timothy Armstrong, Coordinator, Surveillance and Population-based Prevention, Chronic Diseases and Health Promotion, WHO, Geneva, Switzerland

Mr Godrey Xuereb, Technical Officer, Surveillance and Population-based Prevention, Chronic Diseases and Health Promotion, WHO, Geneva, Switzerland

Mrs Leanne Riley, Scientist, Surveillance and Population-based Prevention, Chronic Diseases and Health Promotion, WHO, Geneva, Switzerland

Dr Shanthi Mendis, Coordinator, Chronic Diseases Prevention and Management, Chronic Diseases and Health Promotion, WHO, Geneva, Switzerland

Dr Gojka Roglic, Medical Officer, Chronic Diseases Prevention and Management, Chronic Diseases and Health Promotion, WHO, Geneva, Switzerland

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For further information please contact:

Department of Nutrition for Health and Development
World Health Organization
20 Avenue Appia
1211 Geneva 27
Switzerland

Fax: +41 22 791 4156
E-mail: nutrition@who.int
Web site: www.who.int/nutrition

ISBN 978 92 4 150149 1