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NUTRITION IN OBESITY & DIABETES



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Contents

Preface *ix*
Acknowledgments *xi*

Chapter 1
Energy Requirements **1**

Chapter 2
Nutritional Assessment and Body Composition **12**

Chapter 3
Role of Nutrition and Lifestyle in Obesity and Diabetes **34**

Chapter 4
Goals of Nutritional Management in Obesity and Diabetes **51**

Chapter 5
Nutritional Management in the Obese **54**

Chapter 6
Nutrition in Type 1 Diabetic Children **91**

Chapter 7
Type 2 Diabetes Mellitus **106**

Chapter 8
Gestational Diabetes Mellitus **116**

Chapter 9
Nutrition in Complications of Diabetes **125**

Chapter 10
Complementary and Alternative Medicine Therapy for Obesity and Diabetes **136**

CHAPTER 2

Nutritional Assessment and Body Composition

Abstract

This chapter focuses on nutritional assessment and describes the crucial steps in nutritional assessment such as anthropometry, biochemistry, and clinical and dietary assessment. An accurate assessment of body composition is necessary to identify an individual's health risk associated with an excessively low or high body fat and this chapter provides a comprehensive overview of the different methods for measuring body composition. Equations to estimate percentage body fat using various compartment models (2, 3, 4) are provided in the chapter. The advantages and limitations of the different methods of body composition such as hydrodensitometry, air displacement plethysmography, hydrometry, and dual energy X-ray absorptiometry are discussed.

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Nutritional Assessment of the Overweight/Obese Individual

Maintaining optimal nutritional status at any age is important and can contribute to preventing chronic diseases, frequent episodes of illness, shorter and less expensive hospital stays, fewer complications, and a higher survival rate. The nutritional assessment of an individual/patient requires a combination of the history, physical examination, anthropometrics, and laboratory assessment. Nutritional assessment can provide information on the individual before the start of nutritional intervention and can also help to identify individuals needing detailed screening. The assessment of the patient is critical for three purposes:

1. Identification of modifiable lifestyle behaviors (dietary, physical activity, and behavioral practices).
2. Assessment of current and future risks for medical comorbidities.

3. Assessment of the patient's and family's readiness to make lifestyle changes.

The assessment process includes:

- Review of patient's background data
- Accurate data collection and recording
  - Anthropometric
  - Biochemical
  - Clinical
  - Dietary
- Assessment of physical activity level
- Assessment of individual/patient's motivation and readiness to participate in treatment plan.

Review of Patient's Background Data

This data will provide an insight into the medical history and other factors that may directly or indirectly affect the patient's nutrition needs and health status.

Medical history: It helps to identify health problems and family history that may influence the patient's nutritional status. It is important to assess the presence of underlying diseases such as coronary heart disease, atherosclerotic disease, hypertension, sleep apnea, hypothyroidism, gynecological abnormalities, osteoarthritis, and gall stones.

Drug history: It reviews medications (drugs, nutrient supplements, herbal/ayurvedic drugs that may affect nutritional status).

Socioeconomic history: Details on environmental, personal, religious, social, and economic factors that can influence food availability, food needs, food intake, and nutrient needs.

Accurate Data Collection and Recording

This data can be summarized as: (i) anthropometry, (ii) biochemical, (iii) clinical, and (iv) dietary.

Anthropometric Data

Anthropometric measurements are noninvasive and measure the human body size and proportion. Body weight and height are measures of body size, while ratio of body weight to height represents body proportion. It helps in assessing the nutritional status, identifying individuals at risk, monitoring the efficacy of a nutrition intervention, and in providing information about the body's stores of fat and muscle.

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- *Height*—The height is measured to the nearest 0.1 cm using an accurate stadiometer
- *Weight*—Weight is a sensitive indicator of nutritional status. The body weight is measured to the nearest 0.1 kg using a calibrated digital weighing scale. The patient, wearing light clothing is made to stand on the platform of the weighing scale with the body weight evenly distributed. It is important to calibrate the weighing scale on a regular basis using standard weights (WHO, 1995).[1]

The body mass index (BMI), which relates height and weight, can be mathematically calculated as:

$$\frac{\text{Weight in kg}}{\text{height (meters)}^2}$$

The BMI is used to classify individuals as obese, overweight, normal, and underweight. It is popularly used in studies to identify individuals at risk. The World Health Organization (WHO, 1998) classification of BMI is as follows (Table 1).[2]

Studies have shown that for a given BMI, Indians have more body fat than other ethnic groups, both within and outside Asia.[3,4] This is important, because measures of overall obesity and the location of body fat are strongly associated with insulin sensitivity in Indians. Due to the evidence of the relative increase in adiposity in Indians, it has been suggested that the BMI cut-off for noncommunicable diseases should be reduced for Indians and Asians to about 23 kg/m^2 or even lower (WHO/IASO/IOTF, 2000).[5] The recent WHO Expert Committee while acknowledging this, stopped short of actually suggesting a new BMI cut-off for Indians, instead preferring to refer to a "public health action point" at a BMI of 23 kg/m^2 (WHO, 2004).[6] This approach will help to define the burden of risk of chronic disease in a population, since reducing BMI cut-off values for overweight and obesity would immediately increase their prevalence rates and, therefore, increase public and clinical awareness, but it is not clear whether it would be ideal for the long-term prevention of death in terms of individuals.

TABLE 1: Classification of body mass index[2]

	Obesity class	BMI (kg/m^2)
Underweight		<18.5
Normal		18.5–24.9
Overweight		25.0–29.9
Obesity	I	30.0–34.9
	II	35.0–39.9
Extreme obesity	III	≥40.0

BMI, body mass index.

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In children, cut off based on distribution of anthropometric measurements (weight and BMI) are used to define obesity. The Center for Disease Control and Prevention (CDC) 2000 growth reference charts were developed on American children.[7] BMI categories based on pooled six international data sets were developed in 2000, on children aged 2–18 years and these reference curves have been referred to as the International Obesity Task Force (IOTF) standards.[8] These charts assume that the most appropriate cut-off points for overweight and obesity in children are those corresponding to the BMI of 25 kg/m^2 and 30 kg/m^2, respectively, in the BMI distribution for adults, that are recognized internationally as defining overweight and obesity. The IOTF standards have been widely used to classify overweight and obesity in children. IOTF charts, however, provide only overweight and obesity categories and not a full array of percentile levels and are thus not useful for monitoring the BMI progress of individual children. The WHO developed growth standards on children (WHO, 2006)[9,10] and these standards provide an effective tool for detecting both under nutrition and obesity, thus addressing the double burden of malnutrition. For Indian children, age and gender specific BMI cut offs, based on a reference population of urban Indian affluent children have been recently developed by Khadilkar et al.,[11] such that the cut-offs are linked to the adult accepted BMI of 23 kg/m^2 and 28 kg/m^2 for overweight and obesity for Asians. These cut offs can be used to identify overweight and obesity.

Waist circumference: Waist circumference has received recent attention as an indicator of fat and health risks in children and adults (Table 2). The interest in waist circumference stems from research linking accumulated visceral adipose tissue to increased health risks and metabolic disorders in children and adults. Waist circumference is a good indicator of intra-abdominal fat and is normally measured with a nonstretchable tape by trained staff (exerting the same standard pressure on the tape) at the midpoint of the lowest rib cage and the iliac crest, to the nearest 0.1 cm, in a standing position during end-tidal expiration (WHO, 1995).[1]

Misra et al. in 2006,[12] evaluated several waist circumference cut-off points in relation to BMI cut-off points and cardiovascular diseases in Asian Indians residing in north India and proposed action level for adult Asian Indians: action level 1: men, greater than or equal to 78 cm, women, greater than

TABLE 2: The indicators of risk based on waist circumference[2]

Gender	Waist circumference
Men	≥102 cm
Women	≥88 cm

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or equal to 72 cm; and action level 2: men, greater than or equal to 90 cm, women, greater than or equal to 80 cm. Kuriyan et al. recently developed waist percentile curves for children aged 3–16 years from urban south India.[13] For a start, until larger dataset from different regions in the country are available, these curves can be used to assess abdominal obesity in Indian children.

Waist-hip ratio: The waist-hip ratio is used as an indirect measure of lower and upper body fat distribution (Table 3). Waist-to-hip ratio is a way of measuring where body fat is stored. "Android" or excess upper body fat is seen more typically in men, while gynoid or excess lower body fat is seen more in women. A high waist-to-hip ratio indicates an increased risk of obesity-related health problems. Waist-to-hip ratio is calculated by dividing the measured waist circumference by the measured hip circumference.

$$\frac{W}{H} = \text{waist-to-hip ratio (WHR)}$$

The accuracy of WHR in assessing visceral fat decreases with increasing levels of fatness.

Body fat estimation: The assessment of the body fat and body composition of the patients will provide an insight into the distribution of fat and lean tissue in the body. Increased body fat has been associated with increased risk for chronic diseases. The various methods of body composition have been discussed in the latter part of the chapter.

Biochemical or Laboratory Data Assessment

Based on the patient's existing signs and symptoms, tests are carried out to identify associated comorbidities. There is no single biochemical test that is indicated for all patients with obesity. Some of the common tests performed to rule out certain conditions are presented in table 4.

Clinical Data

The patient's medical, social, and family history for current and potential obesity related symptoms and diseases need to be reviewed. This includes recording of signs and symptoms of the disease, diagnosis, treatment

TABLE 3: The indicators of risk based on waist-hip ratio[2]

The Indicators of risk	
Gender	**WHR circumference**
Men	≥1.0
Women	≥0.85

WHR, waist:hip ratio.

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TABLE 4: Tests to rule out obesity related comorbidity

Test performed	Condition to rule out
• Fasting blood glucose • Postprandial blood glucose • Glycosylated hemoglobin • Fasted insulin levels	• Diabetes
Fasting blood lipid profile	• Hyperlipidemia
Recording of two or more properly measured blood pressure readings	• Hypertension
Serum thyroid stimulating hormone	• Hypothyroidism
• Serum triglycerides • High density lipoprotein cholesterol • Blood pressure • Fasting glucose	• Metabolic syndrome
Cortisol levels	• Cushing's syndrome
• Total testosterone • Prolactin • Thyroid stimulating hormone	• Polycystic ovarian syndrome

information, medical problems relating to food intake (dysphagia), gastrointestinal problems, and blood pressure. Obesity could affect many organs of the body and thus it is important to clinically evaluate for type 2 diabetes, hypertension, gall bladder disease, and metabolic syndrome. Additionally, in an obese individual, the psychosocial complications may be as significant as the health concerns, since these individuals often experience discrimination, difficulties in work place, and personal life leading to low self-esteem, social withdrawal, depression, and other mental health problems. Thus, a comprehensive clinical assessment of an overweight/obese individual needs to be carried out.

Dietary Data

An accurate diet history is an important component of the nutritional assessment process. The diet history provides valuable information about the patient's past and current food intake patterns. The data recorded must capture what the patient usually eats and drinks. The nutritionist collecting the data must be skilled as patients, especially obese patients, tend to omit important information or underestimate the amounts of food intake. Details captured should include quantity eaten, number of meals eaten, snacking habits, meal preparation methods, and social and family history. The nutritionist should avoid reacting to information provided by the patient and

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remember that both verbal and nonverbal communication can influence the patient.

Points to remember while performing a dietary assessment include:

- Self-introduction
- Explain the benefits of the assessment to the patient
- Avoid being judgmental
- Use standard measurements to help in getting an idea of the amount of food intake
- Always make plans for follow up.

There are many methods for obtaining a dietary history. The various methods of dietary assessment with their advantages and disadvantages are given in table 5.

Additional data that can be recorded include data on the patient's general health, food habits, and eating habits

- Monthly family consumption of oil, ghee, coconut, and salt
- History of cigarette smoking and alcohol consumption
- Method of meal planning and preparation
- Food purchasing ability
- Usual meal pattern
- Snack consumption
- Place where meals are eaten regularly
- Food preferences/allergies
- Previous dietary restriction
- Use of supplements (vitamin, herbal, nutritional, or mineral)
- Weight changes
- Bowel habits
- Duration of television viewing, frequency of consumption of meals while watching television
- Frequency of eating meals together with family
- Sleep pattern.

Assessment of Physical Activity

Physical activity is an important component of health and well being. Individuals who are physically active have health benefits of lower risk of coronary heart disease, type 2 diabetes, hypertension, hyperlipidemia, osteoporosis, cancer, and depression rates. There are many methods by which the physical activity can be measured—questionnaire, direct observation, electronic monitoring such as pedometers, accelerometers, and heart rate monitors. Appropriate assessment of physical activity patterns requires accurate and reliable instruments. Physical activity questionnaire is a checklist of frequency, intensity, and duration of specific activities within

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TABLE 5: Dietary assessment methods

Method	Details	Advantages	Disadvantages
24-hour recall	Information on food intake in the previous 24 hours	Quick and easy Patient need not be literate	• Over-/underestimation is possible • Memory dependent • Not representative of patient's usual intake • Requires a skilled interviewer
Food frequency questionnaire	List of foods or food groups from which the patient selects the frequency with which they are consumed	• Beneficial when used with 24-hour recall • Provides details on food consumption over a period of time with key nutrients • Does not influence the usual diet.	• Needs the patient to be literate, unless interviewed • Details is lacking on meal patterns
Food records/diary	Provides 3–7 days record of actual food intake	• Eliminates errors of recall • Provides an accurate record of food eaten and time of consumption	• Needs the patient to be literate • The patients could alter the food intake during the recording period • Requires recording period of at least 3 days (must include a weekend)

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a defined time period (past 24 hours, 1 week, or 1 month). A single page, simple and easy to use physical activity questionnaire has been developed in urban middle class Indians.[14] This questionnaire can be applied to Indian populations to provide valuable insights to physical activity patterns. While the questionnaire is primarily designed for epidemiological use, it can provide insights into physical activity patterns of an individual.

Assessment of Patient's Motivation

Effective treatment for obesity is based on skillful and empathetic communication between the nutritionist/doctor and patients. It is important to evaluate the patient's readiness to make necessary lifestyle changes to lose weight. Suggesting change when patients are not ready, often, leads to frustration and may hamper future efforts. The nutritionist/physician must first assess the patients' readiness for behavior change, and then help them to overcome the barriers to change. The benefits and difficulties of weight management should be discussed with the patient before treatment goals are developed. The patient's readiness and motivation is assessed by evaluating reasons for weight reduction, history of successful and unsuccessful weight loss attempts, family, friends and work support for weight loss, patient's understanding of obesity and its risks, attitude towards physical activity, time available for weight loss, appropriateness of expectations to help establish the likelihood of lifestyle change, psychiatric status, and financial and other barriers.

After the comprehensive assessment of the patient, a nutritional care plan with goals is made catering to individual patient needs.

Body Composition

The measurement of body composition provides an objective means of nutritional assessment and is of interest to nutritionists, medical personnel, and sports scientists. An accurate assessment of body composition is necessary to identify an individual's health risk associated with an excessively low or high relative body fat (% BF). The age adjusted suggested body fat recommendations for adults are provided in table 6.[15]

Periodic body composition measurements can be used to assess the effectiveness of exercise and dietary interventions or monitor changes in body composition associated with growth and maturation or disease states. Body composition has been linked to numerous health conditions, such as cardiovascular disease, diabetes, some types of cancers, osteoporosis, and osteoarthritis. Thus, there is a clinical need to measure not only % BF, but fat distribution, muscle mass, and bone mass.

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TABLE 6: Age adjusted suggested body fat recommendation for adults[15]

Age (years)	Low fat (BMI <18.5)	Healthy range (BMI 18.5–24.9)	Overweight (BMI 25–29.9)	Obese (BMI ≥30)
Women				
20–39 years	≤25	25.1–34.9%	35–39.9%	≥40
40–59 years	≤25	25.1–34.9%	35–40.9%	≥41
60–79 years	≤25	25.1–35.9%	36–40.9%	≥41
Men				
20–39 years	≤13	13.1–22.9%	23–27.9%	≥28
40–59 years	≤13	13.1–23.9%	24–28.9%	≥29
60–79 years	≤14	14.1–23.9%	24–28.9%	≥29

BMI, body mass index.

Regardless of the reason for assessing body composition, it is important to understand the various techniques that are available for assessing body composition. The various techniques used for body composition are based on two compartment (2C), three compartment (3C), four compartment (4C), or multi-compartment model. The models of body composition have been briefly described below.

Two-compartment Model

The most common approach in body composition assessment is to utilize the 2C model, dividing body weight into fat mass (FM) and fat-free mass (FFM). The FM, which is defined as chemically extractable fat, is assumed to have a density of 0.9007 g/cm^3 and be anhydrous, whereas the FFM is assumed to have a density of 1.1000 g/cm^3 with a water content of 73.72%.[16] Most of the error associated with these 2C models lies not in the technical accuracy of the measurements, but in the validity of the assumptions, which are based on analyses of just three male cadavers.[17] The most frequently used 2C models are hyrodensitometry, air displacement plethysmography, and hydrometry.

Three-compartment Model

In order to reduce the limitations of 2C model, the 3C model was developed. In the 3C model, the FFM is divided into total body water (TBW) and the remaining solids [protein and minerals, fat free dry mass (FFDM)]. This is based on measurements of both, body density (Db) and TBW, while assuming a constant mineral-to-protein ratio of 0.35.[18] The 3C model, thus, controls for inter-individual variation in FFM hydration. The 3C model shows better results over the 2C model, while measuring healthy adults and older children, but have to be used with caution in patients with depleted body

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protein or bone mineral mass, as the estimated values for density would not be accurate.[16]

Four-compartment Model

A 4C model (FM, water, and bone mineral, residual) of body composition analysis is theoretically more valid than the 3C model, because it controls for biological variability in both bone mineral and TBW. The density of protein and mineral is assumed to be 1.34 kg/L and 3.075 kg/L.[16] The dual-energy X-ray absorptiometry (DEXA) is used to measure the amount of mineral (bone mass) (Fig. 1).

This model involves independent assessment of Db, body water, and bone and can account for deviations in the quality of fat-free mass, in part, because the 4C model measures the individual constituents of the fat-free mass (aqueous and bone) rather than assuming a constant density of 1.100 g/cm^3 and hydration of 73.2%. Although this approach is preferred, it is impractical for most laboratories because of the cost and necessary equipment needed to measure TBW and bone mineralization.

Multicompartment Models

Atomic models of body composition require the direct analysis of the chemical composition of the body. The total body content of elements (calcium, sodium, chloride, phosphorus, nitrogen, hydrogen, oxygen, and carbon) can be measured using neutron activation analysis (NAA). The 6C model, divides the body into water + nitrogen + calcium + potassium + sodium + chloride.[19] While these multicompartment models provide accurate measures of body



Figure 1 Measurement of body composition using dual-energy X-ray absorptiometry.

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TABLE 7: Equations for estimating percent body fat

Model	Assumption	Equations	Other methods needed	*References*
2C	BW = FM + FFM	% BF = [(4.95/Db – 4.50)] x 100		Siri 1956[20]
		% BF = [(4.57/Db – 4.142)] x 100		Brozek et al. 1963[17]
3C	BW = FM + TBW + (mineral and protein combined)	% BF = [(2.118//Db) – 0.78 W – 1.354] x 100	D_2O dilution	Siri 1961[21]
		% BF = [(6.386//Db) + 3.961M – 6.090] x 100	DEXA	Lohman 1986[22]
4C	BW = FM + TBW + BM + Protein	% BF = [(2.747//Db) – 0.714 W + 1.146 B – 2.0503] x 100	D_2O dilution and DEXA	Selinger 1977[23]
		% BF = [(2.513//Db) – 0.739 W + 0.947 B – 1.790] x 100		Heymsfield 1996[24]
		% BF = [(2.747//Db) – 0.718 W + 1.148 B – 2.050] x 100		Baumgartner 1991[25]
6C	BW = TBW + TBN + TBCa + TBK + TBNa + TBCl	FM (kg) = BW – (TBW + 6.525 TBN + 2.709 TBCa + 2.76 TBK + TBNa + 1.43 TBCl)		Wang et al. 1998[26]

% BF, relative body fat; Db, body density from underwater weighing/air displacement plethysmography; FM, fat mass; BW, body weight; FFM, fat free mass; BM, bone mass; W, total body water/body weight; M, total body mineral/body weight; B, total body bone mineral/body weight; TBN, total body nitrogen; TBCa, total body calcium; TBK, total body potassium; TBNa, total body sodium; TBCl, total body chloride.

composition, for evaluating other methods, the lack of facilities, the high expense, and the exposure to radiation limits the use. The various equations for estimating % BF are provided in table 7.

The various body composition techniques can be divided into laboratory methods and field methods and have been briefly described below.

Laboratory Method

Laboratory techniques are frequently used as reference methods in clinical and research settings for the evaluation of field methods. The common laboratory methods for body composition assessment include hydrodensitometry (HD), air displacement plethysmography, isotope dilution, and DEXA.

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