CHAPTER 22

ASSESSING NUTRITIONAL STATUS

Dietary Intake, Anthropometry, Clinical Signs and Symptoms, and Laboratory Tests

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Outline

• Dietary assessment
• Anthropometric measurements
• Clinical evaluations
• Laboratory tests
• Nutritional status: Looking at the big picture

Objectives

After completing this chapter, you should be able to:

• Identify, describe, and apply various procedures used in the determination of nutritional status, including dietary assessment methods, anthropometric measurements, and laboratory tests (blood and urine)
• Identify clinical signs and symptoms associated with macronutrient and micronutrient excesses or deficiencies
• Describe the advantages and disadvantages of each method used to assess nutritional status
1. INTRODUCTION

People need to maintain optimal nutritional status in order to support their body’s growth and development, to promote their health, and prevent disease. Because of the important relationship between nutrition and health, health professionals need to conduct nutritional assessments to determine an individual’s nutritional status. In the past, intervention efforts have been directed at the important problem of malnutrition owing to inadequate food intake; the Food and Agriculture Organization (FAO) estimates that 800 million people living in low-income countries do not have enough to eat, so this form of malnutrition continues to be a major health concern.

Nutritional measurements are especially critical for at-risk individuals during periods of rapid growth and development, when nutritional requirements are high and inadequate nutrition can have irreversible health consequences. Additionally, in view of the public health threat posed by overweight and obesity in developed as well as developing countries, it is vital for health-care providers to also use available assessment tools to monitor for both undernutrition and overnutrition in patients. This chapter addresses the methods used to assess nutritional status in individuals and in populations overall. These methods fall into four main categories: dietary assessment, anthropometric measurements, clinical evaluations, and laboratory tests (Jensen et al., 2012). It is important to note that each method does not, by itself, provide a complete picture of a person’s nutritional profile, so it is necessary to use them in combination. Once this has been done, appropriate interventions can be planned and implemented or referrals for further examinations made.

2. DIETARY ASSESSMENT

Dietary assessments can provide information on eating habits, food intake, and nutrient intake (Wrieden et al., 2003). A number of tools (e.g., instruments and questionnaires) have been developed to estimate intake of energy and nutrients. These tools range from simple checklists to detailed individual weight records to household surveys. Each tool is associated with specific strengths and weaknesses that should be considered when selecting a method. However, it is imperative that the tool selected be appropriate and tailored to the culture, ethnicity, age, and language of the target group. Furthermore, optimal strategies for dietary intake data collection should always be considered (see Table 22.1).

<table>
<thead>
<tr>
<th>Target group</th>
<th>Optimal strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethnic populations</td>
<td>- Use interviewers of the same ethnic background as the participants.</td>
</tr>
<tr>
<td></td>
<td>- Use food lists and nutrient composition databases that reflect the foods consumed by the population.</td>
</tr>
<tr>
<td>Children</td>
<td>- For young children, include caretakers and caregivers along with the child during any data collection.</td>
</tr>
<tr>
<td></td>
<td>- For older children and adolescents, blend instruments with creative ways to ensure engagement and motivation.</td>
</tr>
<tr>
<td>Elderly persons</td>
<td>- Assess any special considerations (such as memory, special diets, dentition, or use of supplements) and adapt methods accordingly.</td>
</tr>
<tr>
<td>Respondents unable to self-report</td>
<td>- Use the best-informed surrogate: e.g., hospital records; dietitian or nurse for incapacitated patients.</td>
</tr>
<tr>
<td></td>
<td>- Analyze the effect of potential bias on the study results.</td>
</tr>
<tr>
<td>Illiterate persons or populations</td>
<td>- Ensure that the tool used is appropriate; in other words, ensure that tools are interviewer-administered and do not require self-administration.</td>
</tr>
</tbody>
</table>

Source: Adapted from Thompson & Subar, 2001.
Rutishauser and Black (2002) describe the procedure for dietary assessment in five steps, as follows:

1. Record all foods consumed by an individual over a defined period of time.
2. Quantify the portion size of each food item.
3. Determine the frequency with which each food is eaten, if appropriate.
4. Identify the foods eaten such that an appropriate item can be chosen from standard food tables or from choices presented in the software package for nutrient analysis.
5. Calculate the nutrient intake.

### 2.1 Methods Designed to Measure Food and/or Nutrient Intakes

#### 2.1.1 Weighed food records

The 7-day weighed food record is frequently regarded as the “gold standard” against which other methods are compared, because it uses many days of recording – which is more likely to capture the usual intake of an individual – and provides exact measures for portion sizes. Prior to consumption, subjects or investigators are required to weigh each item of food and drink. A detailed description of the food (individual ingredients, brand name, method of preparation, etc.) and its weight are recorded. Other than recording measurements on paper, methods include the use of a dictaphone, PDA (personal digital assistant; a type of electronic handheld device), computer, or self-recording scales (Thompson & Subar, 2001). Furthermore, a record of any leftovers is usually made in order to calculate the actual weight of food that has been consumed. Weighed records can be kept for 3, 4, 5, or 7 days. If they are kept for fewer than 7 days, the investigator should ensure that weights are recorded over consecutive days and include at least one weekend day, because eating habits usually differ between weekdays and weekends. This method may not be applicable in large-scale research surveys, and it may be more applicable in small studies (of 10 to 15 people) or in a clinical setting for individual clients. Using consecutive days is easier for subjects, but it can trigger a “leftover” effect whereby people eat the same foods for several days in a row (see Table 22.2).

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Well established method&lt;br&gt;- Precision of portion sizes</td>
<td>- High respondent burden&lt;br&gt;- Potential for misreporting and/or underreporting&lt;br&gt;- Expense&lt;br&gt;- Food composition data are limited&lt;br&gt;- Can influence or change usual dietary intake</td>
</tr>
</tbody>
</table>

#### 2.1.2 Estimated food records

Estimated food records are similar to weighed food records, the difference being the way in which individuals or investigators quantify food intake. Intake is estimated, rather than weighed, and then converted into amounts that can be used to calculate food and nutrient intake (see Table 22.3).

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Well established method&lt;br&gt;- Lower respondent burden than weighed food records</td>
<td>- Respondent fatigue&lt;br&gt;- Potential for misreporting and/or underreporting including inaccurate estimation of portion sizes&lt;br&gt;- Expense&lt;br&gt;- Food composition data are limited</td>
</tr>
</tbody>
</table>

**Example:** Estimated food records were used in the EPIC study (Voss et al., 1998).
2.1.3 24-hour recall and multiple pass 24-hour recall

A 24-hour recall is a retrospective method and is preferably administered by a dietitian or a trained interviewer. It requires the respondent to recall all the food and drink that he or she consumed in the previous 24 hours. Its accuracy is thus dependent on the respondent’s memory and overall reliability, as well as on his or her ability to estimate and describe portion sizes. For this reason, respondents are prompted to remember what they consumed by linking it to certain times of the day (in the morning, when you woke up) or activities (when you arrived at work). Interviewers may assist respondents in estimating portion sizes by using household measures, such as cups or spoons, and/or food photographs or food models. The interviewer is responsible for recording all the information. At the end of the interview, the respondent is asked to verify the record, and any omissions or errors are corrected.

The Chronic Diseases of Lifestyle (CDL) Unit of the South African Medical Research Council offers tools that can be used to collect dietary intake data. These tools include the Dietary Assessment and Education Kit (DAEK; Steyn & Senekal, 2004). The kit consists of Food Flash Cards, a Food Photo Manual with generic and specific sketches of foods, 24-hour recall recording sheets, and instructions for the interviewer. The DAEK can also be used for nutrition education purposes.

A 24-hour recall is a valuable dietary assessment method, but it can only account for a single day’s intake (see Table 22.4).

Table 22.4: Strengths and weaknesses of 24-hour recall

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Low respondent burden</td>
<td>- Estimation of portion sizes</td>
</tr>
<tr>
<td>- Suitable for large-scale surveys</td>
<td>- Memory-dependent</td>
</tr>
<tr>
<td>- Can be administered by telephone</td>
<td>- Possible bias in reporting intake of “good” and “bad” foods</td>
</tr>
<tr>
<td>- Can be used with illiterate populations</td>
<td>- Does not capture day-to-day variation</td>
</tr>
<tr>
<td>- The person’s usual diet is not affected</td>
<td></td>
</tr>
</tbody>
</table>

A more accurate version of the 24-hour recall method is the multiple pass 24-hour recall. Here, several steps are followed during the interview to allow revisiting and checking of dietary information. The first step involves obtaining a quick list of foods consumed in the past 24 hours. Next, the interviewer prompts the respondent to identify food and drinks that may have been “forgotten,” such as sweets, chocolates, and biscuits. Information is then recorded regarding when and where the various foods were consumed. In addition, more detailed information is obtained, such as detailed descriptions of foods, including preparation methods and individual ingredients. Finally, details regarding portion sizes are recorded. This method is more accurate than the previously described version of the 24-hour recall.

The multiple pass 24-hour recall method was used in the 1999–2000 National Health and Nutrition Examination Study (NHANES; Briefel & Johnson, 2004) in the USA and in the Low Income Diet and Nutrition Survey in the UK (LIDNS; Nelson et al., 2007).

If collected over a number of days, 24-hour recalls provide a potentially valuable picture of an individual’s customary eating habits. For example, where control of excess weight is a concern, information on the intake of fat and sugar may enable a physician to counsel a patient more effectively.

2.1.4 Food frequency questionnaires

Food frequency questionnaires (FFQs) provide information that establishes usual dietary intake. At its simplest, a FFQ consists of a list of foods and a selection of options relating to the frequency of consumption of each of the foods listed (e.g., times per day, daily, weekly, monthly). FFQs are designed to collect dietary information from large numbers of individuals (>100) and are normally self-administered, though an interviewer can carry them out, either through in-person or phone interviews (Haraldsdottir et al., 2001).
The length of the food list can vary depending on the nutrients or foods of interest. If a range of different nutrients and energy values are required, the list of foods may contain upwards of 150 foods; however, if information about a specific type of food (e.g., fruits or vegetables) or nutrient (e.g., calcium) is required, the list may contain as few as 11 foods. The DAEK (Steyn & Senekal, 2004) includes a quantified FFQ that can be used in data collection. Many FFQs also attempt to collect information about portion size; these are referred to as quantitative food frequency questionnaires (QFFQs). Where portion size information is not obtained, standard food portion sizes (MAFF, 1993) are often used to calculate nutrient intakes. Next, the reported frequency of each food is multiplied by the amount of the nutrient in a specified serving of that food. This gives the estimated daily intake of nutrients and dietary constituents. If needed, an estimate can be made of the amount of particular foods or of food groups.

FFQs are used widely in case-control or cohort studies to assess the association between dietary intake and disease risk. They are generally used for ranking subjects according to food or nutrient intake rather than estimating absolute levels of intake (Thompson & Subar, 2001).

Many standard FFQs are available, and many continue to be adapted and developed for different populations and different purposes. Investigators need to carefully consider the appropriateness of the food list to ensure that it is specific to the culture, ethnic group, food brands, and preparation practices of the population being surveyed. Furthermore, questionnaires should be compatible with the database (e.g., South African Medical Research Council, 2001) that will be used for analysis (see Table 22.5).

### Table 22.5: Strengths and weaknesses of food frequency questionnaires

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Low respondent burden</td>
<td>- Potential for inaccurate estimation of portion sizes</td>
</tr>
<tr>
<td>- Suitable for large surveys</td>
<td>- Potential of misreporting</td>
</tr>
<tr>
<td>- Can be self-administered or posted</td>
<td>- Requires validation</td>
</tr>
<tr>
<td>- Can be used to assess association between dietary intake and disease</td>
<td>- Can take up to 60 minutes to complete</td>
</tr>
<tr>
<td></td>
<td>- Difficulty in obtaining accurate reports for foods eaten both as single items and in mixtures</td>
</tr>
</tbody>
</table>

**Examples:**
- Health Habits and History Questionnaire (HHHQ) (also known as Block questionnaire) (Nutrition Quest, 2009)
- Harvard University Food Frequency Questionnaire (also known as Willett questionnaire) (Willett, 1998)
- European Prospective Investigation into Cancer and Nutrition (EPIC; Bingham et al., 1997)
- Abbreviated FFQs (Block et al., 1990)
- The National Food Consumption Survey (NFCS, Labadarios et al., 2000)
- Transition, Health, and Urbanization Study (THUSA; Venter et al., 2000; MacIntyre et al., 2001; Kruger et al., 2002)

### 2.1.5 Household food surveys

A number of surveys are meant to collect information about dietary intake at the household level. This method has been used to monitor long-term dietary intake and provide information on food expenditure and food and nutrient intake trends over a period of time.

Some market research surveys relating to food purchase trends are also conducted at the household level. Recently, a feasibility study has highlighted the potential of utilizing large quantities of readily available data generated from supermarket checkouts in dietary surveys (Ransley et al., 2001). The association between fat and energy measured by this method and 4-day weighed records was found to be strong (see Table 22.6).
Table 22.6: Strengths and weaknesses of household food surveys

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Suitable for large surveys</td>
<td>- Data not collected at the individual level</td>
</tr>
<tr>
<td>- Ability to monitor diet trends at the population level</td>
<td>- Difficulty of assessing foods eaten away from home</td>
</tr>
</tbody>
</table>

Example: The National Food Consumption Survey (NFCS; Labadarios et al., 2000).

2.2 Issues Relating to Dietary Assessment

2.2.1 Derivation of portion size

In all dietary assessment methods, where food is not weighed, portion sizes must be estimated before nutrient intake can be calculated. There are a number of ways to do this. For example, fieldworkers can weigh particular food items, or photographic manuals and food models showing portion sizes of commonly eaten foods can be used (e.g., Nelson et al., 1997), as can data from manufacturers, portion sizes collected from previous weighed food records, and household measures.

2.2.2 Misreporting of dietary intake

Misreporting of energy intake has been routinely observed in various surveys. This occurs when individuals report energy intakes that are inconsistent with biological viability (Huang et al., 2005; Ferro-Luzzi, 1990). The most common form of misreporting is underreporting. Goldberg et al. (1991) derived cut-off points to identify underreporting of energy intake, below which a person of a given sex, age, and body weight could not physiologically survive. The first step in checking for this is to estimate the ratio between energy intake and basal metabolic rate. This can be done using either Schofield equations (Schofield et al., 1985) or using doubly labelled water (Coward et al., 1986). Ratios of <1.37 and >1.67 are indicative of underreporting and overreporting, respectively (Goldberg et al., 1991).

Age and gender often determine the prevalence of misreporting. Various studies have shown that misreporting increases with age (Bandini et al., 1997; Bedard et al., 2003; Johansson et al., 2001). Misreporting in women is associated with psychosocial parameters, such as body image, weight concerns, social desirability, and dietary restraint (Ventura et al., 2006; Tooze et al., 2004; Horner et al., 2002). Furthermore, socio-economic status, procurement of food, food preparation, gender-defined roles, and family responsibility also affect the dietary intake reporting by women (Harrison et al., 2000).

Dietary energy intake misreporting not only affects the absolute energy intake reported, but also the reporting of some macronutrients. People who are concerned about being overweight and those who have been advised to change their diet often underreport foods considered unhealthy, such as those high in fat and added sugar (Harnack et al., 2004; Johansson et al., 2001). Macronutrient misreporting can therefore impact on our understanding of the relationship between diet and health (Venter et al., 2000; Briefel et al., 1997; Lafay et al., 2000). Also of note, alcohol intake is often underreported.

2.3 Diet Analysis

The final step of diet analysis is entering the diet record into a computer programme, which then analyzes the diet and provides extensive information on nutrients and energy. Several websites allow people to carry out this task at no cost. Some books are also available. See Section 10 for further details. The usual first step in this process is to give each food item a code. Carrying out this task on large numbers of diets is labour intensive. Fortunately, some computer software systems allow for direct coding.

When all the diet information has been recorded (e.g., via weighed food record and/or 24-hour recall), the entire diet can be entered into the programme. With a FFQ, the following calculation must be done in order to determine the total intake:

\[
\text{portion size (g)} \times \text{frequency} \times \text{nutrient content per gram} = \text{total intake}
\]
3. **ANTHROPOMETRIC MEASUREMENTS**

Anthropometric measurements are used to estimate the body’s physical dimensions such as weight, height, circumference, and body composition. Most of these techniques are easy to use, inexpensive, and non-invasive and are backed by a strong base of scientific data. An important consideration is that this is an objective measure of dietary intake.

3.1 **Child Growth Standards**

In 2006 the World Health Organization (WHO) published new child growth standards to be used in constructing indicators of nutritional status, such as stunting, wasting, and underweight (WHO, 2006). In cases of emergency nutrition, the new WHO standards are preferred over the previously recommended international growth reference developed by the National Center for Health Statistics, because of documented limitations of the latter (WHO, 2006). The WHO Child Growth Standards are available on the WHO website.

The WHO Child Growth Standards display a series of percentile curves and charts that demonstrate the distribution of selected body measurements of infants and children based on a large population study of children from diverse countries (Vesel et al., 2010). Standards are available for boys and girls from birth to 5 years, and from 5 to 19 years of age. Anthropometric measurements are taken for weight, length or height, head circumference, upper arm circumference, skinfold thickness, and BMI, all in relation to age, as well as for weight relative to height. These measurements are useful for estimating a child’s growth and nutritional status. Clinicians use growth charts to track the growth of an infant or child over time, and to compare one child’s growth to that of children in the general population.

A meaningful way of standardizing data when comparing a child’s growth to others in a group is through use of statistical calculations, such as z-scores, percent of the median, and percentiles. A z-score is defined as the difference between the value for a specific individual and the median value of the reference population (for example, children of the same age or height) divided by the standard deviation of the reference population. The percent of the median is defined as the ratio of a measured or observed value in an individual to the median value of the reference data, expressed as a percentage. Percentile refers to the position of an individual on a given reference distribution. With respect to the specific characteristic under consideration (such as height), an individual’s percentile ranking indicates the percentage of the reference population that the individual’s own score either equals or exceeds.

The z-score is the statistic recommended for use in reports of results of nutritional assessments (Cogill, 2003). Z-scores allow the identification of a fixed point in the distributions of different indices and across different ages. The percent of the median does not allow the same comparison. Further, the proportion of the population identified by a particular percent of the median varies at different ages for the same characteristic.

Cut-offs, which are based on the statistical calculations discussed here, are useful in identifying those infants and children who are suffering from, or who are at a higher risk of, adverse outcomes. The cut-offs for z-scores of –3, –2, and –1 are the lowest 0.13th, 2.28th, and 15.8th percentiles, respectively, of a data set. These percentiles represent the percentage of children in the reference population who are below the cut-off point (Cogill, 2003). The most commonly used cut-offs are z-scores of +/–2 and +/–3, irrespective of the indicator used. For example, an infant or child is defined as stunted, wasted, or underweight if, respectively, his or her length-for-age, weight-for-length, or weight-for-age z-score is less than –2. If these z-score values are less than –3, the infant or child is considered to have severe stunting, severe wasting, or severe underweight (Vesel et al., 2010). In some cases, the cut-off for defining malnutrition used is –1 SD, or a z-score of –1; in the reference, or healthy population, 15.8% of people would be below that cut-off.

Cut-offs for measures of mid-upper-arm circumference (MUAC) are somewhat arbitrary owing to its lack of precision as a measure of malnutrition. A cut-off of 11.0 cm can be used for screening severely malnourished children. Those children <12.5 cm with or without oedema are classified as being severely or moderately malnourished, respectively.

Section 2.1 of Chapter 7 provides additional information on making anthropometric assessments of children.
3.2 Body Weight and Fat Distribution Measurements

BMI is defined as weight in kilograms divided by the square of the height in metres (kg/m²). A BMI assessment is a reliable indicator of total body fat. BMI has been directly linked to health risks and mortality in many populations. Based on BMI values, a range of weight assessments can be made, including underweight, normal weight, overweight, and obese. The WHO has developed BMI classifications aimed for international use. Weight classifications based on BMI are shown in Table 22.7. Most health organizations, such as the National Heart Lung and Blood Institute (of the USA), use BMI criteria to assess body weight in adults. It is recommended that practitioners use the BMI to assess healthy and unhealthy weight of their clients as a way to monitor general health and as a basis for designing intervention strategies. Table 22.8 shows the relationship between height, weight, and BMI. There are many websites available that allow a person to quickly determine BMI based on height and weight; simply do an online search for “calculate BMI.”

Health-care providers should be aware that differences between ethnic groups may exist with respect to appropriate BMI cut-off points. For example, evidence suggests that for some Asian populations, a BMI of >23 is equivalent in terms of health risks to BMIs >25 and >27 in people of European and African decent, respectively (WHO Expert Consultation, 2004). Although the BMI is a useful tool in assessing body fat, some limitations should be noted; it tends to overestimate body fat in muscular individuals, such as athletes, and underestimate body fat in people with decreased muscle mass, such as elderly people and people who are severely undernourished (WHO, 2004).

### Table 22.7: Weight classifications based on BMI

<table>
<thead>
<tr>
<th>BMI value</th>
<th>BMI classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;18.5</td>
<td>Underweight</td>
</tr>
<tr>
<td>18.5–24.9</td>
<td>Normal weight</td>
</tr>
<tr>
<td>25.0–29.9</td>
<td>Overweight</td>
</tr>
<tr>
<td>30.0–39.9</td>
<td>Obese</td>
</tr>
<tr>
<td>&gt;40.0</td>
<td>Severely obese</td>
</tr>
</tbody>
</table>

Source: U.S. Department of Health and Human Services et al., 2013.

### Table 22.8: Body mass index for adults

<table>
<thead>
<tr>
<th>Height in metres (in)</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
<th>27</th>
<th>28</th>
<th>29</th>
<th>30</th>
<th>31</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.47 (58)</td>
<td>100</td>
<td>105</td>
<td>110</td>
<td>115</td>
<td>119</td>
<td>124</td>
<td>129</td>
<td>134</td>
<td>138</td>
<td>143</td>
<td>148</td>
</tr>
<tr>
<td>1.52 (60)</td>
<td>107</td>
<td>112</td>
<td>118</td>
<td>123</td>
<td>128</td>
<td>133</td>
<td>138</td>
<td>143</td>
<td>148</td>
<td>153</td>
<td>158</td>
</tr>
<tr>
<td>1.55 (61)</td>
<td>111</td>
<td>116</td>
<td>122</td>
<td>127</td>
<td>132</td>
<td>137</td>
<td>143</td>
<td>148</td>
<td>153</td>
<td>158</td>
<td>164</td>
</tr>
<tr>
<td>1.60 (63)</td>
<td>118</td>
<td>124</td>
<td>130</td>
<td>135</td>
<td>141</td>
<td>146</td>
<td>152</td>
<td>158</td>
<td>163</td>
<td>169</td>
<td>175</td>
</tr>
<tr>
<td>1.65 (65)</td>
<td>126</td>
<td>132</td>
<td>138</td>
<td>144</td>
<td>150</td>
<td>156</td>
<td>162</td>
<td>168</td>
<td>174</td>
<td>180</td>
<td>186</td>
</tr>
<tr>
<td>1.70 (67)</td>
<td>134</td>
<td>140</td>
<td>146</td>
<td>153</td>
<td>159</td>
<td>166</td>
<td>172</td>
<td>178</td>
<td>185</td>
<td>191</td>
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</tr>
<tr>
<td>1.75 (69)</td>
<td>142</td>
<td>149</td>
<td>155</td>
<td>162</td>
<td>169</td>
<td>176</td>
<td>182</td>
<td>189</td>
<td>196</td>
<td>203</td>
<td>209</td>
</tr>
<tr>
<td>1.80 (71)</td>
<td>150</td>
<td>157</td>
<td>165</td>
<td>172</td>
<td>179</td>
<td>186</td>
<td>193</td>
<td>200</td>
<td>208</td>
<td>215</td>
<td>222</td>
</tr>
<tr>
<td>1.85 (73)</td>
<td>159</td>
<td>166</td>
<td>174</td>
<td>182</td>
<td>189</td>
<td>197</td>
<td>204</td>
<td>212</td>
<td>219</td>
<td>227</td>
<td>235</td>
</tr>
<tr>
<td>1.90 (75)</td>
<td>168</td>
<td>176</td>
<td>184</td>
<td>192</td>
<td>200</td>
<td>208</td>
<td>216</td>
<td>224</td>
<td>232</td>
<td>240</td>
<td>248</td>
</tr>
</tbody>
</table>

Note: Weight is given in pounds. To convert kilograms to pounds, multiply kg by 2.20.

Not only is total body fat content important, its distribution can give important clues to disease risk. In particular, abdominal fat (i.e., fat around the waist) is particularly hazardous. Therefore, waist circumference (WC) is another technique recommended for use in clinical settings. WC provides an initial assessment of a client’s abdominal fat content; above-normal values pose a high risk for chronic disease such as cardiovascular disease and type 2 diabetes (Cameron et al., 2013).

WC is measured at the narrowest part of the waist; however, for best results specified anatomical landmarks should be used to guide measurements. The International Diabetes Federation has established the following criteria for WC cut-offs above which health risks increase: Europid males ≥94 cm, Europid females ≥80 cm, Asian males ≥90 cm, and Asian females ≥80 cm. Other populations (people with ethnicities originating in sub-Saharan Africa, the Middle East, the Mediterranean, and South and Central America) should use the Europid classification until more specific data are available. It is not necessary to measure WC in obese individuals, whose measurements will far exceed the cut-off points and lack predictive value. For comparison, the American cut-off points use ≥102 and ≥88 cm for men and women, respectively (International Diabetes Federation, 2004).

Child obesity deserves particular attention. It is a major public health threat because children who are obese are more likely than other children to become obese adults. It was estimated that in 2010 43 million preschool children were overweight or obese and that 81% of them were living in developing countries (de Onis et al., 2010). It is therefore important to monitor the growth of children through growth charts as a way of assessing overnutrition.

### 3.3 Body Composition Analyses

Health professionals can measure the amounts of body fat and lean tissue in an individual. Dual X-ray absorptiometry (DXA) is currently the gold standard for assessing body composition (Champagne & Bray, 2010). Men with body fat >25% and women with body fat >33% are considered obese (Friedl, 2004). DXA is often used in research settings, but its use in clinical settings is unlikely in developing countries except in rare instances.

Another method for determining body composition is bioelectrical impedance, which is based on measuring electrical conductance through body tissues. Muscle is high in water and conducts electricity well, while adipose tissue is the reverse. The technique is easy to use, but variability can occur from one analyzer to another, and the technique’s accuracy can be affected by hydration status.

Measurement of skinfold thickness is a cheap and simple method that can be very useful in the field. It is one of the most commonly used indirect methods for assessing body fat, and is based on the fact that a representative measure of subcutaneous adipose tissue layer provides a reasonable estimate of total body fat (Lukaski, 1987). The measurement of skinfold thickness is made by grasping the skin with the thumb and index finger, 7.5 cm apart, and the skinfold is then gently pulled away from the muscle below. Caliper jaws are placed perpendicular to the skinfold, over the lifted fold of skin. The thickness of the compressed skinfold is then recorded to the nearest full or fraction of a millimetre within 2 to 3 seconds after releasing the caliper extender (Williams, 1997). In individuals with moderately firm subcutaneous tissue, skinfold measurements are easy to perform, but in subjects with easily compressible or very firm tissue, obtaining valid measurements can be difficult (Lukaski, 1987).

Many equations are available for the prediction of body density and thus body fatness from skinfold thickness measurements (Eston et al., 2005). Durnin and Womersley (1974) developed a widely used formula that uses the logarithmic sum of four upper body sites (biceps, triceps, subscapular, and iliac crest), age, and gender. Another commonly used method estimates body density, and subsequently body fat, by utilizing logarithmic transformation of the sum of seven skinfolds (chest, axila, triceps, subscapular, abdomen, thigh, and suprailiac), age, and wrist and forearm circumference (Jackson & Pollock, 1978). Box 22.1 shows an equation, similar to the two mentioned above, that was developed by Peterson et al. (2003), which combines three upper-body skinfolds (triceps, subscapular, and suprailiac) with a lower-limb skinfold (mid-thigh). Findings from previous studies indicate that including lower-limb skinfolds with upper-body measurements improves the prediction of percent body fat (Eston et al., 2005).
Box 22.1: Examples of Equations Used to Estimate Percent Body Fat

For men: \( \%BF_{\text{new}} = 20.94878 + (\text{age} \times 0.1166) - (\text{height} \times 0.11666) + (\text{sum4} \times 0.42696) - (\text{sum4}^2 \times 0.00159) \)

For women: \( \%BF_{\text{new}} = 22.18945 + (\text{age} \times 0.06368) + (\text{BMI} \times 0.60404) - (\text{height} \times 0.14520) + (\text{sum4} \times 0.30919) - (\text{sum4}^2 \times 0.00099562) \)

*Height is in cm and sum4 is the sum of the triceps, subscapular, suprailiac, and mid-thigh skinfold thicknesses.*

*Source: Peterson et al., 2003*

Skinfold measurements are often combined with mid-upper-arm circumference (MUAC) and used as an indicator of protein-energy malnutrition. The estimated muscle arm circumference, \( C_a \), provides the basis of the body’s muscle mass and thus its main protein reserve. MUAC is determined by measuring to the nearest millimetre the circumference of the right arm, midway between the tip of the acromion and olecranon processes, with the arm relaxed. The triceps skinfold is then measured to the nearest millimetre at the same location in the posterior compartment of the arm. MUAC is derived using the equation: \( C_{\text{in}} = C_a - \pi S \), where \( C_{\text{in}} = \text{MUAC} \) and \( S = \text{triceps skinfold thickness} \). Because these two variables by themselves are not strong predictors of nutritional status, combining them to yield the following equations, in which \( F = \text{mid-arm fat} \) and \( M = \text{mid-arm muscle} \), provides a more reliable estimation of arm fat and muscle (Lukaski, 1987):

\[
F = SC_a/2 + \pi S^2/4
\]

and

\[
M = (C_a - \pi S)^2/4\pi
\]

4. **CLINICAL EVALUATIONS**

A clinical assessment begins by taking vital signs and anthropometric measurements, namely weight, height, and BMI. These can provide important first clues of a client’s nutritional status. Following a BMI determination, terms such as normal weight, underweight, overweight, and obese are used to describe the client. Adults and children who are consistently underweight are at high risk for marasmus and kwashiorkor. Marasmus is a form of protein and energy malnutrition that is characterized by severe tissue wasting and excessive loss of lean body mass and subcutaneous fat stores. Kwashiorkor is mainly a protein deficiency condition whose clinical signs include lethargy, apathy, irritability, retarded growth, changes in skin and hair pigmentation, and oedema of hands and feet. Study findings also suggest that many of the signs and symptoms of kwashiorkor are caused by micronutrient deficiencies, such as that of vitamin A, rather than poor protein intake (Golden, 2002).

The initial evaluation is followed by inspection of the skin, hair, nails, eyes, mouth, and other areas for signs of toxicity or nutrient deficiency. During this stage in the evaluation many micronutrient deficiencies can be uncovered. It has been suggested that 4.5 billion people worldwide are affected by deficiencies of iron, vitamin A, iodine, and zinc (Dickinson et al., 2009). A clinical examination of major body parts can reveal signs of micronutrient deficiencies, such as pale mucous membranes, Bitot’s spots, goitre, and hair loss, that are associated with iron, vitamin A, iodine, and zinc deficiencies, respectively. Table 22.9 describes a list of specific signs associated with macronutrient and micronutrient deficiencies by body region. (A glossary of clinical terms is provided at the end of the chapter.) Lack of energy and inability to perform normal tasks are symptoms that may indicate iron-deficiency anaemia. Clinical evaluations are important in making a diagnosis in later stages of malnutrition, but they are not useful for detecting deficiencies in the early stages, when signs and symptoms are not readily apparent. A clinical evaluation should also include a measure of blood pressure as an indicator of heart disease risk.
Table 22.9: Clinical signs and symptoms of nutritional significance based on physical examination

<table>
<thead>
<tr>
<th>Body system</th>
<th>Signs/symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>- Height, weight, body mass index, waist circumference, percent weight change (underweight, overweight, obese)</td>
</tr>
</tbody>
</table>
| Skin, hair, and mucous membranes | - Dermatitis (marasmus, deficiency of niacin, riboflavin, zinc, biotin, essential fatty acid, vitamin A)  
- Pigmentation changes (marasmus, niacin deficiency)  
- Pressure ulcers/delayed wound healing (kwashiorkor, diabetes)  
- Pallor (deficiency of iron, copper, folic acid, vitamin B₁₂ or E) |
| Head        | - Dispigmentation, easy pluckability (protein), alopecia (zinc, biotin deficiency)  
- Delayed closure of fontanelle (paediatric undernutrition or growth retardation) |
| Eyes        | - Night blindness, xerophthalmia, Bitot’s spots, keratomalacia (vitamin A deficiency)          |
| Mouth       | - Angular stomatitis (riboflavin, iron deficiency)  
- Bleeding gums (vitamins C, K, riboflavin deficiency)  
- Cheilosis (riboflavin, niacin, vitamin B₆ deficiency)  
- Dental caries (fluoride deficiency)  
- Discolouration of teeth (fluoride toxicity) |
| Neck        | - Hypogeusia (zinc, vitamin A deficiency)  
- Goitre (iodine deficiency) |
| Thorax      | - Thoracic rosary (vitamin D deficiency)                                                         |
| Abdomen     | - Diarrhoea (niacin, folic acid, vitamin B₁₂ deficiency; marasmus)  
- Ascites (kwashiorkor, alcoholism) |
| Genital/urinary | - Delayed puberty (marasmus)  
- Hypogonadism (zinc deficiency) |
| Extremities | - Bone ache, joint pain (vitamin C deficiency)  
- Oedema (thiamine and protein deficiency)  
- Muscle wasting and weakness (vitamin D deficiency, protein-energy undernutrition) |
| Nails       | - Softening of bone (vitamin D, calcium, phosphorus deficiency)  
- Spooning (iron deficiency) |
| Neurologic  | - Dementia, delirium, disorientation (niacin, thiamine, vitamin B₁₂, vitamin E deficiency)  
- Loss of reflexes, wrist drop, foot drop (thiamine deficiency)  
- Tetany (vitamin D, calcium, magnesium deficiency) |

Source: Reproduced from Hark et al., 2003. Reproduced with permission.

5. LABORATORY TESTS

Laboratory tests can help confirm nutritional status findings uncovered during a dietary assessment and physical examination. To perform a laboratory test, a sample, such as blood or urine, must be collected and analyzed for various substances. Measurements of haemoglobin and ferritin levels in the blood provide reliable information regarding iron status, while serum retinol is useful in diagnosing vitamin A deficiency. Inadequate levels of these two nutrients represent the most common nutrient deficiencies in developing countries. If undernutrition is suspected, tests that measure protein status in the body are necessary. Serum albumin and prealbumin can be useful indicators of body protein status. However, because tests for these proteins are non-specific and non-sensitive, care should be exercised in interpreting results. Additionally, levels of these proteins may decrease in response to injury, disease, or inflammation, which means that individuals with low serum albumin and prealbumin levels may or may not be malnourished (Gordon, 2002).
A laboratory examination should also include tests for components of the metabolic syndrome, an indicator of risk for heart disease and diabetes. Tests include blood levels of glucose, insulin, and lipids (especially triglycerides and HDL-cholesterol). Table 22.10 lists biochemical tests and their associated nutrients.

Table 22.10: Biochemical tests used as indicators of nutrient status

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Biochemical test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>- Serum albumin (reflects nutritional status over the last 3 months)</td>
</tr>
<tr>
<td></td>
<td>- Serum transferrin (reflects protein status over the previous several weeks)</td>
</tr>
<tr>
<td></td>
<td>- Serum prealbumin (reflects protein and calorie intake over the past week)</td>
</tr>
<tr>
<td>Lipids and other indicators of</td>
<td>- Cholesterol (LDL-cholesterol and HDL-cholesterol)</td>
</tr>
<tr>
<td>heart disease risk</td>
<td>- Triglycerides</td>
</tr>
<tr>
<td>Carbohydrates and other indicators of diabetes</td>
<td>- Serum glucose</td>
</tr>
<tr>
<td></td>
<td>- Haemoglobin (Hgb) A1c</td>
</tr>
<tr>
<td></td>
<td>- Insulin levels</td>
</tr>
<tr>
<td></td>
<td>- C-reactive protein</td>
</tr>
<tr>
<td></td>
<td>- Serum and urinary ketone bodies</td>
</tr>
<tr>
<td>Electrolytes</td>
<td>- Sodium, potassium, chloride, calcium, phosphorus, magnesium, blood urea nitrogen (BUN), creatinine, urine urea nitrogen, uric acid</td>
</tr>
<tr>
<td></td>
<td>- Serum retinol</td>
</tr>
<tr>
<td>Vitamin A Iron</td>
<td>- Complete blood count (CBC), serum iron and ferritin, total iron-binding capacity, transferrin saturation, mean corpuscular volume (MCV)</td>
</tr>
</tbody>
</table>

Source: Reproduced from Hark et al., 2003. Reproduced with permission.

6. LOOKING AT THE BIG PICTURE

In this chapter we have looked at many indicators of both undernutrition and overnutrition. Both conditions are widespread in developing countries. However, prevalence varies widely from country to country. Indeed, even at the community level it is not uncommon to see people who have signs of undernutrition while their neighbours are overweight. A community nutritionist should therefore be familiar with the major nutrition problems within his or her community and choose appropriate tests on that basis.

We shall now look more closely at the problem of overnutrition. This is of enormous concern as the prevalence of chronic diseases of lifestyle (CDL) has been rising rapidly in developing countries in recent years. The pattern of CDL appears first and most prominently in an urbanized environment. The most obvious sign of it is escalating rates of obesity. Various indicators for nutrient status can be used to identify the health problems that appear whenever overnutrition and obesity have become common. Major problems are as follows:

- High blood pressure (or hypertension) is common among overweight and obese middle-aged people. The condition is also associated with a high salt intake. High blood pressure is a major risk factor for heart disease and stroke.
- Insulin resistance and glucose intolerance are strong predictors of elevated risk of type 2 diabetes. This disease is strongly associated with obesity, and risk rises sharply with age. Table 22.10 lists biochemical tests for risk factors linked to diabetes.
- There are several major risk factors for heart disease: high blood pressure, smoking, lack of physical activity, and abnormal blood lipids (high levels of LDL-cholesterol and triglycerides, and low levels of HDL-cholesterol). The presence of type 2 diabetes is another major risk factor.
The condition known as metabolic syndrome refers to a cluster of measurements, notably high blood pressure, abdominal obesity, insulin resistance, glucose intolerance, high blood triglycerides, and low blood HDL-cholesterol (Alberti et al., 2009). The presence of the metabolic syndrome signifies an increased risk for heart disease, stroke, and diabetes (International Diabetes Federation, 2004).

**DISCUSSION QUESTIONS AND EXERCISES**

1. Discuss the advantages and disadvantages of the various dietary assessment methods.
2. Discuss the steps that you would follow to conduct a thorough nutritional assessment of a community.
3. Compare and contrast the various anthropometric methods used to evaluate nutritional status.
4. Select five body systems, and for each one, discuss the clinical signs or symptoms that may be evidence of poor nutritional status.
5. Choose and discuss seven biochemical tests that reflect levels of nutrients in the body.
6. Carry out a 24-hour food recall on three classmates. Compare the intake of different food groups with the food guide used in your country. Next, carry out a computer analysis of each diet (use the various sources referred to in the “Additional Resources” section at the end of this chapter). Compare your findings with the values given in Appendix III at the end of the book. Identify possible problem areas with each of the diets. Use the results of this exercise to help plan ways to improve the diets.
7. Write a report on the nutritional status of children in your community using any recent surveillance data. Classification of nutritional status using anthropometry should be based on the World Health Organization growth standards.

**GLOSSARY OF CLINICAL TERMS**

(Source: Fremgen & Frught, 2009)

- **alopecia**: the loss of hair from the head or body, sometimes to the extent of baldness
- **angular stomatitis**: an inflammatory lesion at the labial commissure, or corner of the mouth, often occurring bilaterally
- **ascites**: accumulation of fluid in the peritoneal cavity
- **Bitot’s spots**: buildup of keratin debris located superficially in the conjunctiva, which are oval, triangular, or irregular in shape
- **cheilosis**: angular stomatitis
- **dermatitis**: inflammation of the skin
- **dispigmentation**: lightening of the skin, or loss of pigment
- **hypogeusia**: diminished ability to taste things (to taste sweet, sour, bitter, or salty substances)
- **hypogonadism**: decreased functional activity of the gonads
- **keratomalacia**: an eye disorder that leads to a dry cornea
- **oedema**: an abnormal accumulation of fluid beneath the skin or in one or more cavities of the body
- **pallor**: a reduced amount of oxyhaemoglobin in skin or mucous membrane; a pale colour that can be caused by illness, emotional shock or stress, stimulant use, lack of exposure to sunlight, anaemia, or genetics
- **spooning**: flexion and dorsal arching of the wrists and hyperextension of the fingers when the hands are extended sideways, palms down
- **tetany**: the involuntary contraction of muscles, caused by diseases and other conditions that increase the action potential frequency
- **thoracic rosary**: enlarged ends of the ribs, resembling beads, that can be palpable and visible at the costochondral junction
- **xerophthalmia**: a medical condition in which the eye fails to produce tears

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South African Medical Research Council. 2001. *Foodfinder 3 Software Programme*. Cape Town, WAMTechnology © and MRC NIRU.

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ADDITIONAL RESOURCES

Information on making anthropometric measurements is available at the website of FANTA (Food and Nutrition Technical Assistance II Project): http://www.fantaproject.org/publications/anthropom.shtml.

Further details on the National Health and Nutrition Examination Study (NHANES) can be found on the following website: http://www.cdc.gov/nchs/nhanes/nhanes_questionnaires.htm

Information on food composition, dietary guidelines, and weight and obesity can be found on the website of the U.S. Department of Agriculture (USDA): http://fnic.nal.usda.gov/

Various food composition tables are available. The first four can be accessed online at no cost:

http://www.nal.usda.gov/fnic/foodcomp/search/. This is the USDA National Nutrient Database (also available via the previous website).

http://www.nutritiondata.com. Operated by NutritionData. This source contains the same data as the USDA database but presented in a different format.

http://www.hc-sc.gc.ca/fn-an/nutrition/fiche-nutri-data/nutrient_value-valueurs_nutritives-eng.php. This Canadian website provides detailed information on the nutrition content of large numbers of foods.

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The following books are available for purchase:


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