Obesity: Methods of Assessment

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By Wanda Lockwood, RN, BA, MA

Purpose

The purpose of this course is to acquaint the health practitioner with various methods of assessing obesity (percentage of body fat and distribution) and to provide an understanding of the effectiveness, positive aspects, and negative aspects of each method.

Goal

Upon completion of this course, the health practitioner should be able to:

- Explain for formula for calculating the body mass index (BMI) and describe the weight status in relation to BMI findings.
- Discuss the value of waist circumference and provide low risk and high risk ranges for males and females.
- Explain the purpose of the waist-to-hip ration and provide examples of measures that indicate increased and high risk for males and females.
- Describe the procedure for skinfold thickness measurement.
- Explain how dual energy X-ray absorptiometry (DXA) is used to estimate the amount of body fat.
- Discuss near-infrared interactance and describe at least 3 factors that may impact results.
- Describe hydrostatic (underwater) weighing.
- Describe the procedure for air displacement plethysmography and discuss at least 3 problems associated with this method.
- Discuss bioelectrical impedance analysis, including 3 types of equipment.

Introduction

Most people recognize obesity when they see it (or think they do). Obesity is an increasing health problem with the CDC reporting that about a third of the adults in the United States are overweight by at least 20% above their ideal weight. Additionally, about 17% of children and adolescents are obese. Most people—including health practitioners—assess obesity by having the person stand on a scale. While this provides information about weight, it provides no information about composition or distribution of body fat and provides only the most general assessment of heath risk. Charts are available that provide “normal” ranges based on height and weight, but these charts often don’t take into account differences in ethnicity, age, body build, and muscle development. For health purposes, the percentage of body fat and its distribution are important factors, but determining these factors is not as easy as one might think. Different assessment methods yield different results, some more accurate than others. There are primarily four types of assessment to determine obesity: anthropometry (direct body measurements), density, conductivity, and radiography.

Body mass index (BMI)

The body mass index (BMI) is a standard measurement used to determine whether a person’s weight is within normal range. The BMI is based on average findings and uses weight and height to determine approximately the degree of obesity. Charts are available to show BMI, but calculating is simple. Calculate BMI by dividing weight in pounds (lbs) by height in inches (in) squared and multiplying by a conversion factor of 703.

- **Formula:** Weight (lb) / [height (in)]^2 x 703 = BMI
- **Example:** Weight = 185 lbs, Height = 5'4" (64") Calculation: 185 divided by (64)^2 x 703 = 31.75.

- **Metric formula:** Weight is in kilograms and height is in meters. There is no conversion factor.
    - Weight / $(\text{Height})^2$ = BMI.

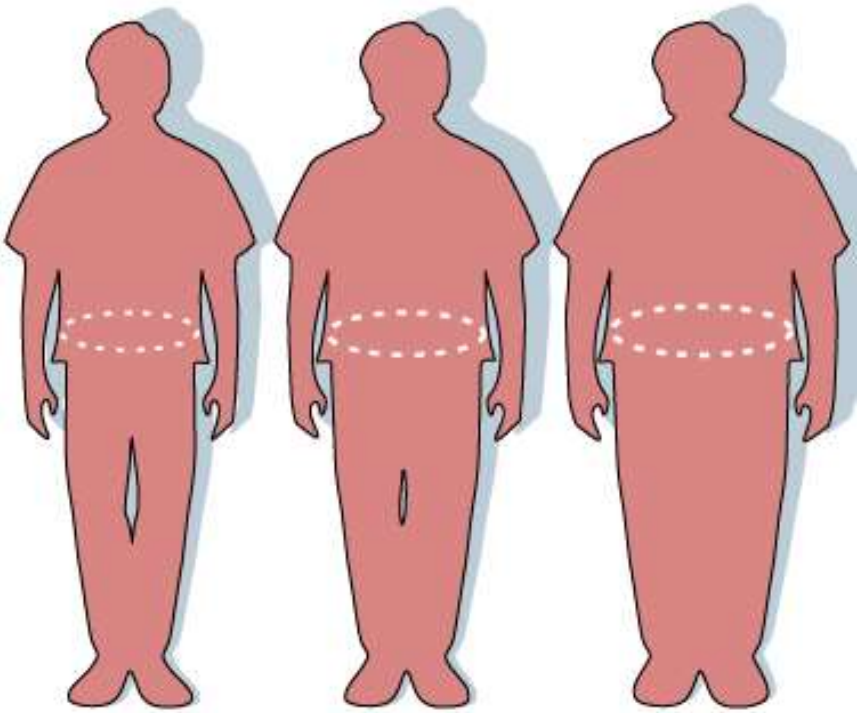
Standards have been established regarding weight status, so one can compare the BMI finding (in this case 31.75) to the weight status chart and see that, according to the chart, this person is obese.

BMI	Weight Status
Below 18.5	Underweight
18.5 – 24.9	Normal
25.0 – 29.9	Overweight
30.0 – 34.9	Obese
35.0 – 39.9	Severe obesity
≥40	Morbid obesity

The BMI is a simple and fairly reliable measure to determine rates of obesity for large populations, but it is less accurate for the individual because it does not measure fat directly and is solely based on height and weight. Thus, a person who has not exercised or eaten an adequate diet--common with a person who has chronic health problems or is older--may lose muscle mass and replace it with fat but still retain a normal BMI while in actuality the person is overweight. Additionally, a body builder or physically active person who bulks up, causing weight gain, but has a low percentage of body fat may have a BMI in the overweight category.

This is problematical because much of the research correlating weight with disease is based on BMI measurements. For example, a recent published report found that increased BMI correlated with increased rates of congestive heart disease, but increased survival rates also correlated with increased BMI, a seeming contradiction. When researchers restudied some of the participants and measured their degree of obesity using other methods, they found that many of the people classified as having normal BMI were, in fact, overweight—altering the findings.

Waist circumference



Another simple method of determining obesity is to measure waist circumference. Waist circumference has been found to be a good (although not completely accurate) predictor of obesity-related health risks. People with large waists are at increased risk even if BMI is normal. Typically, men put on fat in the abdomen, developing what is often described as a “beer belly.”

PH Kenny, Wikimedia Commons

Women, prior to menopause, tend put on fat in the buttocks and hips; but after menopause (as estrogen levels fall), many women begin to deposit fat in the same manner as men, in the abdomen. Increased abdominal fat is associated with diabetes type 2, hyperlipidemia, elevated triglycerides, hypertension,

coronary artery disease, hormonal cancers (such as breast cancer), and sleep apnea.

The waist is measured right above the hipbones, holding the tape snug but not compressing the skin.

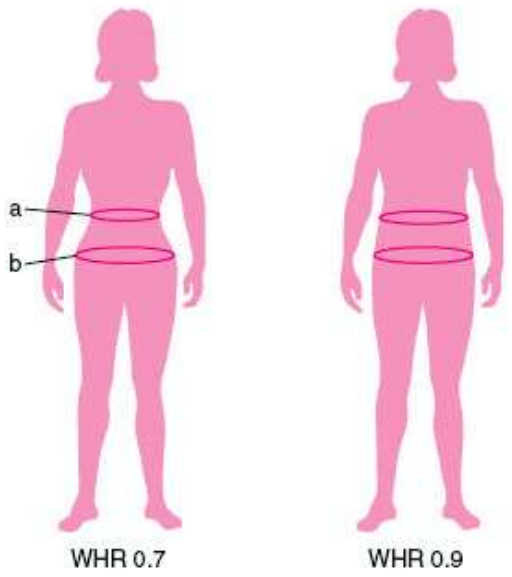
Gender	Low risk	High risk
Male	≤40 inches	>40 inches
Female	≤35 inches	>35 inches

Obviously, waist circumference is based on averages, so if people are outside the average in height (too short, too tall) or body build (too stocky, too slim), waist circumference alone may not be an accurate measure. Additionally, waist circumference (WC) may be combined with BMI when assessing obesity. As the BMI increases, risk increases even with a waist circumference in normal range; but the risk is greater with increased waist circumference.

BMI	Status	WC ≤35 (female) or ≤40 (male)	WC >35 (female) or >40 (male)
<18.5	Underweight		
18.5 – 24.9	Normal		
25.0 – 29.9	Overweight	Increased risk	High risk
30.0 – 34.9	Obese	High risk	Very high risk
35.0 – 39.9	Severe obesity	Very high risk	Very high risk
≥40	Morbid obesity	Extremely high risk	Extremely high risk

Waist-to-hip ratio (WHR)

Body shape is often described as “pear” with excess fat deposited in the buttocks and hips or “apple” with excess fat deposited in the abdomen. Apple-shaped individuals with increased intra-abdominal fat are at higher risk of health problems. In addition to simply measuring weight circumference, the waist-to-hip ratio (WHR) considers the ratio of the waist circumference to the hip circumference to determine if the person is an “apple” or “pear.” The waist is measured at its smallest point (above the umbilicus) and the hips at the widest point:



- **Formula:** Waist (inches) divided by hips (inches) = ratio.
- **Example:** 35 (waist) / 41 (hip) = 0.85

Gender	Ideal	Increased risk	High risk
Male	0.9 to 0.95	0.96 to 1.0	>1.0
Female	0.7 to 0.8	0.81 to 0.85	>0.85

Researchers have found that one cause of abdominal fat deposits is increased cortisol, a response to stress. The amount of abdominal fat correlates with the degree of stress, so it is hard to determine which is the causative factor in health problems—the fat or the stress or (more likely) some combination of both. However, regardless, the WHR is an important determinant of risk. Canadian researchers in the INTERHART study (2005) evaluated the relationship between BMI, waist and hip circumference, and WHR in relation to risk of myocardial infarction. Evaluating 27,000 cases in 52 counties, this study showed that after adjusting for other risk factors, the WHR showed a significant association with MI worldwide and was a much better predictor than the BMI. The researchers recommended that BMI no longer be used as an evaluation of obesity but should be replaced with WHR.

Skinfold thickness

Measurement of skinfold thickness is a direct measure of fat, unlike the previous methods. The premise is that subcutaneous fat is a reflection of the proportion of total body fat. Calipers are used to grasp and measure fatty tissue in various parts of the body (protocols vary), such as the chin, biceps, triceps, subscapular, chest, abdominal hip, thigh, knee and calf, and then an equation used to calculate the percentage of body fat. The selected sites (usually 3 to 7) are believed to represent the average thickness of subcutaneous fat.

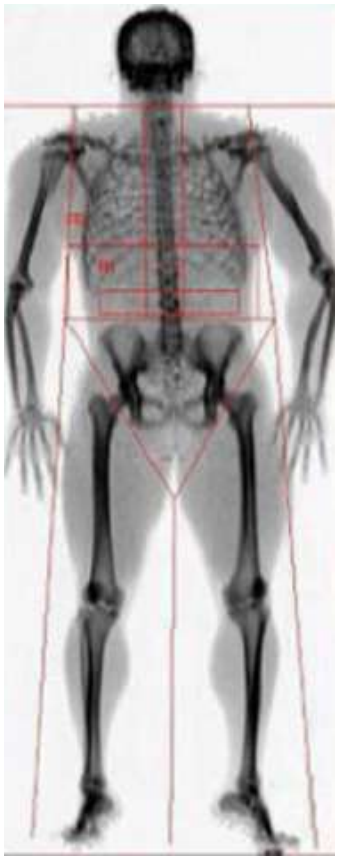
Specific procedures must be followed for each measurement; for example, the abdominal measure is typically taken at the horizontal fold, 5 cm lateral to and at the same level as the umbilicus. The procedure for skinfold thickness measurement includes grasping the skin and underlying tissue, shaking it to separate fat from muscle, and then pinching it between the arms of the caliper. Generally, two measurements are taken at each site and the two averaged to arrive at a measurement.

If done correctly, measurement of skinfold thickness can be up to 98% accurate in determining body fat. However, one problem with skinfold thickness measurement is that different clinicians measuring the same person may get different results, depending upon their knowledge and experience. Another problem is that various equations are used to assess results, so there is little consistency. Skinfold measurement may also be less accurate with those who are morbidly obese because the calipers don't open widely enough for accurate measurement. Skinfold thickness may be most predictive if combined with other measurements, such as circumference (of various parts of the body) and bone breadth.

Dual energy X-ray absorptiometry (DXA)

NIDDK

DXA, more commonly used to determine bone mineral density for diagnosis of osteoporosis, can also be used to determine fat content of the body and provides one of the most accurate measurements. Two different types of beams scan the body. One is absorbed more readily by fat than the other, so the computer is able to differentiate the fat from other tissues and provide the percentage of body fat.



This method has the advantage of measuring fat over the entire body rather than in just certain areas. However, while DXA is generally considered the gold

standard, the results may not always be accurate because fat mass is calculated indirectly by subtracting it from lean soft tissue or body cell mass. The percentage of body fat is calculated and risk assessment based on percentage ranges established for males and females.

Gender	Normal	Overweight	Obese
Adult Male	4-25%	25-30%	>30%
Adult Female	12-29%	29-35%	>35%

A problem with DXA is that it's not always readily available, especially in more rural areas, and most insurance companies do not reimburse the cost of the test, so the person has to pay out of pocket, and DXA can be expensive.

Near-infrared interactance

Near-infrared interactance (NIR) uses a fiberoptic probe and a digital analyzer to determine the body's fat composition. The probe is placed against body sites, most often the biceps. The person's height, weight, size of frame, and level of activity are entered into the analyzer. Light penetrates the tissue and reflects off of the bone back to the equipment, which records optical densities. Based on the information received from the probe and the information entered, the machine calculates the percentage of body fat.

NIR is increasingly popular because it can be done quickly and inexpensively in a doctor's office or sports facility, but it's not a reliable assessment method, especially for those who are very thin or very obese. Determining frame-size and level of activity is subjective, and people are not always honest about level of activity. Single-site assessment tends to be less accurate than multiple-site. Additionally, other factors, such as skin color, pressure applied to probe, and hydration, may interfere with readings. Research has not been done to establish accuracy of NIR, so it should not be used to determine the need for medical intervention.

Hydrostatic (underwater) weighing

Underwater (hydrostatic) weighing is based on the fact that lean body tissue is more dense than fat. While underwater weighing has been used to establish references for percentage of body fat and is generally considered the most accurate measure of body fat, the equipment is usually only available in research facilities. Testing requires a large tank of water (about 1000 gallons) with the water maintained at a constant temperature.

Additionally, the procedure can be unpleasant or virtually impossible for some people. The person is submerged repeatedly (8 to 10 times) in a large tub of water. After submersion, the person holds her breath for about 10 to 15 seconds while the technician records the weight. Calculations are based on the difference between weight in the air and weight under water. The body's density is calculated by dividing the body mass by the volume of water it displaces (subtracting air left in the lungs). From that result, another calculation determines body fat.

Air displacement plethysmography (BodPod)

NIDDK

The air displacement plethysmography method of analyzing body composition utilizes a special enclosed chamber, such as the BodPod, in which the person sits. Because clothing and hair can interfere with the results, the person must wear form-fitting swimwear or compression shorts (and bra for females), such as those made with spandex. The person must remove all jewelry and glasses and cover the hair with a swim cap. Prior to entering the capsule, the person is weighed on a scale to determine the mass measurement (weight), and the volume of air inside the BodPod is measured.

The person sits inside while sensors determine the volume of air the person displaces. For example, if the volume inside the empty chamber was 400 L, and it reduces to 340 L with the person inside, then the volume of the person's body is 60 L. Measurements are taken 2 or 3 times for about 50 seconds each time during which the person can breathe normally. Between measurements, the door can be opened briefly. The person's thoracic gas volume (total volume of air in the lungs) is then measured by the person's breathing into a mouthpiece and tubing (unless standard predictive settings or previous testing results were entered into the computer). The body volume, weight, and thoracic gas volume are used to calculate the percentage of lean and fat mass. The test takes about 5-10 minutes.

Typical readout:

Parameter	Results
Percent fat	10.6%
Percent fat free mass (other tissues)	89.4%
Fat mass	18.560 lb.
Fat-free mass	156.072 lb
Body mass (total weight)	174.632 lb
Body volume	73.712 L
Body density	1.075 kg/L
Thoracic gas volume	4239 L

The BodPod is increasingly used in sports medicine. People who are morbidly obese may not fit into the chamber, and those with claustrophobia may not be able to tolerate being closed inside, even for short durations. Additionally, some studies comparing the BodPod to underwater testing show that the BodPod tends to overestimate body fat by 2 to 3% while other studies show that it underestimates body fat. One study showed the BodPod overestimated body fat in women by 7% and underestimated it by 16% in men. In general, the BodPod tends to be more accurate with those of average weight or overweight and less accurate with those who are lean.

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Bioelectrical impedance analysis (BIA)

The more water tissue contains, the faster electrical current is conducted through the tissue. Thus, electrical current passes through lean body tissue and fluids (blood, urine, muscle) faster than air, bone or fat tissue. This is the basis for bioelectrical impedance analysis (BIA). The BIA equipment measures resistance and estimates body fat by combining measures with height, weight, gender, fitness level, and age. BIA converts the results to percentage of body fat mass and estimate of total body water. Different procedures are available. Single frequency analysis takes only a few seconds but is less accurate than multiple frequency analysis, which takes a few minutes.

During BIA, the person should stand with legs apart and arms held away from the body, making sure to avoid contact with any conducting surfaces. Results can be skewed by changes in hydration and intestinal contents and time of day. Additionally, BIA often overestimates body fat in lean individuals and underestimates fat in obese individuals. For increased accuracy, people should follow guidelines, which usually include avoiding food and drink for 4 hours prior to testing and exercise for 12 hours.

For BIA, a pair of leads is typically placed on the person’s hand and another pair on the opposite foot. A low dose (500 to 800 micro-amp) electrical current passes through the electrodes and the body. The current is small so most people can’t detect it. Electrodes are sometimes built into scales, and the person simply stands with a foot on each electrode/footpad. Handheld devices are also available.

However, the digital scales only measure fat in the lower extremities (the current travels up one leg and down the other), and the handheld devices only measure fat in the upper body (current travels from one arm through the other), so neither of these devices account for abdominal fat. BIA equipment is widely available and often quite inexpensive, so it is frequently used in gyms and homes for personal use. However, the equipment varies widely in accuracy, and there is a considerable margin of error with BIA.

Summary

Assessing the percentage of body fat and distribution are essential in evaluation of obesity, but many methods are available:

- **Body mass index (BMI):** Uses height and weight to determine degree of obesity. A formula is used to arrive at the BMI with ≥25 considered overweight and ≥30 obese.
- **Waist circumference:** Determines risk based on waist measurement with low risk ≤40 inches for males and ≤35 inches for females and high risk >40 inches for males and >35 inches for females.
- **Waist-to-hip ratio (WHR):** Waist measurement is divided by hip measurement to yield the WHR. Ideal WHR for males is 0.9 to 0.95 and for females 0.7 to 0.8. Higher ratios are correlated with increased health risk.
- **Skinfold thickness:** Calipers measure subcutaneous fat, and equations are applied to determine an estimate of body fat.
- **Dual energy X-ray absorptiometry (DXA):** Uses body scans to differentiate fat from other tissue and estimate percentage of total body fat.
- **Near-infrared interactance:** Uses various parameters (height, weight, frame size, and activity level) with a fiberoptic probe and digital analyzer to estimate the amount of body fat.
- **Hydrostatic (underwater) weighing:** Uses the difference between weight in the air and under water to determine amount of body fat but requires repeated submersion in special tank of water.
- **Air displacement plethysmography:** Is similar to underwater weighing but uses displacement of volumes of air in an enclosed chamber to estimate amount of body fat.

- **Bioelectrical impedance:** Estimates amount of body fat based on the speed of electrical current through tissue.

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