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Session Title: BMI: Is there a better way to assess our patients and/or predict death?

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Title: Body Composition Assessment

Objective #1 – Explain Limitations of Body Mass Index.

BMI is a surrogate for body composition and not a direct measure. A number of studies in clinical populations and the general population have shown lower all-cause mortality in overweight persons compared to normal weight and obese persons. The so-called obesity paradox may be due to the limitations of BMI. Body mass index does not account for sex, race, age and fitness related differences in fat, muscle, and bone masses at the same weight. Race, age and fitness all influence the associations among disease risk, mortality and BMI. Fat distribution varies widely among individuals even at the same level of body fat, with some depots (e.g., intra-abdominal, visceral fat) conferring greater health risks. BMI gives no information about fat distribution. Also, a relatively large fat mass may mask low muscle mass. The sole use of BMI as a health risk phenotype groups people with substantial differences in nutritional status, disability, disease and mortality risk into similar BMI categories. Establishing BMI should be only the first step toward a more comprehensive risk evaluation, including assessment of body composition.

Objective #2 – Describe Components of Interest Relating to Disease Risk and Functional Capacity.

Application of more direct methods allows the components of weight to be measured so that phenotypes (e.g., sarcopenic obesity; over-weight-high muscle mass; abdominal obesity; low bone mass for weight) more directly related to risk can be measured. Obesity, especially abdominal obesity, increases risk of metabolic impairment, as does low muscle mass. Low muscle mass is associated with low bone mass which increases the risk of bone fracture. Low muscle mass is also associated with impaired metabolism and poor muscle strength and endurance that compromises mobility and other aspects of functional capacity. Obesity (high body fat), abdominal obesity, sarcopenia (low muscle mass), and osteopenia and osteoporosis (low bone mineral mass and density) are all important public health concerns that contribute to overall morbidity and mortality. The appropriate component of composition and method to assess it depends on the issue of concern.

Objective #3 – Describe General Approaches to Body Composition Assessment.

The body composition assessment tool kit includes methods for assessing components on the atomic, molecular, cellular, tissue and whole-body levels. Individual components on a given level may be of interest, or they can be combined to form compartments with physiological or functional significance. Simple to complex models have been developed to estimate composition. For example, a simple two component model on the chemical level combines all nonfat elements into one compartment and composition is estimated in terms of the fat and fat-free masses. Although fat-free mass is not an anatomical compartment, it is relevant and useful since it encompasses the body cell mass including muscle and thus is strongly related to metabolism and functional capacity. More complex models can be formulated by measuring multiple components, e.g., body water and bone mineral, rather than combining them into one compartment. More complex models require fewer assumptions since the interindividual variation in components is captured. Multiple component models are more valid than simpler models and generally more accurate although they are susceptible to measurement error. Approaches should be chosen with the main component of interest in mind. If inter-individual variation in mineral is a concern, then a model that measures and adjusts for mineral should be applied. If variation in body fluid is likely, a common challenge in clinical populations, then a model that adjusts for variation in hydration is desirable. An understanding of various models is helpful since simple, practical methods are validated against the more complex models.

Objective #4 – Describe Practical Methods for Body Composition Assessment.

Many methods for assessing body constituents and various compartments have been developed. A brief review of a few of the more accessible and practical methods is given below.

Densitometry – Body density is inversely related to body fat. Once body density is known, body fat can be estimated from equations based on the assumed proportions of the fat-free body components (i.e. mineral, protein and body water) and their respective densities. Body density is calculated from body mass and body volume. Historically underwater weighing has been used to estimate body volume. More recently, air displacement (plethysmography) using the Bod Pod, rather than water displacement has gained in popularity and accessibility. Both approaches give comparable estimates of body density and accurate estimates of body fat if the model underlying the equation used to estimate body fat is valid for the individual being assessed. Population-specific equations derived from models representing the population of interest (men, women, children, athletes etc) must be used to achieve valid and accurate results.

Dual Energy X-Ray Absorptiometry (DXA) - DXA provides valid and accurate estimates of whole body and regional bone mineral mass and density, lean soft tissue and fat mass. In recognition of the importance of fat distribution to disease risks, default regions of interest include estimates of trunk, gynoid, and android fat. Although android fat is not equivalent with intra-abdominal fat, they are significantly correlated and predictive of disease risk. The DXA method uses an x-ray tube with a filter to create low energy and high energy photons. When the photons are passed through a tissue, absorption can be expressed as a ratio (R) of the attenuation at the lower energy relative to the attenuation at the higher energy. Attenuation coefficients and R values for elements are known and theoretical R values for fat and lean soft tissue have been derived. Two sets of equations are used to i) separate soft tissue from bone and to ii) separate lean tissue from fat. The attenuation ratios at two different x-ray energies are thought to be constant for all individuals. The major assumptions underlying estimation of soft tissue using this technology include: i) the amount of fat over bone is the same as the amount of fat over bone-free tissue; ii) measurements are not affected by the anteroposterior thickness of the body, and iii) the hydration and electrolyte content of LTM is constant. Variation in fat distribution, patient thickness and hydration introduce error but generally the magnitude is small. Variation in DXA technology and software across manufacturers is likely a bigger source of error and repeat studies should be done on the same scanner or appropriate corrections must be applied. Radiation exposure is small and DXA is considered a safe method for children and adults.

Bioelectrical Impedance Analysis (BIA) - Impedance is the frequency-dependent opposition of a conductor to the flow of an alternating electric. The principle underlying the use of bioelectrical impedance for assessing body composition is the relationship of body composition to the water content of the body. Bioelectrical Impedance analyzers use an alternating current that enters the body at a very low and safe amperage. The conductor is the water content of the body, and the analyzer measures the impedance of this fluid conductor. At low frequencies, the current flows through the extracellular space and at higher frequencies, the current flows through both intracelleular and extracellur spaces. Thus, depending on signal frequency, extracellular fluid, total body water and intracellular fluid can be estimated, and body cell mass and fat-free mass, which contains the body water, can be derived. Early analyzers quantified TBW from single-frequency impedance measures (usually at 50 KHZ). Early measures of impedance were taken in a supine position with electrodes on the right hand-wrist and right ankle foot, to counter the effects of gravity that tend to pool body water in the legs when the subject is standing. The development of segmental impedance and multi-frequency analyzers has expanded the utility of BIA, and measurements can now be taken from hand to hand and foot to foot with the subject standing, sitting or supine, depending on the analyzer used. Single frequency analyzers are limited in their ability to distinguish fluid distribution and the use of impedance to estimate fat-free mass and body fat is based on an assumed constant (73%) fraction of water in the FFM. The ability of multi-frequency impedance to differentiate TBW in ICW and ECW is important to describe fluid shifts and balance and to explore variations in hydration. Development of multi-frequency BIA expanded the use of impedance in clinical and nutritional studies when water distribution is disturbed. There is also increased clinical use of segmental impedance in assessment of diseases that affect body fluid balance. Estimates of fat-free mass, body fat and other compartments using BIA require a regression equation validated against a criterion body composition method. Such equations are only as accurate as the criterion method used to develop them, which is influenced by the age, race, sex and physical condition of the individuals assessed as well as body composition, including its hydration and density. An appropriate equation for the group of interest must be used for accurate and valid results to be achieved.

Anthropometry - In the absence of more sophisticated methods, simple anthropometric measures can be used alone or in combination with BMI to improve risk assessment. Skinfold measures, for example, can be used to estimate whole body fatness or to derive indices that estimate fat distribution. Waist circumference is a proxy for abdominal fatness although it must be noted that at a given circumference intra-abdominal fatness can vary considerably. Nevertheless, waist circumference in combination with BMI has been used to refine risk assessment and create risk categories.

Objective #5 - Choose an appropriate method to measure the component of interest

The choice of method depends on the compartment of interest which in turn depends on the health issue addressed. If cardiometabolic disease risk is of primary concern, obesity and especially abdominal fat should be assessed. While densitometric methods (underwater weighing, air displacement plethysmography) provide estimates of whole body fat, they do not measure regional fatness. Sarcopenia is strongly related to mobility, functional capacity, and ultimately mobility, if malnutrition and wasting are evident. Bioelectrical impedance analysis does not measure muscle directly but regression equations are available for estimating fat-free mass and muscle mass. Dual energy x-ray absorptiometry has the advantage of providing whole body and segmental estimates of body fat, lean soft tissue and bone mineral mass and density. Appendicular (arms and legs) lean soft tissue mass is approximately equal to skeletal muscle mass and has been used to develop indexes of sarcopenia. Numerous regression equations are available for estimating various components of composition when a reference method such as DXA is not available. It is critical that both the underlying model and study sample be relevant to the individual or group being assessed. It can be difficult to determine which equation is best for a particular use. Fortunately, “decision trees” have been developed to help practitioners select equations that have been validated for different populations. *Applied Body Composition Assessment* by Heyward and Wagner (2nd Edition. Human Kinetics. Champaign, IL, 2004) is a useful reference that has these kinds of selection guides.

Resources

Going, S., Hingle, M., and Farr, J. Body Composition. In: Modern Nutrition in Health and Disease, 11th edition. Chapter 48. (2012). A. Catharine Ross, Benjamin Caballero, Robert. J. Cousins, Katherine L. Tucker, and Thomas R. Ziegler (eds). Lippincott, Williams & Wilkins, Baltimore, MD., pg 635-648.

Provides an overview of approaches to body composition for assessment of nutritional status.

Heymsfield S., Lohman, T., Wang, Z., and Going, S. (eds.) Human Body Composition: Methods and Findings II. Champaign IL: Human Kinetics, 2005.

An in depth presentation of body composition methods and models and their application in healthy and clinical populations.

Heyward, V. and Wagner, D.R. Applied Body Composition Assessment, 2nd Edition. Human Kinetics. Champaign, IL, 2004.

For practitioners, provides overview of methods, theory assumptions and application in various populations. Algorithms (decision tress) for selecting appropriate equations for various methods in different populations are provided.