Body Composition Assessment
Balancing Cost with Accuracy.

While we can acknowledge that societal misconceptualizations surrounding body composition contribute to a general dislike of — and in some cases problematic mental health issues associated with — assessing body composition. The reality is that there are good reasons for needing to obtain assessment of body composition. Therefore it is important to acquire an understanding of the methods and techniques available while simultaneously rejecting the premise that body mass alone provides any useful information. Rejecting all forms of body composition assessment as problematic only serves to add credibility to societal misconceptualizations.

Topics: Skinfold Assessment — Bioelectric Impedance Analysis — Plethsmography — Absorptiometry — Imaging — Relative Body Composition

Skinfold Measurements have been a staple of body composition research for more than 50 years. This assessment approach is based on the concept that subcutaneous fat represents about half of all storage fat. So by pinching a small segment of skin using specialized calipers — ensuring that no muscle tissue is trapped underneath — a precise measurement of the thickness of that area can be obtained. Several sites are measured (such as the chest, axilla (armpit), triceps, subscapular (back), abdomen, suprailiac (hip), and thigh) and then the measurements are entered into a formula to obtain estimated percent body fat.

Although the American College of Sports Medicine and various kinesiology related groups still advocate for the use of skinfold measurements given the relatively low expense and ease of measurement; most reasonable individuals generally consider this to be a **historic approach with minimal practical relevance**. The critical issue with this approach is that people do not generally like having their fat pinched and measured in areas that they are most sensitive about. There is considerable discomfort associated with this measurement approach and given that other techniques provide comparable accuracy and cost relative to skinfold measurements, **the discomfort is not justified**. The technique also requires a considerable amount of training to do consistently and accurately as there is a large risk of technician error and a number of factors including exercise, dehydration, and skin conditions impact skin thickness potentially altering the estimated percent body fat.

Bioelectric Impedance Analysis (BI or BIA) is a method that takes advantage of the unique properties of various tissues in the body in conducting the flow of electricity. As adipocytes are nearly free of water, adipose tissue is not only a poor conductor of thermal energy (allowing it to serve as insulation) but also a poor conductor of electricity. In contrast, muscle has substantially higher water levels enabling it to very efficiently conduct electricity. Bioelectric impedance passes a small electric current through the body to measure the resistance to the flow of electricity of that tissue. Bodily tissue that has very little resistance to the flow of electricity reflects a higher level of water and a lower levels of fat, whereas bodily tissue that has very high resistance to the flow of electricity reflects lower levels of water and higher levels of fat. Using different voltage levels and waveform patterns enables the measurement of the two and four component model of body composition.

BIA technology has been available to the general public for nearly 40 years and is frequently integrated into bathroom scales that have multi-point contact pads for the feet, requiring only a few extra seconds on the scale to obtain a two or four component measurement. Such devices cost around $40 to $100 US dollars. Higher end research and clinical measurement devices, which can cost $100 to $5 thousand US dollars, also integrate additional contact points (beyond just the left and right foot) such as points on the hands or modifiable contact points to enable whole body measurements as well as local measurements of body composition within specific regions. The portable and non-invasive nature of these devices which makes measurements relatively quick to perform have been credited for the decline in the use of skinfold assessments. Although the quality of the analyzer is highly related to the accuracy of the measurement, this approach can overestimate lean individuals and underestimate body fat within exceptionally obese individuals.

Plethsmography refers to approaches that measure changes in volume. So the concept of whole body plethsmography assesses the volume of the body (how much space is taken up) relative to the body mass. This approach is similar to the historic approach of underwater weighing that characterized the buoyancy (tendency to float) characteristics of the body, in that the **mass of the body** relative to the **volume of space the body takes up** is the **density** – very dense things tend to sink.

Since muscle weighs more than fat, an individual who has a lot of muscle mass will have an overall body mass that is higher than would be expected given the volume of their body (densities around 1.1 g/cc^3). Conversely, an individual with high body fat will have a larger body volume than would be expected given their overall body mass (densities around 0.9 g/cc[3]).

Air displacement plethsmography approaches such as those used in the **BodPod**, measure body volume by measuring pressure changes in a closed chamber after injection of a known volume of air. When combined with very precise measures of body mass, the proportion of fat and fat-free mass can be obtained. Although this approach has very high accuracy, it also is highly sensitive to day to day variations in body composition and costs $30 to $60 thousand US dollars for just the standard adult version. Infant 'pods' cost an additional $20 to $40 thousand US dollars rendering these approaches as most suitable for use in research and specialty clinics.

Dual-energy x-ray absorptiometry (DXA or DEXA) measures the absorption of two different low-dose x-rays in a whole body scanner. This approach relies upon the different absorption characteristics of bone mineral content, fat mass, and muscle. So by using different wavelengths of x-rays, DEXA is able to use a subtraction approach to differentiate bone and soft tissue mass. This approach is considered to be the new 'gold' standard for measuring body fat and bone density given the exceptional accuracy and ability to examine both whole body composition as well as composition within critical areas (such as within vertebral regions corresponding to the abdominal cavity). The nature of the measurement approach which takes less than twenty minutes also makes it useful for both human and comparative animal models (e.g., mice, pigs). Although the dose of radiation is 1/10th the dose of a standard chest x-ray, such that the technician can remain in the room during the scanning process; not all individuals may be willing to undergo such assessment. Further, the individual cost per scan ranges from $200 to $300 US dollars with the actual cost of the machine ranging from $50 to $150 thousand US dollars.

Infrared Spectroscopy which relies upon light absorption characteristics and **Ultrasound** which relies upon sound absorption characteristics are emerging techniques to provide non-invasive and portable measurement approaches for body composition assessment. However, at present these approaches provide only focused assessment of small areas of the body. Although there remain questions as to what extent such data are valuable, there is some suggestion that these approaches could be used similar to skinfold calipers — obtaining assessment of body fat at key locations around the body (without the need for pinching) that could then be used within a prediction equation. The potential benefit being that they would enable quantification of changes in subcutaneous adipose tissue for areas that people are generally interested in — a characteristic that other approaches such as bioelectric impedance and plethsmography are unable to obtain given their whole-body focus.

The use of **computed tomography** (CT, essentially a 3-D x-ray) and **structural magnetic resonance imaging** (sMRI) to obtain three-dimensional high resolution full body assessments of body composition are able to provide millimeter level precision of body composition measures. Thus, these approaches can be particularly useful in differentiating subcutaneous and visceral adipose tissue. Such scanning sequences require the individual to remain still within the scanner for 30 to 60 minutes and require highly skilled specialists to process and interpret the results. The cost of such assessments range from $300 to $5 thousand US dollars for each scan depending upon the extent to which the individual's medical insurance will cover the assessment. However, the radiation from CT scans in particular have been associated with increased risk of developing cancer.

Any time body composition comes up, a common statement is that smart scales are not as accurate as clinical assessments with calipers (skinfold assessment) or DEXA scans. Unfortunately such statements are usually misunderstood as to what they are communicating or are taken out of context. Remember that DEXA is considered as the modern gold standard approach for assessing body composition. As a result any attempts to validate or test a new method take their measurements and then compare them against an assessment of the individual using DEXA. BIA approaches have been found to be strongly correlated (0.8 or higher) with DEXA measures. Meaning that if you were to observe a patient's body fat increase when measured using BIA, you would see that body fat assessed using DEXA would also increase. From a clinical utility perspective, we care far more about the extent to which measures are **associated** with one another as changes in one measure will be predictive of changes in another measure.

Accuracy refers to how close a measurement is to the true value — in this case the value that DEXA gives us. Skinfold assessment (as well as infrared spectroscopy and ultrasound) techniques take localized measurements at key sites around the body and then put those measurements into a prediction equation to get at overall body fat. As a result the accuracy of the assessment will depend upon the relevance of the prediction equation to the person being assessed. While it is possible to compare localized assessment of body fat using DEXA with particular sites using Skinfold approaches, as they are strongly correlated very few people actually have looked at the accuracy in this way. BIA and air displacement Plethysmography provide measures of overall body composition — although using high end BIA devices some localized measures can be obtained. With these approaches, the accuracy of the assessment will depend upon the settings used as there are certain assumptions in the technique that are made that may need to be changed (e.g., if the person is highly athletic, missing a limb, has particular medical conditions). Regardless of the equation or settings however, for all of these approaches the inaccuracy represents what is called a bias — whereby the value is simply offset from the value observed by DEXA. So long as you are consistent with the approach that you use, this bias has no/very little clinical relevance.

Using Body Composition Data

Absolute Body Composition — Represent the actual compartment mass. Commonly measured in units (lbs, kgs, N; e.g., kg of fat; kg of fat–free mass).

Relative Body Composition — Represents the compartment mass in relation to some aspect of body mass (e.g., % fat; % fat–free mass).

Although the common U.S. approach is to refer to body composition using relative expressions such as percent body fat, the way body composition should best be expressed depends upon the context in which it is being used. **For comparisons made on the same person, absolute values are preferred**. This enables tracking specific changes in the compartment of interest without being confounded (confused) by changes in other compartments (e.g., water mass). However, the U.S. population exhibits an unhealthy relationship with body mass expressed in pounds. Thus, in practice the recommendation is to report compartment mass using the metric system (kg). Since 1 kg is equal to 2.2 lbs and the rest of the world uses the metric system, many medical assessments have shifted to using Newtons to simply avoid the issue. **For comparisons made between individuals, a relative expression is preferred**. This better enables comparison as underlying differences in overall body mass can be taken into account. However, again as the U.S. population exhibits unhealthy expectations of body composition expressed in percent fat, the recommendation is to instead focus and report on percent fat–free mass.

Unfortunately, the vast majority of commercial products, medical reports, and even apps such as Apple Health and Fitbit have default characteristics that deviate from these recommendations. In particular, they predominately use overall body mass as their primary focus under the assumption that if overall body mass changes it would reflect changes in adipose tissue. While the general concept is obviously true — the parts make up the whole — this one-component model approach deviates from best-practice. Using this one-component model approach some general prediction formulas suggest a 50% approach whereby half of any changes in body mass are attributed to fat tissue and half are attributed to fat free tissue (e.g., a 10 lb reduction in body mass would reflect a 5 lb reduction in body fat). Nevertheless, actual measures of body composition can be obtained using techniques such as bioelectric impedance for effectively the same cost and time as obtaining overall body mass; making it such that **there is not a good reason to rely upon a one-component approach**.

The other issue with these commercial products, medical reports, and apps is that they deviate from recommendations regarding the use of absolute and relative measures of body composition. If the medical report is providing the patient with an assessment of their level of body fat, clearly it makes sense that it would be shown relative to normative data and clinical recommendations. In this way the comparison is essentially between individuals and as such the information should use relative measures. While medical reports do this, they unfortunately focus on % fat mass rather than % fat-free mass — meaning that patients generally do not respond well to obtaining the information and the provider may miss important information regarding potential risk of sarcopenia.

When multiple assessments are available, these reporting platforms also fail to appropriately shift to reflect the comparison — the comparison is no longer that person relative to others but that person relative to themselves. Thus, rather than using absolute measures of body composition and showing changes over time; they show changes in % fat mass over time. Unfortunately this means that changes in other compartments of interest such as % water mass or % muscle mass may skew the interpretation. The person may misunderstand those factors that are contributing to reducing adipose tissue and the clinician may miss critical changes in muscle mass that could place their patient at risk of other complications.

Promisingly, an increasing number of platforms are moving in the direction of mimicking the approach used by Fitbit, which plots total weight alongside lean mass or fat-free mass. The fat mass is then reflected as the shading between overall body mass and fat-free mass. The benefit of this approach is that it is using the absolute measure of body composition to show changes in the body over time so that it is clear if there are changes in fat-free mass that might be driving the changes in overall body mass. The downside is that changes in fat mass are not always readily apparent. Usually when adipose tissue diminishes, we also see that fat-free mass tends to be reduced as well. The goal of any fat loss program should be to help retain as much of that fat-free mass as possible, but it is important to keep in mind that water is a part of that fat-free mass. As such, nutritional changes to reduce caloric intake also tend to reduce body water — meaning that some reduction in this fat-free mass would be expected. However, we do want to retain as much of the muscle mass as possible.

Why is it important to discuss body composition in KIN240?

As future professionals in the fields of **kinesiology, exercise, and medicine** it is important to understand:

- **1)** how body composition is related to health and wellness
- **2)** the societal misconceptions regarding body composition
- **3)** how to effectively communicate such topics to your clients, patients, or the general public.

1 COMPONENT	mass		
2 COMPONENT	fat mass	+	fat free mass
4 COMPONENT	fat mass	+	mineral + water + protein
ANATOMICAL	essential + storage fat	+	organs + bone + skin + muscle + blood

Assessing Body Composition

The chosen method of body composition depends on:

- Compartment/component of interest
- Cost
- Time
- Location
- Technical training of staff
- Availability of techniques
- Condition of patient/level of discomfort of the individual
- Accuracy desired/necessary

Technique	Cost	Time	Skill	Comfort	Accuracy
Skinfold	Moderate	Moderate	High	Low	Not Good
BIA	Moderate	Moderate	Moderate	High	Very Good
Plethsmography	High	Slow	High	Moderate	Very Good
DEXA	High	Slow	High	Moderate	Excellent
CT/MRI	Very High	Slow	Very High	Low	Excellent

Skinfold Measurements

- Subcutaneous fat represents about half of all storage fat.
- By pinching a small segment of skin using specialized calipers a precise measurement of the thickness of that area can be obtained.

Skinfold Measurements

7 Major Measurement Sites:

- Chest
- Axilla (Armpit)
- Tricep
- Subscapular (Back)
- Abdomen
- Suprailiac (Hip)
- Thigh

Measurements are entered into a formula to obtain estimated percent body fat.

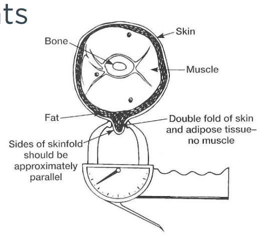


Figure 6.15
The double fold of skin and adipose tissue between the tips of the skinfold caliper should be large enough to form approximately parallel sides. Care should be taken to elevate only skin and adipose tissue, not muscle.

Skinfold Measurements

Possible Problems:

- Large risk of technician error.
- Skinfold thickness affected by factors other than amount of fat.
- Exercise increases skin thickness.
- Dehydration reduces skin thickness.
- Edema increases skin thickness.
- Poorly predicts visceral fat.
- Validity depends on equation used.
- Discomfort.

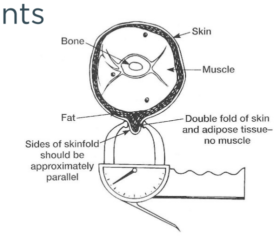
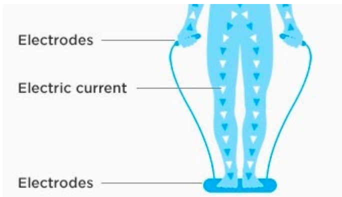
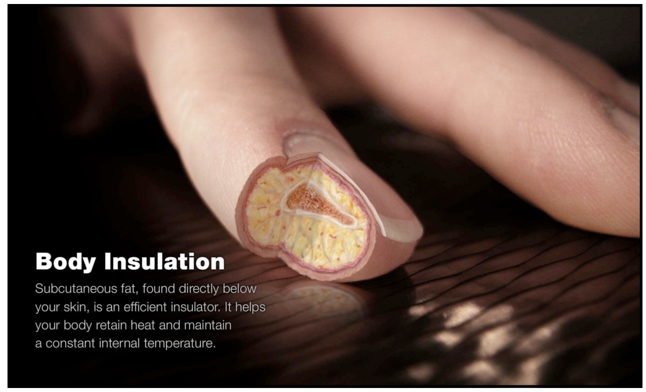


Figure 6.15
The double fold of skin and adipose tissue between the tips of the skinfold caliper should be large enough to form approximately parallel sides. Care should be taken to elevate only skin and adipose tissue, not muscle.

Bioelectric Impedance Analysis (BIA)

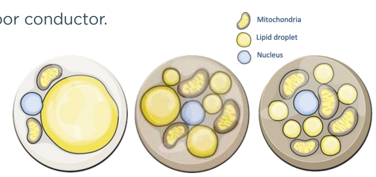
Measures the resistance of the body to the flow of electricity





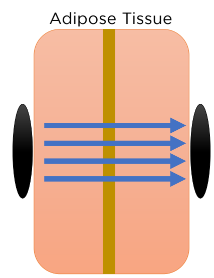
Bioelectric Impedance Analysis (BIA)

- Insulation
  - Resists allowing heat to transfer between the inside and outside of the body.
  - Adipose tissue is a poor conductor.
    - Thermal
    - Electrical
  - Adipose tissue has very little water.



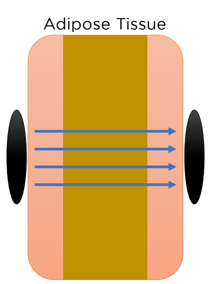
Bioelectric Impedance Analysis (BIA)

- When adipose tissue is **low**, there is **very little resistance** to the flow of electricity.
  - Muscle has a lot of water, water conducts electricity.
  - Adipose tissue is an insulator.



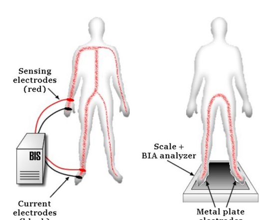
Bioelectric Impedance Analysis (BIA)

- When adipose tissue is **high**, there is **a lot of resistance** to the flow of electricity.
  - Muscle has a lot of water, water conducts electricity.
  - Adipose tissue is an insulator.



Bioelectric Impedance Analysis (BIA)

- Using different voltage levels and waveform patterns enables the measurement of the two and four component model of body composition.
- Can overestimate lean individuals and underestimate body fat within exceptionally obese individuals.



Bioelectric Impedance Analysis (BIA)

- Commercially available for $40 to $100.
- Research/clinical devices can range from $100 to $5,000.
- Integrate additional contact points.
- Repositionable electrodes.
- The quality of the analyzer is highly related to the accuracy of the measurement.

Plethysmography

Measures the air displacement of the body relative to the mass.

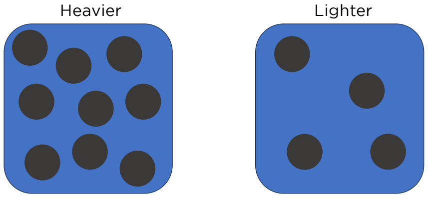
Similar to underwater weighing.

Plethysmography

Lead Ball

Total Displacement stays the same.

Heavier — Lighter



Cube of Jello — Cube of Jello

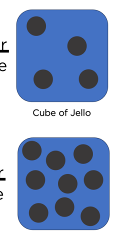
Plethysmography

Lead Ball

$$Density = \frac{Mass}{Volume}$$

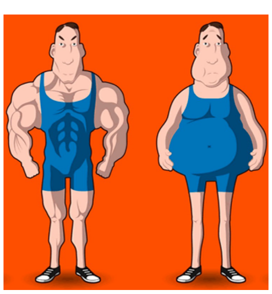
Lighter
Same Volume

Heavier
Same Volume



Plethysmography

$$Density = \frac{Mass}{Volume}$$



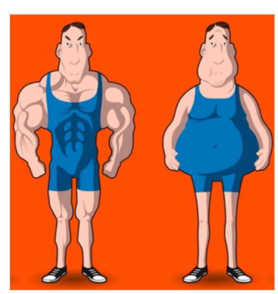
"Muscle weighs more than fat"

If two bodies take up the same volume of space, the body that has more muscle tissue will weigh more.

Plethysmography

Individuals with high muscle mass will be more dense (1.1 g/cc^3).

Mass greater than expected for the space they take up.



Individuals with high adipose mass will be less dense (0.9 g/cc^3).

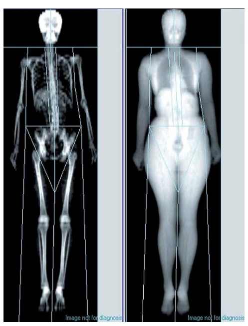
Take up more space than expected for body mass.

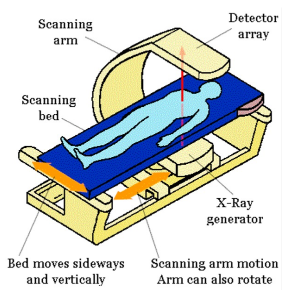
Plethysmography

- Air displacement plethysmography approaches measure body volume by measuring pressure changes in a closed chamber after injection of a known volume of air.
- When combined with very precise measures of body mass, the proportion of fat and fat-free mass can be obtained.
- Very high accuracy, but highly sensitive to day-to-day variations in body composition.
- $30,000 to $60,000 for the standard pod.
- $20,000 to $40,000 for the Infant pod.

Dual Energy X-ray Absorptiometry (DEXA)

- DEXA measures are considered the ‘gold’ standard for measuring body fat and bone density.
  - Exceptional accuracy.
  - Whole body measurement and ability to localize to regions of interest.
- By using different wavelengths of x-rays, subtraction methods allow for differentiating bone, fat, and muscle mass.
- Takes around 20 minutes with a radiation dose 1/10th that used in a chest X-ray.
- Cost per scan is around $200 to $300.
- Machine costs $50,000 to $150,000.

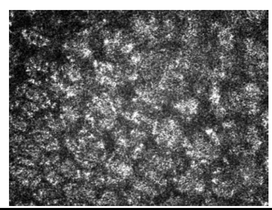




Medical Imaging Measures

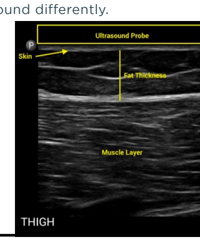
Infrared Spectroscopy

Adipose tissue and muscle absorb infrared light differently.



Ultrasound

Adipose tissue and muscle absorb sound differently.



Medical Imaging Measures

Computed Tomography (CT)

3-d X-ray body scan.

Similar concept to a DEXA but at much higher doses of x-ray exposure.

Medical Imaging Measures

Structural MRI (sMRI)

Uses magnetic fields to align hydrogen atoms in the body, then pulses the body with a strong radio wave to knock the hydrogen atoms out of alignment. Measures the time it takes for the atoms to return to alignment.

Fat and muscle have different rates of return.

Medical Imaging Measures

- CT and sMRI offer millimeter level precision of body composition.
- Takes 30 to 60 minutes for scanning sequence.
- Requires highly skilled specialists to interpret the data.
- Costs $300 to $5,000 for each scan depending upon insurance coverage.

How Accurate are these Approaches to Assess

Body Composition?

- DEXA is considered as the gold standard to compare against.
  - BIA is strongly correlated (0.8 or higher) with DEXA measures.
  - If body fat assessed using BIA increases, we would see that body fat assessed with DEXA also increases.
- "Not as accurate"
  - Accuracy refers to how close a measurement is to the true value (i.e., the value DEXA gives us).
  - Accuracy of these devices depends on the equations/settings used.
  - Regardless of the settings, the inaccuracy represents a bias whereby the value is simply offset from the value observed by DEXA.

How do we Express

Body Composition

- The U.S. population exhibits an unhealthy relationship with body mass expressed in pounds.
  - Recommendation to use metric system (kg).
  - Since 1 kg = 2.2 lbs and the rest of the world uses the metric system, many medical assessments have shifted to using Newtons.

Absolute

(kg of fat; kg of fat-free mass)

Represent the actual compartment mass.

Commonly measured in units (lbs, kgs, N)

How do we Express

Body Composition

- The U.S. population exhibits unhealthy expectations of body composition expressed in percent fat.
  - Recommendation to focus on fat-free mass.

Relative

(% fat; % fat-free)

Represent the compartment mass in relation to some aspect of body mass.

How do we Express

Body Composition

Absolute

(kg of fat; kg of fat-free mass)

Represent the actual compartment mass.

Commonly measured in units (lbs, kgs, N)

For comparisons made on the same person, absolute values are preferred.

For comparisons made between individuals, a relative expression is preferred.

Relative

(% fat; % fat-free)

Represent the compartment mass in relation to some aspect of body mass.

How do we Express

Body Composition

- The vast majority of commercial products deviate from these recommendations.
  - Look at the default characteristics emphasized by Apple Health and Fitbit.
  - Most use overall body mass as the primary focus.
    - General assumption that half of any changes in body mass reflect changes in fat. **(50% rule)**
      (e.g., a 10 lb loss of mass suggests a 5 lb loss of fat)

How do we Express
Body Composition

- Medical reports tend to use relative measures (% fat).
  - Patients generally do not respond well to receiving this information.
- Even when multiple assessment points are available, reports tend to still use relative measures instead of transitioning to absolute measures.
  - Changes may be occurring in other compartments of interest.
  - Patients and clinicians may miss relevant information!

How do we Express
Body Composition

- The Fitbit Effect
  - In part because Fitbit is owned by Google/Alphabet subsidiaries, more platforms are beginning to show body composition using their format.
  - Graphs plot lines for Total Body Mass and Fat Free Mass, and shade the space between these lines to reflect Fat Mass.

Body Composition Assessment Worksheet

1. What components are included within the following models of body composition?

<table>
<tr><th>Body Composition Model</th><th colspan="4">Components</th></tr>
<tr><td>One Component Model</td><td></td><td colspan="3"></td></tr>
<tr><td>Two Component Model</td><td></td><td></td><td colspan="2"></td></tr>
<tr><td>Four Component Model</td><td></td><td></td><td></td><td></td></tr>
</table>

2. What component makes up the majority of the Anatomical Model of Body Composition? What component makes up the minority of the fat-free component of the Anatomical Model of Body Composition?

3. What is the specialized function of White Adipose tissue, Brown Adipose tissue, and Beige Adipose tissue?

4. What is the difference between subcutaneous and visceral adipose tissue? Which one is more problematic?

5. Calculate Body Mass Index (BMI; rounded to 1 decimal place) for the following examples:

	Height (meters)	Weight (kg)	BMI
Case 1	1.69	65	
Case 2	1.83	110	
Case 3	1.53	40	
Case 4	1.74	71	
Case 5	1.91	95	

6. Based upon the table above, which case would be considered obese according to the World Health Organization risk classifications? Which case would be considered underweight according to the World Health Organization risk classifications?

7. Using the prediction formula to convert BMI to percent body fat, complete the table below. Round to 1 decimal place.

	BMI	Age	Sex	Body Fat Percentage
Case 1	18.7	41 years	1 (male)	
Case 2	26.4	33 years	0 (female)	
Case 3	23.1	65 years	0 (female)	
Case 4	31.3	29 years	1 (male)	
Case 5	24.8	24 years	1 (male)	

8. In general, subcutaneous fat makes up what percentage of overall storage fat?

9. Explain the concept that allows for bioelectric impedance analysis to work as a measure of body composition.

10. Explain the concept that allows for plethsmography to work.

11. You are interested in assessing the differences in fat mass in children who live in rural versus suburban areas. You have obtained permission to measure body composition during the school day in the nurse's office. What is the best measurement tool for this purpose?

12. You are interested in assessing how an exercise intervention in older adults changes muscle mass and bone density. What model of body composition should you use and what measurement tool would provide this information?

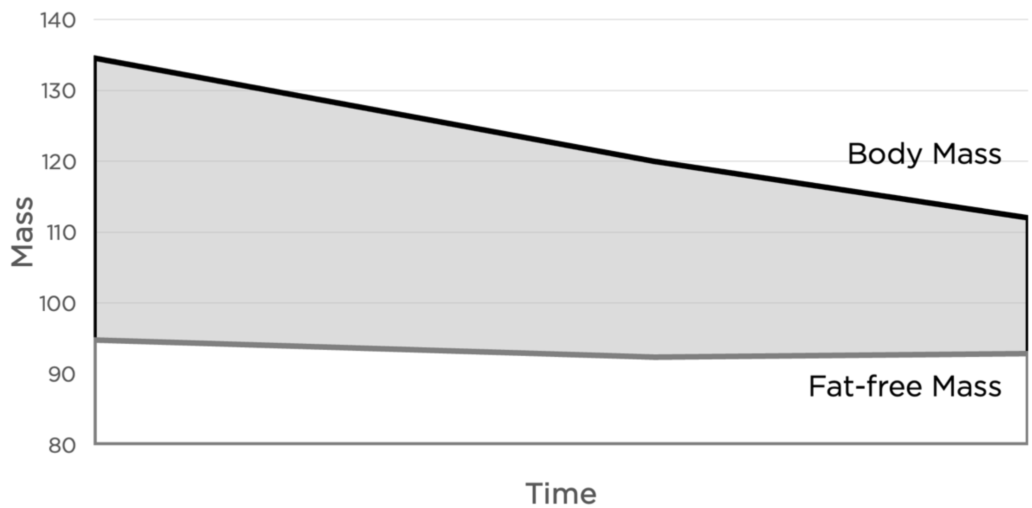
13. To help make money over the summer you have been picking up hours at your local gym. One of the clients you are responsible starts showing up to work out in a vinyl sweatsuit so that they can lose more fat. What effect will this have on their potential fat loss?

14. Complete the table below. Round to 1 decimal place.

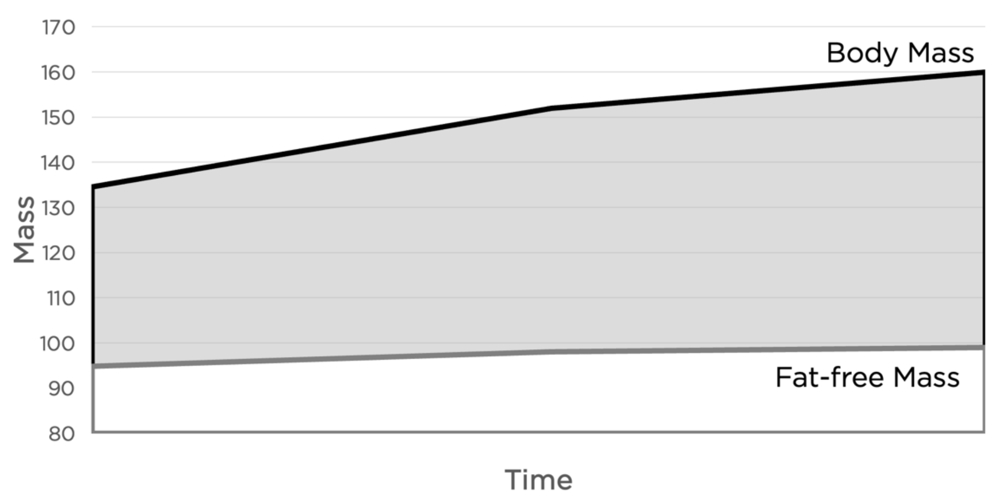
	Baseline	**4 weeks**	**8 weeks**
Weight (lbs)	145.0 lbs	138.2 lbs	131.7 lbs
Percent Body Fat (%)	32.8%	31.9%	33.3%
Fat Mass (lbs)			
	Change from previous measure		
	Change from baseline measure		
Fat-Free Mass (lbs)			
	Change from previous measure		
	Change from baseline measure		

15. Based upon the table above, what is your assessment of their change in body composition?

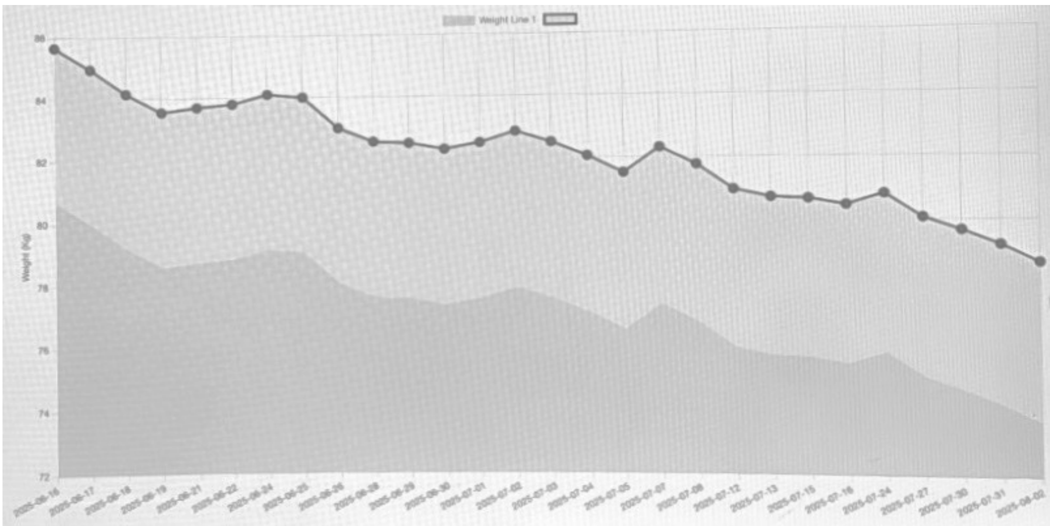
16. Based upon the graph below, what is your assessment of this individuals change in body composition?



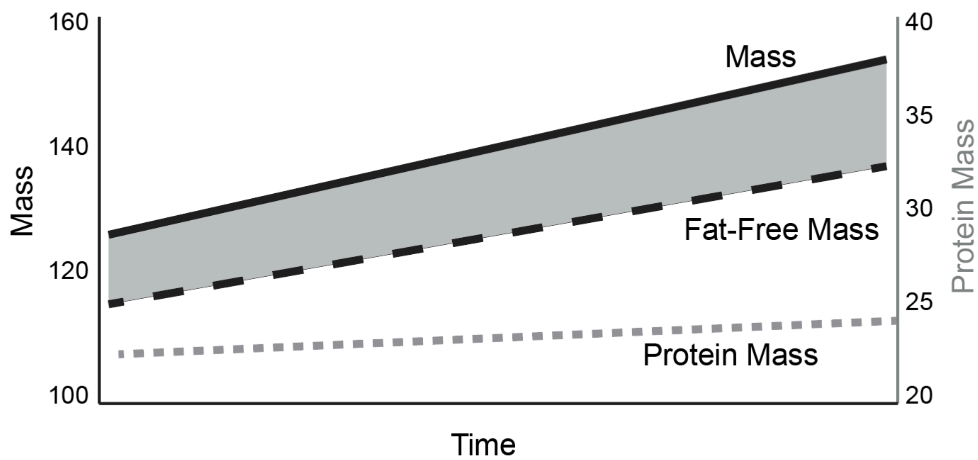
17. One of your friends has been talking about how they have put on 25 pounds of muscle in the gym since they started “bulking”. As your friend you have been helping them by measuring their body composition periodically. When you look at the graph of their data below, what is your assessment of their change in body composition?



18. One of your high school friends posts on social media regularly about their "weight-loss journey" and how they have been changing their life around to be healthy. In one of their posts they shared their body composition data talking about how the latest weight-loss product they have been using has helped them lose over 15 lbs of fat. When you look at the graph of their data below, what is your assessment of their change in body composition?



19. One of your friends has been talking about how effective creatine has been in helping them to put on muscle mass in the gym. Below is a graph of their changes in body composition. Make estimations based upon the data in the graph to complete the table below.



	Starting	**Ending**	**Change**
Weight (lbs)			
Fat-Free Mass (lbs)			
Protein Mass (lbs)			

20. Based upon the table above, how might we explain the increase in fat-free mass if protein mass increased only a small amount? Did your friend actually "put on muscle"?