CUTTING EDGE TECHNOLOGY & TECHNIQUES TO ASSESS THE HUMAN BODY

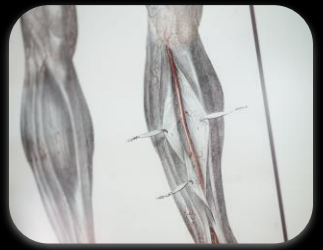
Joshua Dexheimer, PhD, CSCS, PES

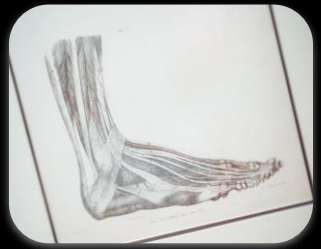
LEARNING OBJECTIVES AND OVERVIEW

- Discuss the history of anthropometric and body composition measurements
- Understand what anthropometric measurements and body composition are
- Distinguish between the 5 levels of body composition
- Demonstrate a working understanding of the different component models
- Demonstrate a working knowledge of why anthropometric and body composition assessments are performed
- Analyze the differences between measurement techniques and assessment
- Determine the best measurement assessment method for certain KPI's and goals

HISTORY OF HUMAN BODY ASSESSMENT

1500's Anatomical studies and drawings by Leonardo Davinci





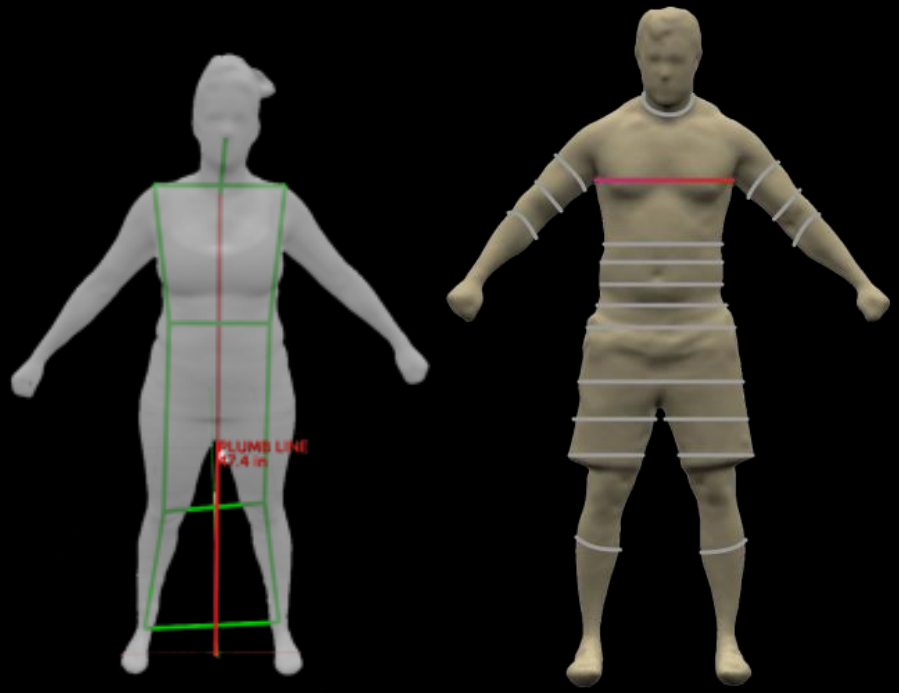
1700's Anthropological research focused on the cranium

1800's Bertillonage System for Criminal Identification

1900's Emergence of Somatometric Analysis

SOMATOMETRIC ANALYSIS

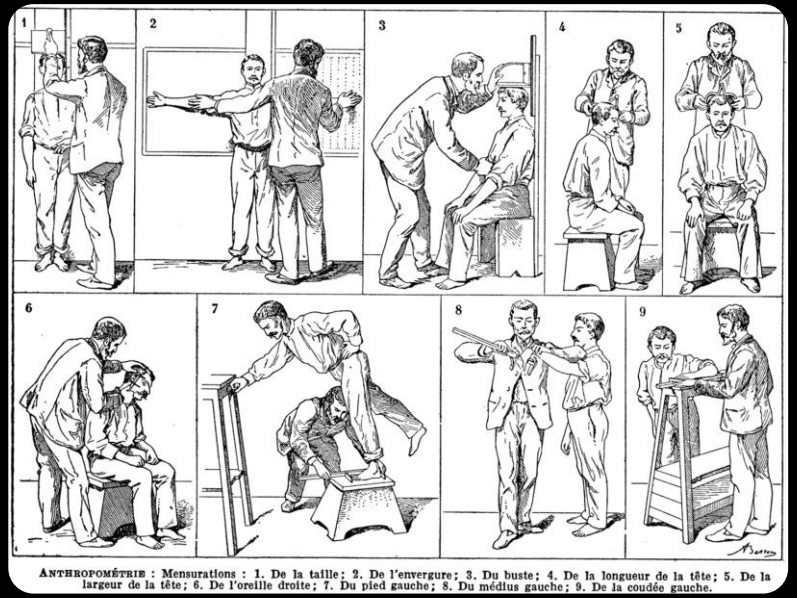
- Somatometric analysis branch of anthropometry that is focused on body parts other than the head
- Body composition equations derived from anthropometric measurements (like skinfolds, lengths, widths, and circumferences)
- Body composition assessments are all ***estimations***, unless using a cadaver



WHAT ARE ANTHROPOMETRICS AND BODY COMPOSITION?

- Anthropometrics defined as systematic measurement and collection of human bodily measurements
  - Anthros = human
  - Metro = measure

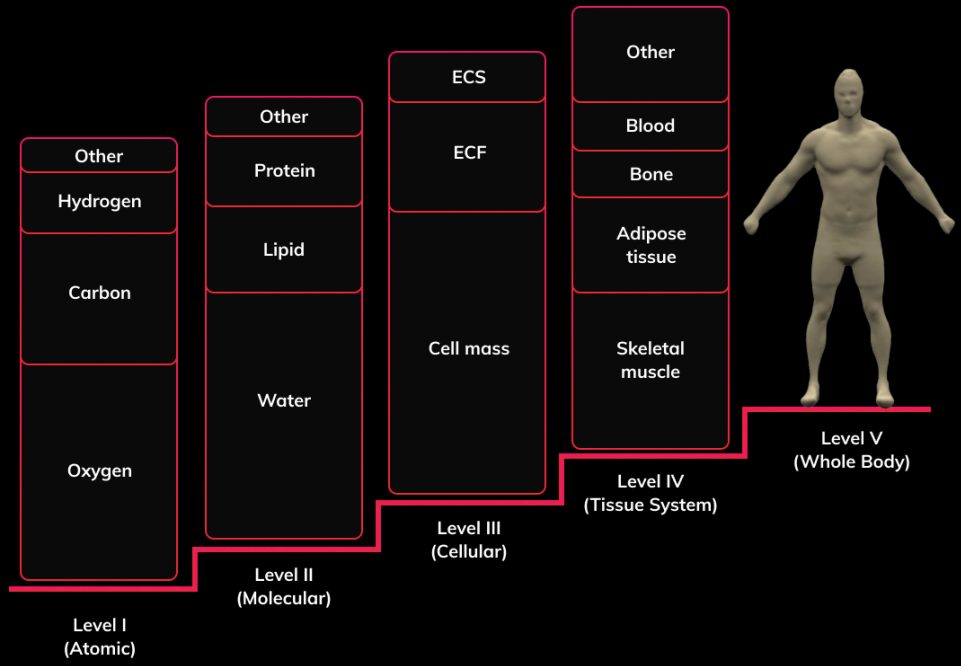
- Body composition describes the percentage of:
  - Fat
  - Bone
  - Water
  - Muscle



ANTHROPOMÉTRIE : Mensurations : 1. De la taille; 2. De l'envergure; 3. Du buste; 4. De la longueur de la tête; 5. De la largeur de la tête; 6. De l'oreille droite; 7. Du pied gauche; 8. Du médius gauche; 9. De la coudée gauche.

BODY COMPOSITION - 5 LEVEL MODEL

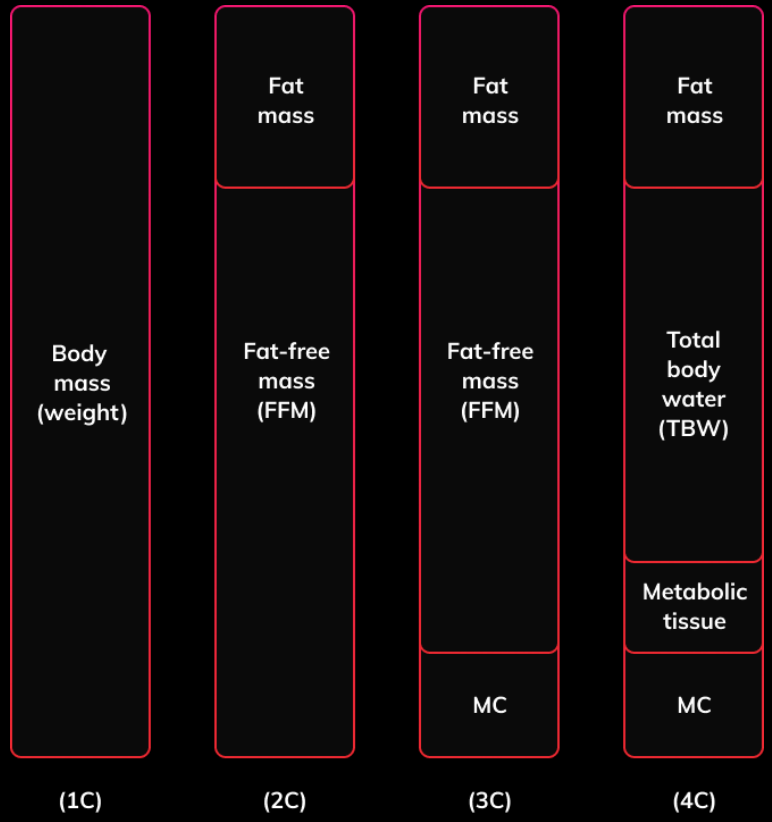
- Example from a 70kg man
- **Level 1 - Atomic:**
  - 61% Oxygen, 23% Carbon, 10% Hydrogen, 6% other (Nitrogen, Calcium, etc.)
- **Level 2 - Molecular:**
  - 60% Water, 19% Lipids, 15% Protein, 6% Minerals/Others
- **Level 3 - Cellular:**
  - 26% ECF, 9% ECS, 65% Cell Mass (ICS, ICF, Fat)
- **Level 4 - Tissue:**
  - 40% Skeletal Muscle, 21% Adipose Tissue, 7.1% Bone, 7.9% Blood, 24% Other (Skin, Liver, etc.)
- **Level 5 - Whole Body**



Wang, Z. M., Pierson Jr, R. N., & Heymsfield, S. B. (1992). The five-level model: a new approach to organizing body-composition research. *The American journal of clinical nutrition*, *56*(1), 19-28.

BODY COMPOSITION - COMPARTMENT MODELS

- We can successfully measure body composition with just one device in the first 3 compartment models.
  - Scale
    - **1 Compartment** - Body Mass
  - BodPod, BIA, Hydrostatic Weighing
    - **2 Compartment** - Fat Mass + Fat Free Mass
  - DXA
    - **3 Compartment** - Fat Mass, Fat Free Mass, Bone Mineral Content

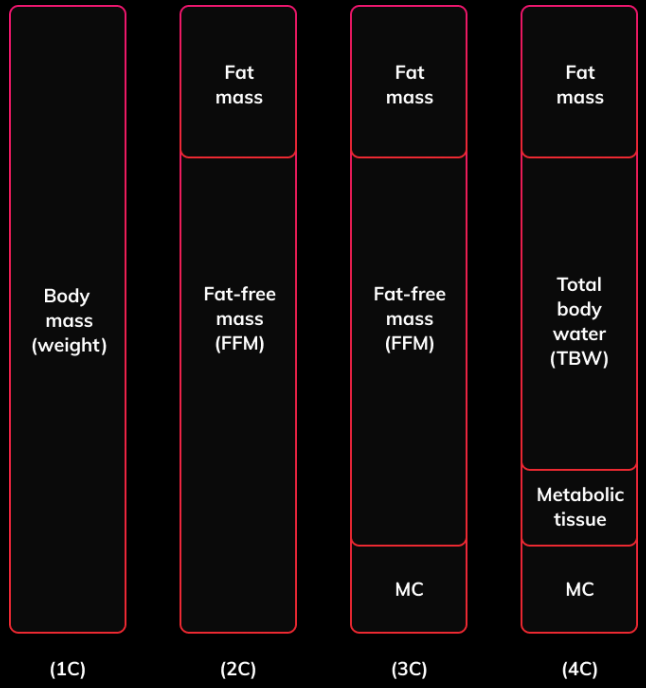


BODY COMPOSITION - COMPARTMENT MODELS

- The **4 compartment** requires more devices of measurement (high accuracy).
  - Bioelectrical impedance (BIA) to measure **total body water**
  - Dual energy x-ray absorptiometry (DXA) to measure **total body bone mineral**
  - Air Displacement Plethysmography (ADP or Bod Pod) to measure **body volume**
  - Scale for **body mass**.

4C MODEL EQUATION

- **FM(kg)** = 2.748(BV) - 0.699(TBW) + 1.129(Mc) - 2.051(BM)
- **FFM(kg)** = BM - FM
- **%BF** = (FM/BM) x 100

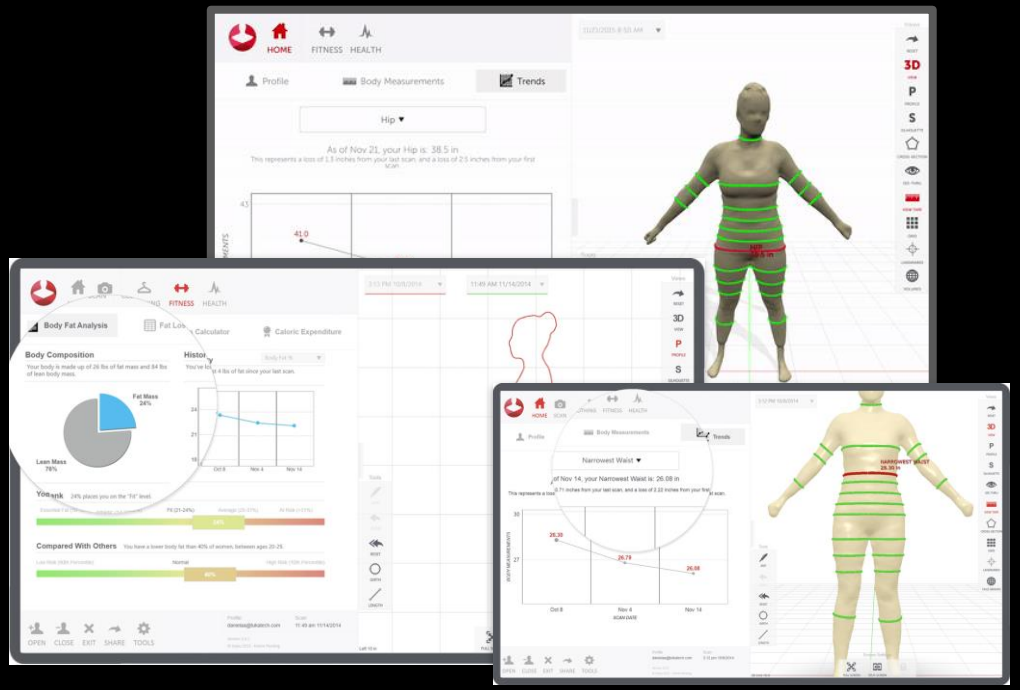


Kuriyan, R. (2018). Body composition techniques. *The Indian journal of medical research*, *148*(5), 648.

ANTHROPOMETRIC AND BODY COMPOSITION METRICS (KPI's)

- Anthropometrics
  - Body mass index (BMI)
  - Waist circumference (WC)
  - Waist-to-height ratio (WHtR)
  - Waist to hip ratio (WHR)
  - Limb lengths

- Body Composition
  - Body fat mass (BF)
  - Lean mass (LM)
  - Fat free mass (FFM)
  - Trunk fat mass (TFM)
  - Body fat percent (BF%)



WHY PERFORM ANTHROPOMETRIC AND BODY COMPOSITION MEASUREMENTS

- Assess the risk and development of various diseases:
  - Diabetes
  - Cancer
  - Cardiovascular Disease
  - All cause mortality
  - **Example: A WHR greater than 0.8 for females and greater than 0.95 for males increases one's risk of cardiovascular disease and heart attack**

- Predictors and/or be indicators of human performance like:
  - Aerobic Performance
  - Strength
  - Power
  - **Example: Runners that are lighter weight and with longer legs perform better in distance running events**

ASSESSMENT TECHNIQUES

- Unless we are assessing a cadaver, dead body, ***we are only ever estimating body composition with equations***

- The techniques and devices should not only be accurate but also reliable and precise

    - Cadaver Dissection
    - Tape Measure/Stadiometer/Scale
    - Skin Fold Calipers
    - Imaging Techniques: Magnetic Resonance Imaging (MRI) & Computerized Tomography (CT Scan)
    - Hydrostatic Weighing (Hydrodensitometry) & Air Displacement Plethysmography (ADP/Bod Pod)
    - Dual Energy X-Ray Absorptiometry (DXA/DEXA)
    - Bioelectrical Impedance (BIA)
    - 3D Optical Imaging (3DO)

CADAVER DISSECTION

- True Gold Standard but not feasible unless deceased
- Many equations we use for other devices are derived from measurements taken from cadaver dissection
- For instance, **skinfold assessments** and **hydrostatic weighing** (the dunk tank) use **body density equations** which have been derived from cadaver analysis
  - Fat Free Mass has has a density of **1.1 g/cm^3**
  - Fat Mass has a density of **0.90 g/cm^3**
  - However, if someone does have a FFM density *higher* than 1.1 g/cm^3 then there would be an *underestimation* of FM and an *overestimation* of FFM and vice versa.

CADAVER DISSECTION

STRENGTHS

- Most accurate form of measurement
- Can tangibly determine composition of the body (ie. skeletal muscle, organs, visceral vs subcutaneous adipose tissue, etc.)
- Dissection can be learned as a skill for studying the human body

WEAKNESSES

- Not practical
- Must be deceased

IMAGING TECHNIQUES - MRI AND CT

- CT scan uses X-rays (exposure to radiation)
- MRI uses magnetic fields and radio waves
- MRI and CT have demonstrated to be:
  - Accurate (compared to a cadaver)
  - Valid
  - Precise
  - Reliable
- MRI and CT has been used extensively for the ***quantitative estimation*** of the size of visceral organs, adipose tissue, and skeletal muscle
- Mathematical reconstruction algorithms used to create borders around regions representing various tissues

IMAGING TECHNIQUES - MRI AND CT

STRENGTHS

- Accurate to cadaver dissection
- Precise and reliable measurements
- 3-Dimensional tissue quantification
- Assess composition at the tissue level
- Regional and whole body composition measurements

WEAKNESSES

- Exposure to radiation (CT Scan)
- Expensive
- Requires a medical professional
- Conducted in a medical setting
- Precludes study of claustrophobic and very overweight individuals (MRI)
- Cannot study individuals with implanted devices (MRI)

TAPE MEASURE/STADIOMETER/SCALE

- A tape measure has marked off units, such as, inches, centimeters, etc. and is quite simply used for measuring lengths and circumferences.
- May be *more reliable* than measuring skinfold thickness
  - Requires training and standardization
  - Proper positioning
  - Distinguish anatomical landmarks
  - Use millimeters for units of measure
  - Keeping the tape directly on the skin without compressing it
  - Keeping the tape at 90 degrees can help ensure intrarater and interrater reliability

TAPE MEASURE/STADIOMETER/SCALE

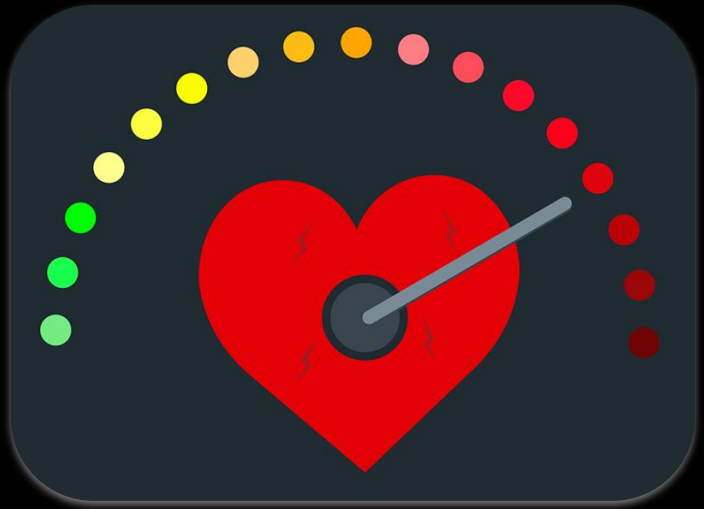
- A stadiometer measures height using a vertical ruler or measuring tape with a sliding horizontal paddle that sits atop your head.
- Stadiometers are pretty straightforward, but they’re clunky and new technology that is more portable may replace this device in the future.

TAPE MEASURE/STADIOMETER/SCALE

- A “weight” scale, measures the total body mass of a person.
    - This is an important to note that weight and mass are not the same, though they get used interchangeably.
- Scale should be calibrated, set to zero and on a hard and flat surface

TAPE MEASURE/STADIOMETER/SCALE

- Height and weight are used to determine BMI and disease risk
- Circumferences around the waist and hip provide a WHR and disease risk
- BMI, WC, WH ratio, and other measurements have all been used to create equations to **estimate or predict BF%**



TAPE MEASURE/STADIOMETER/SCALE

STRENGTHS

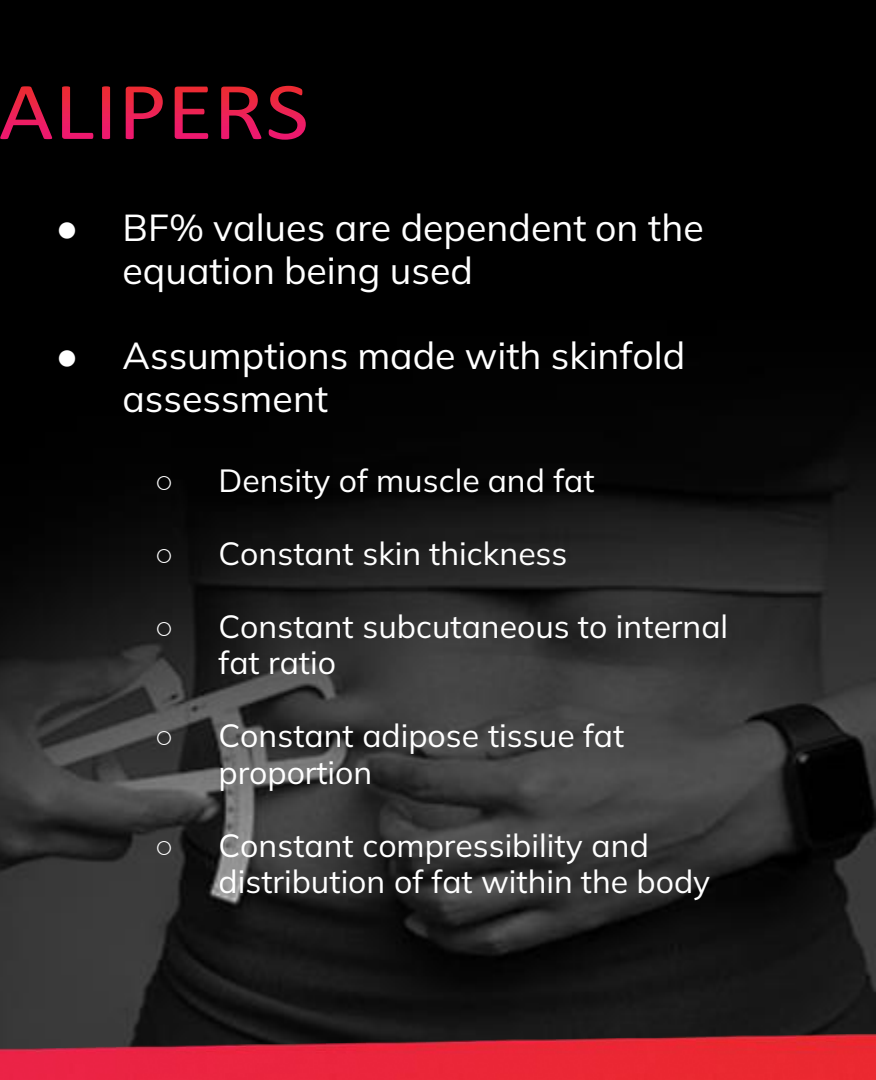
- Affordable
- Simple measurement and calibration techniques
- May be more reliable than measuring skinfold thickness (tape measure)
- Quick measurement of height and weight

WEAKNESSES

- Requires multiple devices
- Time consuming (tape measure)
- Consistent landmark identification
- Even with practice there is high intra-observer variability
- Need to be trained to perform proper assessment
- Lack of consistency in manually measured sites to predict body fatness

SKIN FOLD CALIPERS

- Popular body composition assessment technique (50% of professionals say they use skinfold assessments)
    - Requires training and proper technique to ensure inter- and intra-rater reliability
    - Assessment on overweight/obese and very lean people may also be less valid (accurate)
    - Evidence also suggests that different skinfold calipers may yield different results
- BF% calculated by deriving body density
- BF% values are dependent on the equation being used
- Assumptions made with skinfold assessment
    - Density of muscle and fat
    - Constant skin thickness
    - Constant subcutaneous to internal fat ratio
    - Constant adipose tissue fat proportion
    - Constant compressibility and distribution of fat within the body

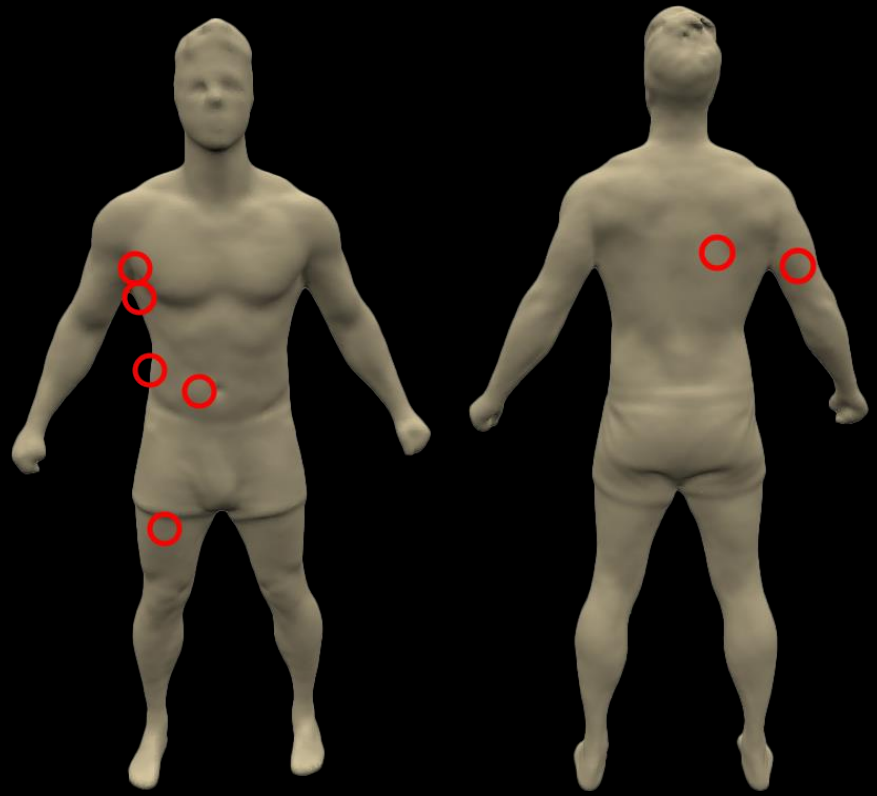


SKIN FOLD CALIPERS

- The Jackson Pollock 7 site equation: measurements taken at chest, midaxillary, triceps, subscapular, abdominal, suprailiac, and thigh.

  Males:
  - Body density = 1.112 – (0.00043499 x sum of all the skinfolds) + (0.00000055 x sum of all of skinfolds squared) – (0.00028826 x age)
  - Body Fat Percentage (%) = [(495 / Body Density) – 450] x 100

  Females:
  - Body density= 1.097 – (0.00046971 x sum of all of skinfolds) + (0.00000056 x sum of all of skinfolds squared) – (0.00012828 x age)
  - Body Fat Percentage (%) = [(495 / Body Density) – 450] x 100



SKINFOLD CALIPERS

STRENGTHS

- Affordable
- 3, 7, and 8-site measurements can be performed quickly
- Minimal equipment and technology
- High reliability with experienced testers
- Safe and portable
- Allows for regional body composition analysis

WEAKNESSES

- Body composition variation range from 4-15%
- Requires someone to be trained on the appropriate techniques
- May be inaccurate even with proper technique depending on population
- Inaccuracies between equations and manufacturer calipers
- Must first calculate body density and then body fat
- Client comfort level with exposing skin to get pinched

HYDROSTATIC WEIGHING & AIR DISPLACEMENT PLETHYSMOGRAPHY

- Hydrostatic Weighing, also known as hydrodensitometry, which is a fancy term we use for the “dunk tank” (10% of professionals use this form of assessment)
- Air Displacement Plethysmography which is more commonly referred to as the Bod Pod (17% of professionals use this form of assessment)
- Strict procedures are needed prior to completing these assessments as fluid and food intake as well as exercise influences the reliability of the measurements

HYDROSTATIC WEIGHING & AIR DISPLACEMENT PLETHYSMOGRAPHY

- These devices provide a body density measurement based on water or air displacement
    - An indirect measurement of body composition as body density must first be calculated (like skinfold)
    - Dunk Tank: Someone with more fat will weigh less in water as FM is less dense than FFM
    - BodPod: Subtract the volume of the air remaining inside the chamber when the subject is inside from the volume of air in the chamber when it is empty

AIR DISPLACEMENT PLETHYSMOGRAPHY

STRENGTHS

- Participants do not need to get wet like with hydrostatic weighing
- Reliable with standardized procedures
- Test takes approximately 5-8 minutes

WEAKNESSES

- Body composition variation range from 4-10%
- Large footprint and expensive piece of equipment, typically used in research facilities
- Lengthy calibration process
- Experienced technician required
- Clothing, hair, temperature, and hydration status can influence measurements
- Strict testing procedures should be followed
- Does not support regional body composition assessment
- Body density is first calculated to then estimate body composition

HYDROSTATIC WEIGHING

STRENGTHS

- Accuracy ranges between 2-3%
- Safe option for those with pacemakers or other implanted bodily devices

WEAKNESSES

- Body density is first calculate to then estimate body composition
- Large footprint
- Time consuming and messy process
- Expensive cost of materials plus plumbing, drainage, and maintenance
- The data is not stored anywhere except where you decide to keep it
- Does not provide a regional body composition analysis

DUAL ENERGY X-RAY ABSORPTIOMETRY (DXA)

- Using *algorithms*, the X-ray beam is able to distinguish between bone from soft tissue to estimate body composition (38% of professionals use this form of assessment)
    - Gives off some radiation (approximately 1 days worth)
- Accurate to the 4 compartment model
    - Variability in the measurements among manufacturers
- Assumes the hydration of fat-free tissue remains constant at 73%
    - Hydration values may range from 67-85% and if the subject contains more than the average amount of water, DXA with overestimate fat content

SELECTING DUAL ENERGY X-RAY ABSORPTIOMETRY

STRENGTHS

- DXA has a high accuracy with differences of only 1-3%
- Provides regional body composition analysis
- Test can be completed anywhere from 5-20 min
- Gives off minimal amount of radiation (less than a days worth)

WEAKNESSES

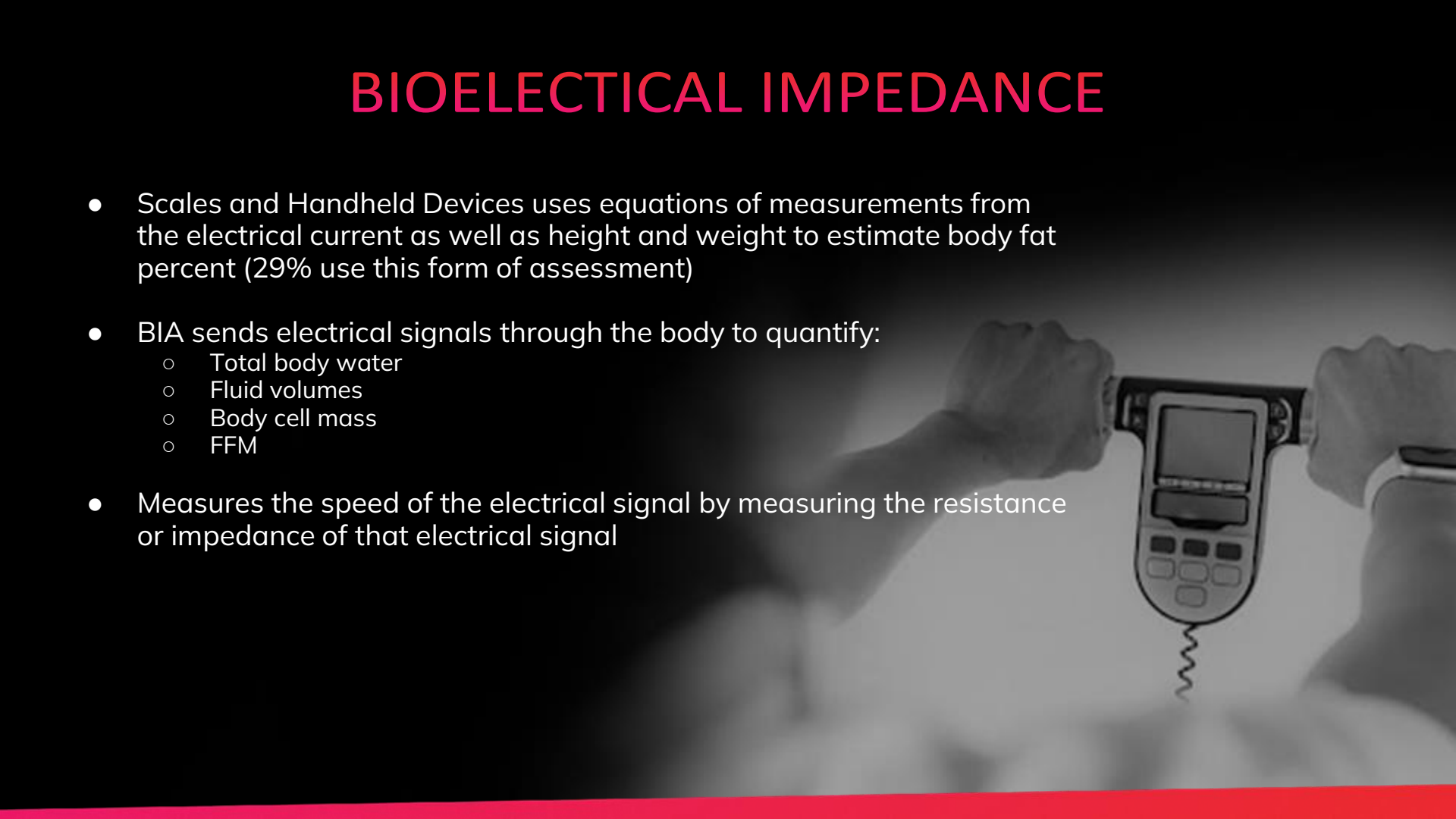
- Should not be performed on those that are pregnant
- The operator does need to have a certification
- The equipment is expensive
- May be differences between manufacturers
- Strict testing procedures should be followed

BIOELECTICAL IMPEDANCE

- Scales and Handheld Devices uses equations of measurements from the electrical current as well as height and weight to estimate body fat percent (29% use this form of assessment)

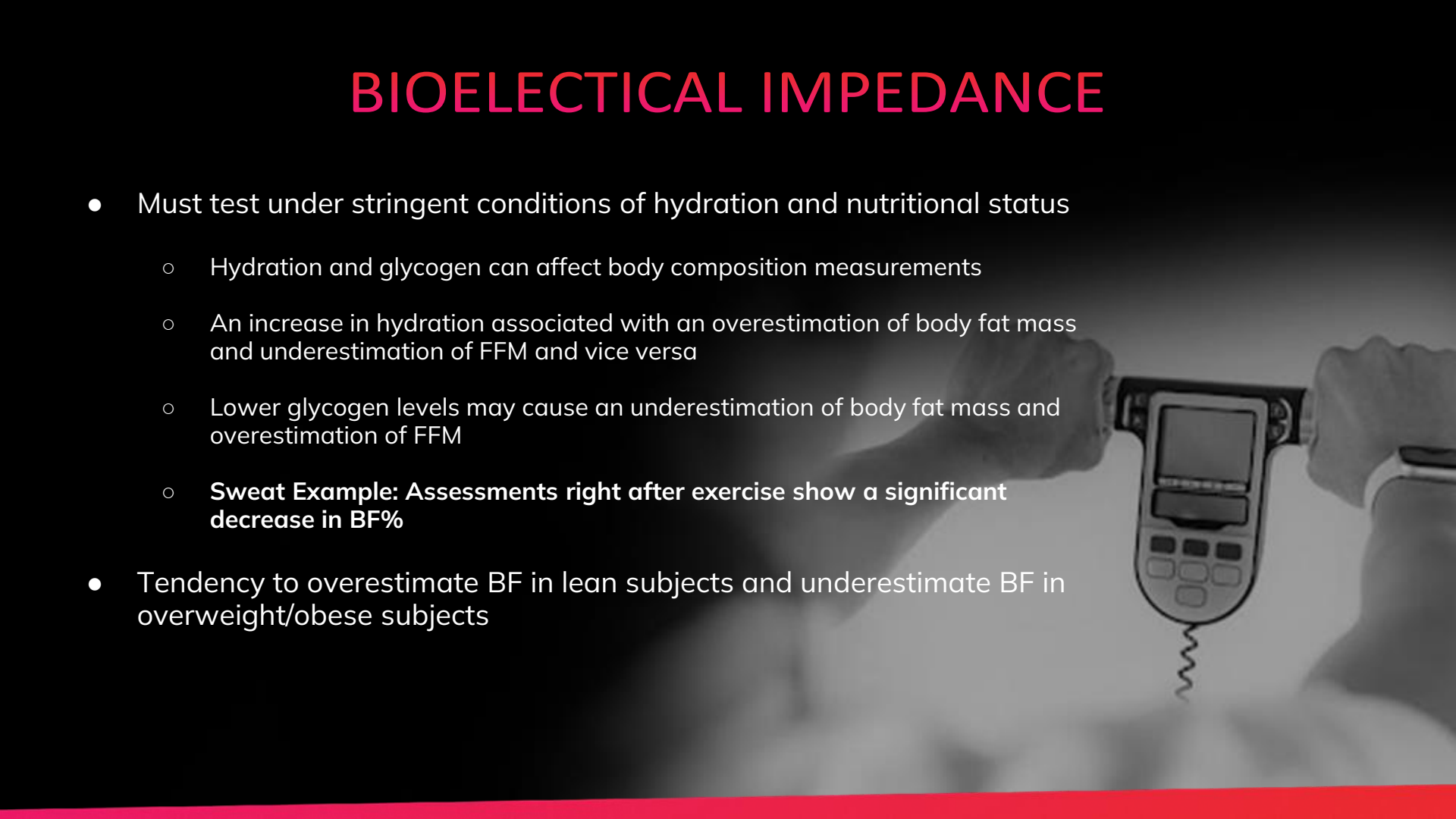
- BIA sends electrical signals through the body to quantify:
  - Total body water
  - Fluid volumes
  - Body cell mass
  - FFM

- Measures the speed of the electrical signal by measuring the resistance or impedance of that electrical signal



BIOELECTICAL IMPEDANCE

- Must test under stringent conditions of hydration and nutritional status
    - Hydration and glycogen can affect body composition measurements
    - An increase in hydration associated with an overestimation of body fat mass and underestimation of FFM and vice versa
    - Lower glycogen levels may cause an underestimation of body fat mass and overestimation of FFM
    - **Sweat Example: Assessments right after exercise show a significant decrease in BF%**
- Tendency to overestimate BF in lean subjects and underestimate BF in overweight/obese subjects



SELECTING BIOELECTRICAL IMPEDANCE

STRENGTHS

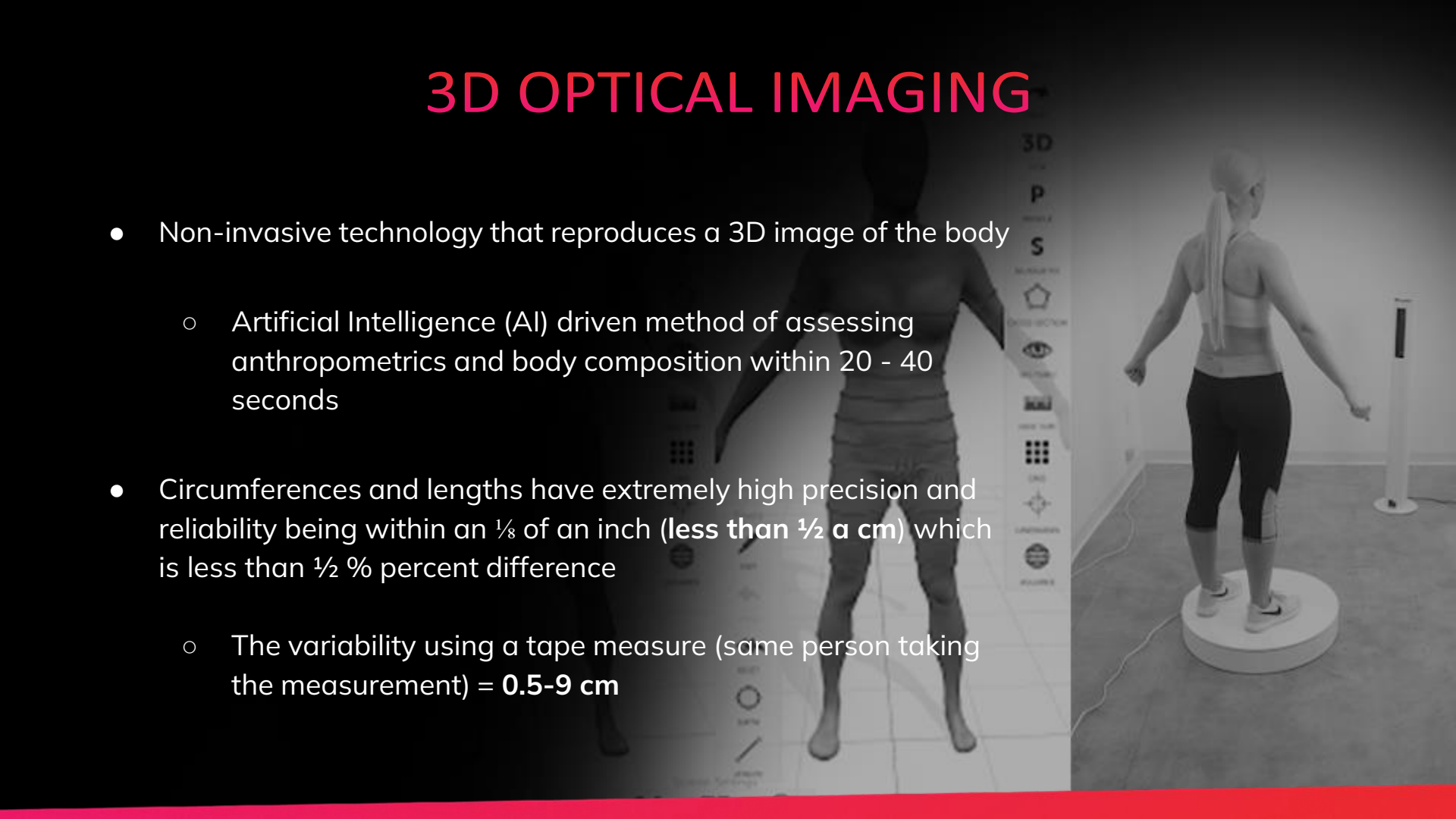
- Cheaper piece of technology
- Widely available in scales and handheld devices
- Test can be performed in under a minute
- Can be performed fully clothed
- Portability
- Minimal expertise required
- Provides measurements of total body water, intracellular and extracellular water

WEAKNESSES

- Measurement variation anywhere between 4-10%
- Differences between devices due to different equations used per manufacturer
- Cannot use on those with implanted devices or pregnant
- Body temperature, skin conductibility, age, hydration status, and ethnicity all influence results
- Strict testing guidelines should be followed to ensure accuracy and reliability

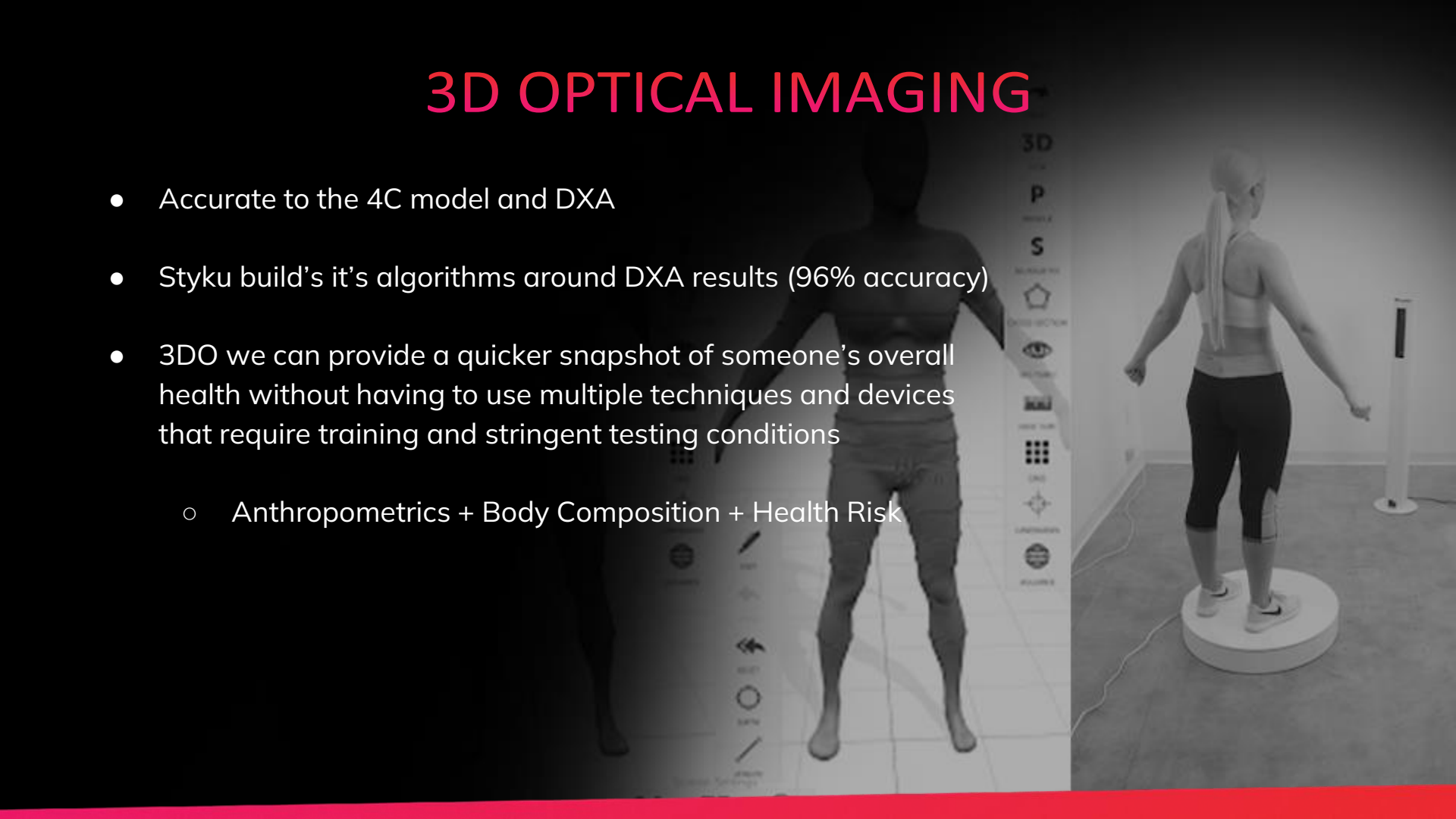
3D OPTICAL IMAGING

- Non-invasive technology that reproduces a 3D image of the body
    - Artificial Intelligence (AI) driven method of assessing anthropometrics and body composition within 20 - 40 seconds
- Circumferences and lengths have extremely high precision and reliability being within an ⅛ of an inch (**less than ½ a cm**) which is less than ½ % percent difference
    - The variability using a tape measure (same person taking the measurement) = **0.5-9 cm**



3D OPTICAL IMAGING

- Accurate to the 4C model and DXA
- Styku build’s it’s algorithms around DXA results (96% accuracy)
- 3DO we can provide a quicker snapshot of someone’s overall health without having to use multiple techniques and devices that require training and stringent testing conditions
    - Anthropometrics + Body Composition + Health Risk



3D OPTICAL IMAGING

STRENGTHS

- Demonstrated to be within approximately 2-4% when compared to DXA
- Provides both reliable and accurate tape measure, scale, stadiometer, and body composition results all in the time frame of a 20-40 scan
- Can remain fully clothed in form fitting clothing
- Software provides easy data collection and storage
- Safe non-invasive measurement for all

WEAKNESSES

- Wide range of costs (hardware and software)
- Some devices are portable while others are not
- Lighting and environment requirements

CUTTING EDGE TECHNOLOGY & TECHNIQUES TO ASSESS THE HUMAN BODY

Joshua Dexheimer, PhD, CSCS, PES
Contact Email: josh.dexheimer@styku.com