Assessment of body composition and obesity in patients living with spinal cord injury/disease

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FINANCIAL DISCLOSURES

- National Institute on Disability, Independent Living, and Rehabilitation
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- National Institutes of Health
  - NICHD grant number 1K01HD079582
- Paralyzed Veterans of America
  - Grant number 3146
LEARNING OBJECTIVES

1. Describe changes in body composition that occur with SCI/D and how these impact physical function and risk of chronic disease in this group.

2. Explain limitations of using current clinical measures of obesity with patients with SCI/D.

3. Discuss new measures and emerging technology for improved clinical assessment of obesity in patients with SCI/D.
OVERVIEW

- **What** is obesity
- **Why** does obesity matter in SCI/D
- **How** do we measure obesity in SCI/D
- **Where** do we go from here: current research and future directions
WHAT IS OBESITY

- **World Health Organization**
  
  Overweight and obesity are defined as abnormal or excessive fat accumulation that presents a risk to health.

- **CDC**
  
  Overweight and obesity are both labels for ranges of weight that are greater than what is generally considered healthy for a given height. The terms also identify ranges of weight that have been shown to increase the likelihood of certain diseases and other health problems.

- **NIH**
  
  The terms "overweight" and "obesity" refer to body weight that’s greater than what is considered healthy for a certain height.
WHY DOES OBESITY MATTER?

Obesity

- Depression
- Cancer
- Gallbladder Disease
- Nonalcoholic Fatty Liver Disease
- Stroke
- Heart Disease
- Obstructive Sleep Apnea
- Kidney Problems
- Type 2 Diabetes
- Deep Vein Thrombosis
- Risks for Expectant Mothers and Baby
- Premature Death
- Chronic Venous Insufficiency
- Urinary Incontinence
- Hypertension
- Cataracts
- Infertility
- PCOS
- Osteoarthritis
- Depresssion
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- PCOS
- Osteoarthritis
- Depression
- Cancer

The diagram illustrates the various health risks associated with obesity, including but not limited to:

- Depression
- Cancer
- Gallbladder Disease
- Nonalcoholic Fatty Liver Disease
- Stroke
- Heart Disease
- Obstructive Sleep Apnea
- Kidney Problems
- Type 2 Diabetes
- Deep Vein Thrombosis
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- Cataracts
- Infertility
- PCOS
- Osteoarthritis
Why Does Obesity Matter in SCI/D

- Obesity is 58% higher in people with disability (PWD) than non-disabled, and as high as 66% in adults with SCI/D.

- Advances in medical technology over the last 40 years have led to significant increases in life expectancy after SCI/D.

- With the prolonged life expectancy has come a shift in comorbidities and secondary conditions, with a rise in diseases of aging.
### Table 2. Age-Adjusted\(^a\) Prevalence of Hypertension and Adjusted Prevalence Ratios\(^b\) of Hypertension, by Disability Status and Type, Adults Aged 20 Years or Older, National Health and Nutrition Examination Survey, 2001–2010

<table>
<thead>
<tr>
<th>Disability Status</th>
<th>% Hypertension (95% CI)</th>
<th>Hypertension APR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any disability(^c)</td>
<td>34.2 (33.1–35.4)(^d)</td>
<td>1.13 (1.08–1.20)</td>
</tr>
<tr>
<td>Cognitive limitation</td>
<td>36.4 (33.8–39.1)(^d)</td>
<td>1.16 (1.05–1.28)</td>
</tr>
<tr>
<td>Hearing limitation</td>
<td>29.7 (27.0–32.5)</td>
<td>0.99 (0.91–1.09)</td>
</tr>
<tr>
<td>Vision limitation</td>
<td>32.9 (31.5–34.4)(^d)</td>
<td>1.12 (1.04–1.20)</td>
</tr>
<tr>
<td>Mobility limitation</td>
<td>39.1 (37.4–40.8)(^d)</td>
<td>1.23 (1.16–1.32)</td>
</tr>
<tr>
<td>No disability</td>
<td>26.9 (25.8–28.1)</td>
<td>1 [Reference]</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval; APR, adjusted prevalence ratio.

\(^a\) Age-adjusted to the 2000 US standard population by direct method using age groups 20–44, 45–64, and ≥65.

\(^b\) Adjusted for age, sex, race/ethnicity, education level, income-to-poverty ratio, health insurance status, and times received care in the previous 12 months.

\(^c\) Disability types are not mutually exclusive.

\(^d\) \(P < .001\) when compared with “No disability”; \(P\) values determined using a 2-tailed \(t\) test.

Stevens et al, 2014
WHY DOES OBESITY MATTER IN SCI/D

- Obesity and rehabilitation outcomes
  - Decreased acute rehabilitation outcomes
  - Decreased mobility
  - Increased pain
  - Increased psychological symptoms
WHY DOES OBESITY HAPPEN AFTER SCI/D

- Changes in body composition
  - Reduction in lean mass
  - Increased adiposity

- Metabolic changes due to injury/disability
  - Reduced resting metabolic rate
  - Reduced caloric expenditure
    - Increased sedentary behavior
    - Reduced active energy expenditure

- Environmental barriers
  - Limited access to accessible fitness and recreation opportunities
BODY COMPOSITION

- Fat Mass
- Fat-Free Mass
- Water
- Organs
- Muscle
- Bone
- Cellular/Molecular Level
- Subcutaneous Adipose Tissue
- Visceral Adipose Tissue
- Ectopic Fat

Body Weight
HOW DO WE MEASURE OBESITY

- CT scan
- MRI
- Hydrostatic Weighing
- DXA
- Air Displacement Plethysmography (BodPod)
- Bioelectrical Impedance
- Skinfold Calipers
- Waist Circumference
- Body Mass Index (BMI)
DUAL-ENERGY X-RAY ABSORPTIOMETRY (DXA)
DUAL-ENERGY X-RAY ABSORPTIOMETRY (DXA)
DUAL-ENERGY X-RAY ABSORPTIOMETRY (DXA)

Contracture

Muscle Spasm
Body Mass Index (Adults)

- weight (kg)/height (m)$^2$
- $\text{kg/m}^2$

<table>
<thead>
<tr>
<th>Weight Status</th>
<th>BMI Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.5 kg/m$^2$</td>
</tr>
<tr>
<td>Normal Weight</td>
<td>18.5-24.9 kg/m$^2$</td>
</tr>
<tr>
<td>Overweight</td>
<td>25-29.9 kg/m$^2$</td>
</tr>
<tr>
<td>Obese Class I</td>
<td>30-34.9 kg/m$^2$</td>
</tr>
<tr>
<td>Obese Class II</td>
<td>35-39.9 kg/m$^2$</td>
</tr>
<tr>
<td>Obese Class III</td>
<td>&gt;40 kg/m$^2$</td>
</tr>
</tbody>
</table>
Body Mass Index (Children/Adolescents)

- CDC growth charts
- Dependent on age, gender
- Overweight: 85th-95th percentile
- Obese: >95th percentile
Body Fat Measurement - Body Mass Index (BMI) or Body Composition

BMI Body Comparison
MRI: Similar BMI, different body composition
CT Scan: Similar BMI, different abdominal obesity patterns

Fat mass: 19.8 kg
VFA: 155 cm²

Fat mass: 19.8 kg
VFA: 96 cm²

BMI RECOMMENDATIONS FOR ADULTS WITH SCI/D

- Changes in body composition
- Reduction in lean mass
- Increased adiposity

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</tr>
<tr>
<td>Overweight</td>
<td>22 kg/m²</td>
</tr>
<tr>
<td></td>
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</tr>
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Exploratory Study Examining Clinical Measures of Adiposity Risk for Predicting Obesity in Adolescents with Physical Disabilities

ABSTRACT


- n=29
- Ages 14-17 yrs.
- SCI, Spina Bifida, or CP
- Clinical measures of adiposity: BMI, waist circumference
- Reference measure: DXA
### TABLE 1 Participant characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n (%)</th>
<th>Mean (SD)</th>
<th>Range of Mean (SE) of the General Population, 14–17 Yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yrs</td>
<td>15.97 (1.18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>12 (41.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>17 (58.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCI</td>
<td>21 (72.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>5 (17.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spina bifida</td>
<td>3 (10.3)</td>
<td></td>
<td></td>
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<tr>
<td>Wheelchair type</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Manual</td>
<td>21 (72.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Powered</td>
<td>8 (27.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height, cm</td>
<td>159.79 (13.58)</td>
<td>161.60 (0.76)–175.9 (0.69)&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Weight, kg</td>
<td>57.21 (16.30)</td>
<td>61.6 (1.13)–77.4 (2.41)&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>22.43 (6.39)</td>
<td>22.4 (0.59)–24.9 (0.70)&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>84.08 (13.82)</td>
<td>78.8 (1.48)–85.6 (1.82)&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Triceps skinfold, mm</td>
<td>24.36 (10.98)</td>
<td>12.9 (0.83)–19.7 (0.87)&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Upper arm circumference, cm</td>
<td>25.47 (5.01)</td>
<td>27.8 (0.52)–31.5 (0.62)&lt;sup&gt;a&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Upper leg circumference, cm</td>
<td>39.98 (8.79)</td>
<td>49.3 (0.77)–53.3 (0.63)&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>Percentage of body fat</td>
<td>33.43 (10.97)</td>
<td>24.3 (0.80)–33.4 (0.50)&lt;sup&gt;c&lt;/sup&gt;</td>
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<sup>a</sup> As measured by NHANES 2007–2010.<sup>34</sup>  
<sup>b</sup> As measured by NHANES 2003–2006.<sup>35</sup>  
<sup>c</sup> As measured by NHANES 1999–2004.<sup>36</sup>
BMI IN ADOLESCENTS WITH MOBILITY DISABILITIES

Wingo, Mehta, Rimmer (2015)
Waist circumference considered better estimation of visceral adiposity

Risk of type 2 diabetes and CVD increase with higher waist circumference

Risk cut points (non-injured)
- Males: >102 cm
- Females: >88 cm

Primary disadvantages:
- Inconsistent protocols
- Measurement error
Matched within 5% for age, waist circumference, weight, BMI, and male sex
SCI subject: age: 47 y; WC: 97.7 cm; weight: 88.0 kg; and BMI: 25.4
AB subject: age, 46 y; WC, 97.3 cm; weight, 91.2 kg; and BMI, 25.9

Edwards et al 2008
WAIST CIRCUMFERENCE IN SCI/D

- Risk cut points
- Males: $>102 \text{ cm}$
- Females: $>88 \text{ cm}$

86-100 cm
WAIST CIRCUMFERENCE IN ADOLESCENTS WITH MOBILITY DISABILITY

Wingo, Mehta, Rimmer (2015)

Males
WC cut off: 83 cm

Females
WC Cut off: 78 cm
OTHER OPTIONS FOR CLINICAL ASSESSMENT OF OBESITY

Bioelectrical Impedance Analysis (BIA)
BIOELECTRICAL IMPEDANCE ANALYSIS
BIOELECTRICAL IMPEDANCE ANALYSIS

- **Pros**
  - Inexpensive
  - Portable options available
  - Fast
  - Non-invasive
  - Potential for segmental estimation

- **Cons**
  - Many confounding factors for test results
  - Test-retest reliability not established
  - Many clinical options require ability to stand
  - Not validated in many disease populations
VALIDATION OF SEGMENTAL BIA

Original article

Comparison of segmental body composition estimated by bioelectrical impedance analysis and dual-energy X-ray absorptiometry

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c Department of Nutrition and Hospitality Management, University of Alabama, 412 Russell Hall, Box 870311, Tuscaloosa, AL, 35487, USA

- n=30
- Ages 18-65
- Generally healthy
- Segmental estimates of body composition via BIA
- Reference measure: DXA
Table 2
Total and segmental body composition estimates by DXA and BIA.

<table>
<thead>
<tr>
<th></th>
<th>DXA Mean (SD)</th>
<th>BIA Mean (SD)</th>
<th>p value for Paired Sample t-test</th>
<th>Cohen's d</th>
<th>Pearson r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total body</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total mass, kg</td>
<td>82.56 (22.15)</td>
<td>81.58 (21.85)</td>
<td>.11</td>
<td>.31</td>
<td>.99**</td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>27.92 (13.36)</td>
<td>23.76 (11.17)</td>
<td>.14</td>
<td>.95</td>
<td>.95**</td>
</tr>
<tr>
<td>Lean mass, kg</td>
<td>51.77 (13.13)</td>
<td>54.89 (14.92)</td>
<td>&lt;.001</td>
<td>1.17</td>
<td>.99**</td>
</tr>
<tr>
<td>Arm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total mass, kg</td>
<td>9.33 (2.99)</td>
<td>8.54 (2.79)</td>
<td>&lt;.001</td>
<td>1.08</td>
<td>.97**</td>
</tr>
<tr>
<td>Right arm</td>
<td>4.70 (1.49)</td>
<td>3.76 (1.20)</td>
<td>&lt;.001</td>
<td>2.15</td>
<td>.97**</td>
</tr>
<tr>
<td>Left arm</td>
<td>4.63 (1.51)</td>
<td>4.79 (1.60)</td>
<td>.05</td>
<td>.41</td>
<td>.97**</td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>3.01 (1.32)</td>
<td>2.59 (1.31)</td>
<td>&lt;.001</td>
<td>.80</td>
<td>.92**</td>
</tr>
<tr>
<td>Right arm</td>
<td>1.51 (.65)</td>
<td>1.31 (.12)</td>
<td>&lt;.001</td>
<td>.37</td>
<td>.92**</td>
</tr>
<tr>
<td>Left arm</td>
<td>1.50 (.67)</td>
<td>1.28 (.64)</td>
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<td>.89</td>
<td>.93**</td>
</tr>
<tr>
<td>Lean mass, kg</td>
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<td>6.91 (2.68)</td>
<td>&lt;.001</td>
<td>1.24</td>
<td>.96**</td>
</tr>
<tr>
<td>Right arm</td>
<td>2.99 (1.16)</td>
<td>3.53 (1.34)</td>
<td>&lt;.001</td>
<td>1.36</td>
<td>.96**</td>
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<tr>
<td>Left arm</td>
<td>2.94 (1.15)</td>
<td>3.38 (1.34)</td>
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<td>1.10</td>
<td>.96**</td>
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<tr>
<td>Leg</td>
<td></td>
<td></td>
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<tr>
<td>Total mass, kg</td>
<td>29.20 (7.42)</td>
<td>26.46 (6.49)</td>
<td>&lt;.001</td>
<td>1.64</td>
<td>.98**</td>
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<tr>
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<td>14.71 (3.74)</td>
<td>13.22 (3.23)</td>
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<tr>
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<td>13.24 (3.25)</td>
<td>&lt;.001</td>
<td>1.54</td>
<td>.98**</td>
</tr>
<tr>
<td>Fat mass, kg</td>
<td>9.46 (3.96)</td>
<td>7.52 (2.92)</td>
<td>&lt;.001</td>
<td>.96</td>
<td>.87**</td>
</tr>
<tr>
<td>Right leg</td>
<td>4.76 (2.01)</td>
<td>3.77 (1.47)</td>
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<td>.96</td>
<td>.87**</td>
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<td>3.75 (1.45)</td>
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<td>.86**</td>
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<td>Lean mass, kg</td>
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<td>18.35 (5.48)</td>
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<td>.97**</td>
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<tr>
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<td>.97**</td>
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<tr>
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<td>9.22 (2.78)</td>
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<td>.07</td>
<td>.97**</td>
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<tr>
<td>Trunk</td>
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<td>Total mass, kg</td>
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<td>40.40 (12.12)</td>
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<td>.32</td>
<td>.97**</td>
</tr>
<tr>
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<td>.08</td>
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<tr>
<td>Lean mass, kg</td>
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<td>29.58 (6.89)</td>
<td>&lt;.001</td>
<td>2.43</td>
<td>.96**</td>
</tr>
</tbody>
</table>

**p < .001.
d. Lean Mass - Leg

- Bar graph showing lean mass for different participants.

Legend:
- • Leg Mass (DXA)
- ○ Leg Lean Mass (BIA)
SEGMENTAL BODY COMPOSITION ASSESSMENT

b. Lean Mass - Trunk

- Trunk Lean Mass (DXA)
- Trunk Lean Mass (BIA)
SEGMENTAL BODY COMPOSITION ASSESSMENT

c. Lean Mass: Arm

- Arm Lean Mass: DXA
- Arm Lean Mass: MRI

Participant number

Lean mass [kg]

0.000  2.000  4.000  6.000  8.000  10.000  12.000  14.000  16.000

1  3  2  5  6   4  12  7  9  13  8  17  11  15  10  18  14  16  19  21  18  24  28  20  26  24  29  30
VALIDATION OF BIA IN SCI/D

ACCU-Measure Study

**Purpose:** to develop a valid method for segmental body composition assessment using BIA in a group of adults with chronic SCI.

**Aims:**

1. To determine optimal lead placement for measurement of upper and lower extremity and trunk impedance.
2. To develop and validate prediction equations for upper and lower extremity, abdominal, and whole body fat mass and lean mass.
Participants

- **Inclusion Criteria**
  - SCI/D >1 year
  - BMI 18.5-45 kg/m²
  - No overt signs/symptoms of edema or dehydration

- **Exclusion Criteria**
  - Electrical or metallic implant contraindicated for DXA
  - Extensive tattoos on the arms, legs, or torso
  - Amputation
  - Pregnancy or breastfeeding

Measures

- Anthropometrics: height, weight, waist and limb circumference
- Total body water: Deuterium dilution
- BIA: 8 lead and 4 lead
- DXA
### Characteristics of study participants  (n=53)

<table>
<thead>
<tr>
<th></th>
<th>N (%)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>16 (30.2)</td>
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</tr>
<tr>
<td>Male</td>
<td>37 (69.8)</td>
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<tr>
<td><strong>Ethnicity</strong></td>
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<tr>
<td>White</td>
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<td></td>
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<tr>
<td>Black</td>
<td>26 (49.1)</td>
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<tr>
<td>Hispanic</td>
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<tr>
<td>Obese</td>
<td>12 (22.6)</td>
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<tr>
<td>Overweight</td>
<td>24 (45.3)</td>
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<tr>
<td>Normal</td>
<td>17 (32.1)</td>
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<tr>
<td><strong>Injury Type</strong></td>
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</tr>
<tr>
<td>Complete Tetraplegia</td>
<td>2 (3.8)</td>
<td></td>
</tr>
<tr>
<td>Complete Paraplegia</td>
<td>19 (35.8)</td>
<td></td>
</tr>
<tr>
<td>Incomplete Tetraplegia</td>
<td>10 (18.9)</td>
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</tr>
<tr>
<td>Incomplete Paraplegia</td>
<td>22 (41.5)</td>
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<tr>
<td><strong>Age</strong></td>
<td>46.0 (12.1)</td>
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</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>175.89 (10.41)</td>
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</tr>
<tr>
<td><strong>Weight (kg)</strong></td>
<td>84.55 (22.11)</td>
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</tr>
<tr>
<td><strong>BMI</strong></td>
<td>27.23 (6.21)</td>
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</table>

SD=Standard Deviation. BMI = Body Mass Index.
ACCU-MEASURE RESULTS

Whole Body Composition

* p < .001
**Lean Mass**

- **Cervical (n=10):**
  - DXA: 101.31
  - BIA: 115.84
- **Thoracic (n=11):**
  - DXA: 102.38
  - BIA: 113.42
- **Lumbar (n=1):**
  - DXA: 84.9
  - BIA: 104.1

**Fat Mass**

- **Cervical (n=10):**
  - DXA: 73.1
  - BIA: 60.1
- **Thoracic (n=11):**
  - DXA: 69.6
  - BIA: 57.4
- **Lumbar (n=1):**
  - DXA: 73.2
  - BIA: 55.7

* p<.001
ACCU-MEASURE

**Trunk Lean Mass**

- Normal: 45.82, 51.06
- Overweight: 52.12, 67.71
- Obese: 65.41, 78.99

**Leg Lean Mass**

- Normal: 26.82, 29.1
- Overweight: 33.46, 40.9
- Obese: 42.51, 55.88

**Arm Lean Mass**

- Normal: 14.06, 13.31
- Overweight: 15.02, 17.55
- Obese: 17.63, 21.94

* Results are significant at p<.001

---

DXA

BIA

* p<.001

THE UNIVERSITY OF ALABAMA AT BIRMINGHAM
## ACCU-MEASURE: PRELIMINARY RESULTS

### Placement Results: Arm

<table>
<thead>
<tr>
<th>Placement versus 15</th>
<th>Reactance Difference (Placement-15)</th>
<th>p-value</th>
<th>Resistance Difference (Placement-15)</th>
<th>p-value</th>
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<td>1</td>
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**Bold** = statistically significant at the 0.05 level based on paired t-tests. Resistance and Reactance measured in ohms.
### ACCU-MEASURE: PRELIMINARY RESULTS

#### Placement Results: Trunk

<table>
<thead>
<tr>
<th>Placement versus 25 (Placement-25)</th>
<th>Reactance Difference</th>
<th>p-value</th>
<th>Resistance Difference (Placement-25)</th>
<th>p-value</th>
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<tr>
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Bold = statistically significant at the 0.05 level based on paired t-tests. Resistance and Reactance measured in ohms.
### Placement Results: Legs

<table>
<thead>
<tr>
<th>Placement versus 21</th>
<th>Reactance</th>
<th>p-value</th>
<th>Placement versus 21</th>
<th>Resistance</th>
<th>p-value</th>
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</table>

**Bold** = statistically significant at the 0.05 level based on paired t-tests. Resistance and Reactance measured in ohms.
Determine impact of hydration on placement resistance/reactance differences

Fit current estimation models with each placement and compare to DXA

Develop new models with SCI-specific variables
  - Level of injury
  - Time since injury
Limitations

- Incomplete data collection for some data points
- Limited generalizability for specific prediction equations
- DXA as reference value

Future directions

- Expansion to multi-frequency BIA methods
- Repeated measures data collection (short and long term)
ACKNOWLEDGEMENTS

- Participants
- Research Staff
  - Kathryn Green, BS, RD
  - Victoria Wicks, BS
  - Alex Yates, MS
- UAB Nutrition Obesity Research Center Metabolism Core (NIDDK grant number P30DK056336)
- RJL Systems