Arm Ergometry Exercise Stress Testing, Body Composition and Exercise Prescription in Persons with Spinal Cord Injury

PVA Summit 2011 & EXPO
Renaissance Orlando at SeaWorld
Orlando, FL
September 18, 2011

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Grant sources of funding include:

VA Rehabilitation Research & Development Service
Spinal Cord Research Foundation  Washington, D.C.
James J. Peters VA Medical Center  Bronx, NY
Mount Sinai School of Medicine  New York, NY
Kessler Foundation for Medical Research and Kessler Institute of Rehabilitation, West Orange, NJ
Rancho Los Amigos National Rehabilitation Hospital, Downey, CA
Obtaining CME Credit

• If you would like to receive CME credit for this activity, please visit:

http://www.pesgce.com/PVAsummit2011/

• This information can also be found in the Summit 2011 Program on page 8.
Learning Objectives

1) Define the key components of an arm ergometry exercise stress test;

2) Interpret the results relative to physical fitness;

3) Use the arm ergometry exercise test results to recommend exercise training workloads;

4) Identify corollaries to peak exercise performance; and

5) Identify the magnitude of body composition changes from spinal cord injury.
Arm exercise is the predominant mode of aerobic physical activity for persons with paraplegia (Para). Fitness levels and peak performance can be determined from maximal arm ergometry exercise stress testing.
Outline of Presentation

• Basic principles and physiology arm ergometry
• Exercise Rx from arm exercise stress test
• Body composition
  – Acute SCI, longitudinal study
  – Chronic SCI, cross-sectional studies
Arm Exercise Stress Testing

...The “101” Basics

• **Arm ergometer**
  – Stabilized to handle lots of torque
  – Measurable increments in Watts
  – Minimal increments of <15 watts

• **Exercise protocol**
  – Ramp is ideal
  – One minute increments

• **Heart rate monitor**
  – 3 lead ECG
  – Polar pacer monitor

• **Metabolic cart**
  – FIO₂, FICO₂, FEO₂, FECO₂
    • O₂ uptake, CO₂ production
  – RR, TV, VE
  – Calculation of derivatives
Phases of the Exercise Test

**Pre-exercise** Data collected during baseline, just prior to initiation of the exercise protocol.

**Sub-maximal** From onset of arm cranking to peak performance.

**Anaerobic Threshold (AT)** The highest oxygen uptake attained without sustained increase in blood lactate concentration.

**Ventilatory Threshold (VT)** Determined by the V-slope technique, the point during exercise that CO$_2$ (VCO$_2$) is produced more than O$_2$ (VO$_2$) is taken up (Wasserman, 1986). The VT closely correlates with anaerobic threshold.

**Peak Exercise** The highest attained O$_2$ uptake during a maximal ergometry exercise test.

**Recovery** The phase of rest after termination of exercise.
# Ambient and Exhaled Gas Concentrations

<table>
<thead>
<tr>
<th>Variable/Parameter</th>
<th>Pre Exercise/Resting</th>
<th>Max/Peak Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIO₂ (%)</td>
<td>20.93</td>
<td>20.93</td>
</tr>
<tr>
<td>FEO₂ (%)</td>
<td>16.00 – 19.00</td>
<td>15.00 – 18.00</td>
</tr>
<tr>
<td>FICO₂ (%)</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>FECO₂ (%)</td>
<td>2.50 – 4.00</td>
<td></td>
</tr>
<tr>
<td>FETCO₂ (%)</td>
<td>5.60 ± 0.07</td>
<td>4.60 – 6.80</td>
</tr>
</tbody>
</table>
\[ \text{VO}_2 = \frac{(1-\text{FEO}_2-\text{FECO}_2)}{(1-\text{FIO}_2-\text{FICO}_2)} \times \text{FIO}_2 - \text{FEO}_2 (100) \times 10 \times \text{VE (STPD)} \]

[Haldane Transformation] [Conzolazio, 1963]
## Pulmonary and Gas Exchange

<table>
<thead>
<tr>
<th>Variable/Parameter</th>
<th>Pre Exercise/Resting</th>
<th>Max/Peak Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>VE (L/min)</td>
<td>6 – 12</td>
<td>30 – 280</td>
</tr>
<tr>
<td>TV (ml)</td>
<td>200 – 700</td>
<td>&lt;IC_{max}</td>
</tr>
<tr>
<td>RR (f)</td>
<td>10 – 15</td>
<td>20 – 50</td>
</tr>
<tr>
<td>VO_{2} (ml/min)</td>
<td>180 – 400</td>
<td>500 – 6000</td>
</tr>
<tr>
<td>VCO_{2} (ml/min)</td>
<td>150 – 350</td>
<td>400 – 6200</td>
</tr>
<tr>
<td>RER (VCO_{2}/VO_{2})</td>
<td>0.80 – 0.85</td>
<td>0.98 – 1.40</td>
</tr>
<tr>
<td>VEO_{2} (L/1L VO_{2})</td>
<td>20 – 40</td>
<td>20 – 40</td>
</tr>
<tr>
<td>VECO_{2} (L/1L VCO_{2})</td>
<td>25 – 50</td>
<td>25 – 50</td>
</tr>
</tbody>
</table>
## Hemodynamic and Gas Exchange

<table>
<thead>
<tr>
<th>Variable/Parameter</th>
<th>Pre Exercise/Resting</th>
<th>Max/Peak Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{SaO}_2(%) )</td>
<td>94 – 99</td>
<td>94 – 99</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>50 – 90</td>
<td>120 – 220</td>
</tr>
<tr>
<td>( \text{O}_2 \text{ Pulse} ) (ml/beat)</td>
<td>3.0 – 7.8</td>
<td>8 – 40</td>
</tr>
<tr>
<td>HR Slope</td>
<td>n/a</td>
<td>3.5 – 7.0</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>90 – 120</td>
<td>150 – 200</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>60 – 90</td>
<td>70 – 100</td>
</tr>
<tr>
<td>RPE (6-20)</td>
<td>6</td>
<td>15 – 20</td>
</tr>
</tbody>
</table>
Anaerobic Threshold (AT)

• The AT occurs when the O$_2$ required by the exercising muscles cannot be totally supported by the O$_2$ delivery system.

• Energy demands are supplemented by the anaerobic mechanism of the conversion of pyruvate to lactate.

• AT is the VO$_2$ threshold, above which the anaerobic mechanisms supplement the aerobic ones and yields $>$VCO$_2$ relative to VO$_2$.

• **Continued work above the AT is not sustainable.**

Principles of Exercise Testing and Interpretation
“Isocapnic buffering” refers to curvilinear increase in VE and VCO₂.

“Respiratory Compensation” occurs after isocapnic buffering because of the metabolic acidosis of exercise.

AT occurs when lactate increases.

AT ≈ 180 W (63% of Pk)
Pk = 285 W (Leg Ergometry)

Principles of Exercise Testing and Interpretation
Wasserman, K. et al. 1986, Lea & Febiger
Publishers, Philadelphia, PA, Pg 12.
Peak versus Maximum Arm Exercise Performance

• Criteria for a “Max” Test
  – \( \text{VO}_2 \) ceases to rise with continued increases in work

• Criteria for a “Peak” Test
  – RER >1.10
  – HR >80% predicted max
  – \( \text{VE} \) >60% predicted max or MVV
  – \( \text{VO}_2 \) >60% predicted for Leg
Maximal Arm Ergometry Exercise Testing in Monozygotic Twins Discordant for Paraplegia
Arm and Leg Exercise Stress Testing

✓ Arm PWC was tested in both sets of twins
✓ Leg PWC was tested in the NonPara twins
✓ Arm: Para vs. NonPara
✓ Para Arm and NonPara Arm vs. NonPara Leg
Methods: Twin DNA Testing

- Blood was collected for restriction fragment length polymorphism (RFLP) analysis of Pst I digested DNA for twin zygosity.
- The results of the analyses were obtained with six probes which detect independent, highly polymorphic loci.
- The chance of two non-identical twins having identical DNA patterns at six loci was 1 in 4,096 (Lifecodes Corp, Stamford, CT)
Methods

• A prospective study was performed in 10 pairs of monozygotic twins.
• Arm and leg: lean and fat tissue masses were determined by dual energy x-ray absorptiometry (DXA).
• Paired t-tests were used for comparisons within twin pairs.
• Unpaired t-tests and ANOVAs were used for comparisons between the gender (male vs. female) and activity level (active vs. inactive) subgroups.
Methods: Arm and Leg Ergometry

Heart rate

Polar Pacer Heart Monitor, Polar USA Inc., Port Washington, NY

Gas exchange and ventilation

System 2900 Metabolic Measurement Cart, SensorMedics Corp., Yorba Linda, CA

$VO_2$ and $VCO_2$ were calculated from mixed expired $O_2$ and $CO_2$ concentrations.

Venous plasma lactate

2200 Stat, YSI Inc., Yellow Springs, OH

The following were obtained:

- **Work** (watts)
- **$VO_2$** (ml/min)
- **$VCO_2$** (ml/min)
- **$VE$** (L/min)
- **RR** (f)
- **TV** (ml)
- **HR** (bpm)
- **LA** (mmole/L)

Their derivatives were calculated.
# Arm and Leg Exercise Protocols

<table>
<thead>
<tr>
<th></th>
<th>Arm Ergometry</th>
<th>Leg Ergometry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mode:</strong></td>
<td>arm cycle</td>
<td>leg cycle</td>
</tr>
<tr>
<td><strong>Ergometer:</strong></td>
<td>Fleisch</td>
<td>Ergoline</td>
</tr>
<tr>
<td></td>
<td>Ergostat</td>
<td>Ergometrics</td>
</tr>
<tr>
<td></td>
<td>Switzerland</td>
<td>Germany</td>
</tr>
<tr>
<td><strong>Work units:</strong></td>
<td>watts</td>
<td>watts</td>
</tr>
<tr>
<td><strong>RPMs:</strong></td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td><strong>Protocol:</strong></td>
<td>incremental</td>
<td>ramp</td>
</tr>
<tr>
<td><strong>Increments:</strong></td>
<td>12 watts/min</td>
<td>25 watts/min</td>
</tr>
<tr>
<td><strong>Initial wkld:</strong></td>
<td>12 watts</td>
<td>0 watts</td>
</tr>
</tbody>
</table>
Exercise Test Termination Criteria

Subject wished to stop.

Subject unable to maintain 60 rpms at specified wkld.

HR ≥85% of max pred. heart rate

RER ≥1.10

VO₂ plateau
Subjects
6 male pairs
4 female pairs
Age = 36±8 y

Para twins:
Lower paraplegia
(T₇ to L₂)
DOI 13 ±10 y
(1-27 y)
10 active (≥3x/wk)

NonPara twins:
10 active (≥3x/wk)
## Characteristics of the Twins

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Para</th>
<th>NonPara</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height (m)</td>
<td>1.72±0.13</td>
<td>1.73±0.11</td>
<td>Ns</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>64.1±13.1</td>
<td>71.6±17.2*</td>
<td>0.01</td>
</tr>
<tr>
<td>BMI (kg/m$^2$)</td>
<td>21.4±2.6</td>
<td>23.7±3.9*</td>
<td>0.03</td>
</tr>
<tr>
<td>Arm Lean (kg)</td>
<td>7.1±2.2*</td>
<td>6.2±2.0</td>
<td>0.03</td>
</tr>
<tr>
<td>Leg Lean (kg)</td>
<td>10.5±3.0</td>
<td>18.3±4.7*</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
# Baseline and Predicted Maximum Values

<table>
<thead>
<tr>
<th>Static Pulmonary Function</th>
<th>Para</th>
<th>NonPara</th>
<th>*P&lt;0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FVC</strong> (L)</td>
<td>4.23 ±1.39</td>
<td>4.82 ±1.38</td>
<td>*</td>
</tr>
<tr>
<td><strong>FEV\textsubscript{1}</strong> (L)</td>
<td>3.49 ±0.99</td>
<td>3.78 ±0.97</td>
<td></td>
</tr>
<tr>
<td><strong>IC</strong> (L)</td>
<td>3.03 ±1.12</td>
<td>3.45 ±1.06</td>
<td>*</td>
</tr>
<tr>
<td><strong>MVV</strong> (L)</td>
<td>116 ±20</td>
<td>116 ±34</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Predicted Maximum</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR</strong> (bpm)</td>
<td>185 ±7</td>
<td>185 ±7</td>
</tr>
<tr>
<td><strong>VO\textsubscript{2}</strong> (ml/min)</td>
<td>2683 ±514</td>
<td>2715 ±542</td>
</tr>
<tr>
<td><strong>VE</strong> (L/min)</td>
<td>121 ±35</td>
<td>131 ±34</td>
</tr>
<tr>
<td><strong>VO\textsubscript{2}/kg</strong> (ml/kg/min)</td>
<td>38.0 ±4.5</td>
<td>38.5 ±4.9</td>
</tr>
<tr>
<td><strong>Watts</strong> (W)</td>
<td>203 ±52</td>
<td>209 ±50</td>
</tr>
</tbody>
</table>
# Pre-Exercise Data

<table>
<thead>
<tr>
<th></th>
<th>Para ARM</th>
<th>NonPara ARM</th>
<th>NonPara LEG</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HR (bpm)</strong></td>
<td>90±18 *</td>
<td>81±11</td>
<td>95±7 •</td>
</tr>
<tr>
<td><strong>VE (L/min)</strong></td>
<td>11.6±2.9</td>
<td>11.2±3.7</td>
<td>14.1±6.0</td>
</tr>
<tr>
<td><strong>VO₂ (ml/min)</strong></td>
<td>307±71</td>
<td>348±111</td>
<td>373±177</td>
</tr>
<tr>
<td><strong>RER (VCO₂/VO₂)</strong></td>
<td>0.94±0.13</td>
<td>0.90±0.11</td>
<td>0.90±0.11</td>
</tr>
<tr>
<td><strong>LA (mmol/L)</strong></td>
<td>1.14±0.30</td>
<td>1.03±0.38</td>
<td>1.16±0.36</td>
</tr>
</tbody>
</table>

* *P*<0.05 ARM: Para vs. NonPara

• *P*<0.05 NonPara: Arm vs. Leg
# Anaerobic / Ventilatory Threshold Data

<table>
<thead>
<tr>
<th></th>
<th>Para</th>
<th>NonPara</th>
<th>NonPara</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ARM</td>
<td>ARM</td>
<td>LEG</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>149±17 * •</td>
<td>121±6</td>
<td>134±11 ♦</td>
</tr>
<tr>
<td>VE (L/min)</td>
<td>39.1±13.1</td>
<td>35.3±12.9</td>
<td>39.2±13.8</td>
</tr>
<tr>
<td>VO₂ (ml/min)</td>
<td>1155±400</td>
<td>1087±432</td>
<td>1365±596</td>
</tr>
<tr>
<td>RER (VCO₂/VO₂)</td>
<td>1.03±0.07</td>
<td>1.03±0.06</td>
<td>1.00±0.07</td>
</tr>
<tr>
<td>LA (mmol/L)</td>
<td>4.96±1.83</td>
<td>4.59±1.49</td>
<td>3.05±1.49</td>
</tr>
<tr>
<td>Work (watts)</td>
<td>82±36</td>
<td>69±27</td>
<td>117±44</td>
</tr>
</tbody>
</table>

* P<0.0005 ARM:  Para vs. NonPara  
* P<0.05 ARM Para vs. LEG NonPara  
* P<0.005 NonPara:  Arm vs. Leg
## Peak Exercise Data

<table>
<thead>
<tr>
<th></th>
<th>Para ARM</th>
<th>NonPara ARM</th>
<th>NonPara LEG</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR (bpm)</td>
<td>179±10</td>
<td>174±11</td>
<td>171±11</td>
</tr>
<tr>
<td>VE (L/min)</td>
<td>75.9±31.0</td>
<td>92.9±30.3</td>
<td>93.6±34.4</td>
</tr>
<tr>
<td>VO(_2) (ml/min)</td>
<td>1709±679</td>
<td>1940±579</td>
<td>2259±855*</td>
</tr>
<tr>
<td>RER (VCO(_2)/VO(_2))</td>
<td>1.25±0.10</td>
<td>1.28±0.14</td>
<td>1.31±0.11*</td>
</tr>
<tr>
<td>LA (mmole/L)</td>
<td>10.8±3.1</td>
<td>14.6±4.4\§</td>
<td>7.9±4.3</td>
</tr>
<tr>
<td>Work (watts)</td>
<td>118±41</td>
<td>120±29</td>
<td>207±69*</td>
</tr>
</tbody>
</table>

\* \(P<0.05\) for Para Arm vs. NonPara Leg

\§ \(P<0.05\) for NonPara: Arm vs. Leg

\* \(P<0.01\) for Para Arm and NonPara Arm vs. NonPara Leg
Peak Exercise Values as a Percent of Predicted Maximum

<table>
<thead>
<tr>
<th></th>
<th>ARM Para %pMax</th>
<th>ARM NonPara %pMax</th>
<th>LEG NonPara %pMax</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR</td>
<td>97±7</td>
<td>94±7</td>
<td>93±6</td>
</tr>
<tr>
<td>VE</td>
<td>64±19</td>
<td>72±20</td>
<td>73±24</td>
</tr>
<tr>
<td>VO₂</td>
<td>63±17</td>
<td>71±16</td>
<td>85±27 *</td>
</tr>
<tr>
<td>Watts</td>
<td>58±10</td>
<td>58±10</td>
<td>100±27 *</td>
</tr>
</tbody>
</table>

* P<0.01 for SCI Arm and NonSCI Arm vs. NonSCI Leg
Heart Rate vs. Watts (Arm only)

Heart Rate (bpm)

Watts

Para

NonPara

*P < 0.05
$\text{VO}_2$ vs. Watts (Arm only)

[Graph showing the relationship between VO$_2$ (ml/min) and Watts.]
VO₂ Response to Arm and Leg Ergometry

VO₂ (ml/min)

Watts

SCI Arm  NonSCI Arm  NonSCI Leg  NJ Data¹

Heart Rate vs. Watts (Arm and Leg)

- NonPara LEG, slope = 0.298
- NonPara ARM, slope = 0.586 *
- Para ARM, slope = 0.434 *

*P<0.05 for Para Arm and NonPara Arm vs. NonPara Leg
Lactate vs. VO$_2$ (Arm and Leg)

![Graph showing Lactate (mmole/L) vs. VO$_2$ (ml/min) with data points for Para ARM, NonPara ARM, and NonPara LEG.](image)
Arm Exercise for Total Group: Active (n=10) vs. Inactive (n=10)

- **Percent of Max Predicted**
  - Y-axis: 30 to 110
  - X-axis: VO₂, Watts

- **Groups**
  - Para
  - NonPara
  - Trained
  - Untrained

- **Statistical Significance**
  - P < 0.05
  - * P < 0.01
Arm Exercise for Total Group: Male (n=12) vs. Female (n=8)

*P<0.05

Percent of Max Predicted

Heart Rate | VO₂ | Watts | Ventilation
MALE | FEMALE

Heart Rate

VO₂

Watts

Ventilation

*P<0.05
**Relationship of Arm Lean Tissue Mass with Peak Exercise VO$_2$**

- **NonPara**
  - $R^2 = 0.73$
  - $P = 0.003$

- **Para**
  - $R^2 = 0.74$
  - $P = 0.0007$
**V-Slope Method for Anaerobic Threshold Detection**

- **Untrained Para**
- **Trained Para**

Graphs showing VO2 and VCo2 data over different levels of Watts for both untrained and trained para. The V-Slope method is indicated by the arrow, marking the anaerobic threshold.
Lactate and Ventilatory Threshold

Sample of Arm Exercise: Para

PEAK Exercise
- LA: 20.0 mmole/L
- VO₂: 2500 Ml/Min
- VCO₂: 3000 Ml/Min
- W: 160 Watts

AT %: ≈43%
Male: Para
Age: 34 y
DOI: 13 y
Ht: 180 cm
Wt: 89 kg
BMI: 27.5

PK HR: 187
PM HR: 95%
PK W: 156
PK VO₂: 2572
PM VO₂: 83%

Rx HR: ≈ 140
Rx W: ≈ 125
Body Composition Changes after Acute SCI – Longitudinal Data
Chronic SCI – Cross sectional Data
Methods

• **Study Design**
  – Prospective, longitudinal study of newly injured patients

• **Measurement Time Points**
  – Baseline (16 to 65 days since SCI)
  – Sequentially at months 1, 3, 6, 12, 15, 18, and 24 after the baseline measurement
  – Real time was determined as days and months since SCI
Subjects

- 20 patients with acute SCI
- All were motor complete (ASIA A or B)
  - One subject was removed s/p change in status of motor completeness of SCI
- 19 Subjects
  - Gender: 14 Male, 5 Female
  - SCI: 7 Tetra, 12 Para
    - Tetra: 3 Female, 4 Male
    - Para: 2 Female, 10 Male
## Characteristics of the Subjects

### Acute SCI Longitudinal Data

(Data reported in mean ± SD and ranges)

<table>
<thead>
<tr>
<th></th>
<th>Tetra (n=7)</th>
<th>Para (n=12)</th>
<th>P Value</th>
<th>Male (n=14)</th>
<th>Female (n=5)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td>43 ± 13</td>
<td>29 ± 7</td>
<td>&lt;0.005</td>
<td>32 ± 10</td>
<td>36 ± 15</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Ht (cm)</strong></td>
<td>171 ± 12</td>
<td>177 ± 6</td>
<td>NS</td>
<td>178 ± 6</td>
<td>166 ± 9</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td><strong>Wt (kg)</strong></td>
<td>70.0 ± 16.0</td>
<td>75.0 ± 16.0</td>
<td>NS</td>
<td>79.0 ± 13.0</td>
<td>58.4 ± 11.2</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td><strong>BMI (kg/m²)</strong></td>
<td>24.0 ± 4.1</td>
<td>24.0 ± 5.0</td>
<td>NS</td>
<td>25.0 ± 4.3</td>
<td>21.0 ± 2.5</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Days since SCI</strong></td>
<td>46 ± 16</td>
<td>44 ± 16</td>
<td>NS</td>
<td>43 ± 16</td>
<td>50 ± 15</td>
<td>NS</td>
</tr>
</tbody>
</table>

(Data reported in mean ± SD and ranges)
Baseline Body Composition of the Subjects  
(Mean  SD and Ranges)

<table>
<thead>
<tr>
<th>Baseline Values</th>
<th>Tetra  (n=7)</th>
<th>Para  (n=12)</th>
<th>$P$ Value</th>
<th>Male  (n=14)</th>
<th>Female  (n=5)</th>
<th>$P$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TB Fat (kg)</td>
<td>15.0  7.6 (3.3-25.3)</td>
<td>16.3±12.3 (6.0-44.9)</td>
<td>NS</td>
<td>15.3±11.1 (3.3-45.0)</td>
<td>17.3±10.6 (8.2-34.9)</td>
<td>NS</td>
</tr>
<tr>
<td>TB Fat (%)</td>
<td>23±10 (4-33)</td>
<td>21±12 (10-46)</td>
<td>NS</td>
<td>19±10 (4-41)</td>
<td>29±12 (18-47)</td>
<td>0.10</td>
</tr>
<tr>
<td>TB Lean (kg)</td>
<td>50.7  16.8 (35.0-80.4)</td>
<td>75.0±16.0 (34.3-66.6)</td>
<td>NS</td>
<td>57.0±8.9 (46.8-80.4)</td>
<td>37.1±3.0 (34.3-41.9)</td>
<td>&lt;0.005</td>
</tr>
</tbody>
</table>

Females had sig, less lean mass in the arms and legs than males. Arm and leg fat mass trended (ns) to be higher in females.
## Number of Subjects Studied at Each Time Point

<table>
<thead>
<tr>
<th>Time</th>
<th>Number of S’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>19</td>
</tr>
<tr>
<td>Month 1</td>
<td>19</td>
</tr>
<tr>
<td>Month 3</td>
<td>19</td>
</tr>
<tr>
<td>Month 6</td>
<td>17</td>
</tr>
<tr>
<td>Month 12</td>
<td>13</td>
</tr>
<tr>
<td>Month 24</td>
<td>10</td>
</tr>
</tbody>
</table>
Acute SCI Longitudinal Data

Total Body % Fat by Level of SCI

Study Visit
- BL
- 1
- 3
- 6
- 12
- 15
- 18
- 24

Real Time
- 1.4
- 2.5
- 4.6
- 7.5
- 13.6
- 16.9
- 20.5
- 25.6

TB Fat (%)

Months
Arm Fat Mass

(No differences: Para vs. Tetra or Male vs. Female)

Arm Fat Mass (kg)

Study Visit
BL 1 3 6 12 18 24

Real Time
1.4 2.5 4.6 7.5 13.6 20.5 25.6

Months since SCI

* p<0.05
Acute SCI Longitudinal Data

Total Body Lean Mass (kg) – By Gender

*P<0.05
Acute SCI Longitudinal Data

Leg Lean Mass (kg) – By Gender

*P<0.02
Body Composition in Chronic SCI Cross Sectional Data
Monozygotic Twin Data

Total Body Lean Differences within Twins Pairs

12.6±7.9 kg diff
Total Body Lean Tissue Loss with Duration of Injury in the SCI Twins

Monozygotic Twin Data

Difference of an average of 7.8 kg LTM per decade of injury

R = 0.87, slope = -0.782 ±0.181, p<0.005
Monozygotic Twin Data

**Leg Lean Differences within Twins Pairs**

- **Leg Lean Tissue (kg)**
- **10.1±4.0 kg diff**

![Graph showing the differences in leg lean tissue between NonSCI and SCI twins.](image-url)
Monozygotic Twin Data

Average Differences for Fat Mass

Fat Mass (kg)

Non SCI

SCI

* P<0.01

* P<0.05

Arms

Legs

Trunk

Total Body

SCI

Non SCI

Average Differences

SCI

Non SCI

2.9±2.4 kg

3.6±3.3kg

6.4±6.1kg

* P<0.05

0

5.0

10.0

15.0

20.0

25.0

30.0
Relationship of Body Mass Index with Fat Mass

Monozygotic Twin Data

SCI: \( r=0.75, \ p<0.05 \)
NonSCI: \( r=0.82, \ p<0.01 \)
Comparison of **Percent Lean** between SCI and Controls by Age Category

Cross-sectional Data

Cross-sectional Data

**TOTAL BODY PERCENT Lean TISSUE**

(C=100, T=66, P=67)

- **Controls**
  - (-1.0% / 10 y)

- **SCI**
  - (-3.2% / 10 y)

Comparison of Percent Fat between SCI and Controls by Age Category

<table>
<thead>
<tr>
<th>Age Category</th>
<th>SCI N=133</th>
<th>Controls N=100</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 40 y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 40 y</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*P < 0.0001

*P < 0.01

THE RELATIONSHIP OF PERCENT FAT WITH BODY MASS INDEX (BMI)


Cross-sectional Data
Arm Exercise Summary:  Para ARM vs. NonPara ARM

The twins with paraplegia compared with their able-bodied co-twins:

- Had significantly lower static pulmonary function, likely due to varying degrees of abdominal wall paralysis.
- Had significantly higher heart rates at the sub-maximal work rates (12 to 96 watts) and at the anaerobic/ventilatory thresholds.
- Demonstrated no differences at peak exercise for any of the parameters measured.
- Had nearly identical oxygen uptake levels and lactate production for each sub-maximal work rate.
Arm Exercise Summary: Arm vs. Leg

For Para ARM and NonPara ARM vs. NonSCI Leg

- Heart rate was significantly higher for any given sub-maximal workload or oxygen uptake.
- The heart rate slope of arm work was significantly steeper than for leg work.
- The anaerobic contribution to arm work was significantly greater than for the same oxygen consumption for leg work (i.e., greater lactic acid production).
- Both Twins, using their arms, attained:
  - 63% of their maximum predicted VO$_2$
  - 58% of their PWC (peak Watts) for legs.
Arm Exercise Conclusions

- Twins with paralysis who use their arms daily for mobilization are able to perform the same amount of arm work as their non paralyze twins.

- In the NonPara twins, trunk and lower extremity skeletal muscle recruitment during arm ergometry may have contributed to the higher VO\(_2\) at peak exercise despite lower arm lean tissue mass.

- In ergometric work, the oxygen cost of any given workload performed by the arms or the legs is the same whether performed by a person with lower extremity paralysis, a non paralyzed person, trained, untrained, males, or females.

- In both groups, arm peak exercise performance was highly correlated with arm lean tissue mass, suggesting the importance of upper body strength training.
Body Composition Summary

Paralysis from SCI is associated with a rapid loss of lean tissue below the level of lesion.

Fat mass is significantly increased within months after SCI and continues to increase for at least 2 years.

The rate or relative amount of fat increase is similar between males & females and paraplegia & tetraplegia.

Percent fat is higher for any unit of BMI in those with SCI.

Muscle continues to decline with advancing age and duration of injury, at a greater rate than in the general population.
Body Composition Summary

Absolute fat mass increase after SCI may partially explain the high prevalence of metabolic consequences commonly found in this population.

The influence of this increased amount of fat mass on cardiovascular risk is unknown.

These deleterious increases in regional and total body fat should be vigorously targeted in future intervention studies.
James J. Peters VA Medical Center
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