Amputee Medicine 101

Brad Tucker, MD
2019 P&O course
University of Pennsylvania
Physical Medicine and Rehabilitation
Objectives

To have a better understanding of:

- The types of PAIN common to amputees, the cause or current theory for symptoms and the recommended management.

- The common DERMATOLOGIC & musculoskeletal conditions in amputees and associated treatment.

- The ENERGY cost of gait associated with the different levels of lower extremity amputation.
Advancements in Amputee Medicine
Distribution of Amputations

In the USA

- 185,000 amputations per year
- 1.6 million persons living w/ limb loss
- 86% are lower limb amputations
- Approx. 380,000 have a TTA
  - around 72% due to vascular d/z
  - around 7% due to trauma
Volume Management - Goals

- Pre-prosthetic:
  - Reduce swelling
  - Form optimal shape to best fit in to socket

- Post-prosthetic:
  - Maintain limb volume for proper prosthetic fit
  - Minimize dermatologic and MSK issues
    - Pain
    - Wounds
Volume Management – Methods

- ACE wraps
  - Initial mgmt
  - Risk of Choke Syndrome
  - (Circumferential wrap)

- Tubigrip/Stump Shrinkers
  - Chronic treatment
  - After incision has healed
Volume Management – Methods

- IPORD - Immediate Post-Op Rigid Dressing
Dermatologic Conditions

- Dermatitis (most common in traumatic)
- Ulcer/pressure sites (most common in vascular disease)
- Verrucous Hyperplasia
- Fungal/Bacterial Infection
- Callus
- Cyst
# Table 2 Dermatologic conditions in amputees and types of prosthesis

<table>
<thead>
<tr>
<th>Dermatologic condition</th>
<th>Total patients Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irritant contact dermatitis</td>
<td>32 (30.4)</td>
</tr>
<tr>
<td>Allergic contact dermatitis</td>
<td>25 (23.9)</td>
</tr>
<tr>
<td>Infected irritant contact dermatitis</td>
<td>5 (4.8)</td>
</tr>
<tr>
<td>Infected allergic contact dermatitis</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>Bacterial infection</td>
<td>12 (11.5)</td>
</tr>
<tr>
<td>Callus</td>
<td>11 (10.4)</td>
</tr>
<tr>
<td>Fungal infection</td>
<td>4 (3.8)</td>
</tr>
<tr>
<td>Erosion</td>
<td>5 (4.8)</td>
</tr>
<tr>
<td>Verrucous hyperplasia</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>Epidermoid cyst</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>Keloid</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td>Haematoma</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>105 (100)</strong></td>
</tr>
</tbody>
</table>
# Dermatologic Conditions – PVD

<table>
<thead>
<tr>
<th>TABLE 1 Patient demographic and amputation information for five most common skin problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ulc</strong>er (n = 141)</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Age at amputation</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Transtibial</td>
</tr>
<tr>
<td>Transfemoral</td>
</tr>
<tr>
<td>Other</td>
</tr>
<tr>
<td>Reason for amputation</td>
</tr>
<tr>
<td>Peripheral vascular disease ± diabetes, diabetes</td>
</tr>
<tr>
<td>Trauma</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>

* Indicates a significant difference when compared with all other skin problems with respect to that factor (P < 0.05).
Dermatologic Conditions: Dermatitis

http://www.dermnetnz.org
Choke Stump Syndrome
Dermatologic Conditions: Fungal Infection

http://www.dermnetnz.org
Etiology of common Skin problems

Determinants of Skin Problems of the Stump in Lower-Limb Amputees

Henk E. Meulenbelt, MD, Jan H. Geertzen, MD, PhD, Marcel F. Jonkman, MD, PhD, Pieter U. Dijkstra, PT, MT, PhD

Skin Problems of the Stump in Lower Limb Amputees: 1. A Clinical Study

Henk E. J. MEULENBELT¹, Jan H. B. GEERTZEN¹, Marcel F. JONKMAN² and Pieter U. DIJKSTRA¹,³
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Provocative Determinants:
Higher level of amputation
Poor socket fit
Smoking
High Frequency of washing stump (≥ 1 time/day)
Derm Treatment/Recommendations

### TABLE 3 Recorded management of the five most common skin problems

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ulcer (n = 141)</th>
<th>Irritation (n = 93)</th>
<th>Inclusion Cyst (n = 79)</th>
<th>Callus (n = 60)</th>
<th>Verrucous Hyperplasia (n = 47)</th>
<th>All Skin Problems (n = 528)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of office visits</td>
<td>9.3 (± 6.9)</td>
<td>6.4 (± 4.3)</td>
<td>6.7 (± 4.9)</td>
<td>5.2 (± 5.0)</td>
<td>7.8 (± 6.2)</td>
<td>1.6 (± 1.4)</td>
</tr>
<tr>
<td>Prosthetic adjustment or new prosthesis</td>
<td>109 (77.3%)</td>
<td>78 (83.8%)</td>
<td>62 (78.5%)</td>
<td>53 (88.3%)</td>
<td>43 (91.5%)b</td>
<td>418 (79.2%)</td>
</tr>
<tr>
<td>Modify prosthetic use</td>
<td>32 (22.7%)b</td>
<td>2 (2.2%)b</td>
<td>9 (11.4%)</td>
<td>3 (5.0%)</td>
<td>3 (6.4%)</td>
<td>57 (10.8%)</td>
</tr>
<tr>
<td>Sock change</td>
<td>25 (17.7%)</td>
<td>22 (23.6%)</td>
<td>7 (8.9%)b</td>
<td>8 (13.4%)</td>
<td>12 (25.5%)</td>
<td>109 (20.6%)</td>
</tr>
<tr>
<td>Medication (topical and/or oral)</td>
<td>60 (42.6%)b</td>
<td>7 (7.6%)b</td>
<td>13 (16.4%)b</td>
<td>6 (10.0%)b</td>
<td>7 (14.9%)</td>
<td>141 (26.7%)</td>
</tr>
<tr>
<td>Cream (nonmedicinal)</td>
<td>11 (7.8%)b</td>
<td>8 (8.6%)</td>
<td>16 (20.3%)</td>
<td>12 (20.0%)</td>
<td>7 (14.9%)</td>
<td>71 (13.4%)</td>
</tr>
<tr>
<td>Dressing</td>
<td>76 (53.9%)b</td>
<td>4 (4.3%)b</td>
<td>8 (10.2%)b</td>
<td>5 (8.3%)b</td>
<td>6 (12.8%)</td>
<td>116 (22.0%)</td>
</tr>
<tr>
<td>Specialist referral</td>
<td>7 (5.0%)</td>
<td>6 (6.5%)</td>
<td>12 (15.2%)b</td>
<td>2 (3.4%)</td>
<td>1 (2.1%)</td>
<td>44 (8.3%)</td>
</tr>
<tr>
<td>Surgical treatment</td>
<td>6 (4.3%)</td>
<td>5 (5.4%)</td>
<td>11 (13.9%)b</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>27 (5.1%)</td>
</tr>
</tbody>
</table>

* Each problem may have had one or more management interventions.

b Indicates a significant difference when compared with all other skin problems with respect to that factor (P < 0.05).

Socket modification, Hygiene, Skin care, Medications
Gel Liners

Silicone vs. Urethane
Pressure Sensitive Areas

ANTERIOR VIEW

1. PATELLA
2. LATERAL TIBIAL CONDYLE
3. TIBIAL TUBEROSITY
4. TIBIAL CREST
5. ANTERIOR-DISTAL END OF TIBIA
6. FIBULAR HEAD
7. DISTAL END OF FIBULA
8. DISTAL END OF STUMP WITH SURGICAL SUTURE
9. MEDIAL FEMORAL CONDYLE
10. LATERAL FEMORAL CONDYLE

LATERAL VIEW

Major source of PAIN
Amputee Pain

- Stump pain
- Phantom Limb Sensation (PLS)
- Phantom Limb Pain (PLP)
Stump Pain

- Pain in the residual portion of the limb or stump
- Bone spurs (#1 cause of MSK residual limb pain)
- Boney overgrowth
- HO
- Neuroma
- Edema (Tx: wrapping/shrinker)
- Skin conditions

Treatment
- Socket Modification/Replacement
- Medications (NSAIDs)
- Surgical
Phantom Limb Sensation and Pain

Phantom Limb Sensation
- Any sensation (paresthesia, dysesthesia, hyperpathia) of the missing limb except pain.
- Often not treated with medication

Phantom Limb Pain
- A painful sensation perceived in the missing limb after amputation, that is distinct from stump pain.
- Rates: 2% – 80% (vary depending on methods of study)
- Prospective research: 60% - 70% have PLP 1 year after amputation
- Believed to diminish with time

Parkes, 1972
Phantom Limb Sensation and Pain

- Phantom Limb Pain
  - May be related to “Pain Memory”
    - Painful phantom sensations mimic the pain felt before amputation
  - Cerebral imprinting is the commonly accepted theory
  - Neuroma formation may be related

Parkes, 1972
PLP Risk Factors

- Older (most under 35 yr have moderate or no PLP)
- Osteomyelitis – “always have severe pain”
- Left sided lesions
- Multiple surgical operations
- Recurrent depression
- Tender Stump

Parkes, 1972
PLP Treatment

- **Time**
  - Optimal socket fit / proper fit

- **Non-Pharmacological**
  - Mirror therapy
  - Biofeedback
  - Mental Imagery
  - Hypnosis
  - Meditation

- **Medications**
  - Surgeries/procedures
    - Chemo-denervation
    - Cryo-ablation
    - Neurostimulation devices
PLP Medications

- **Short-term peri-operative treatment**
  - IV ketamine and IV morphine

- **Intermediate to long-term (8 weeks to 1 year)**
  - **PO morphine (Considered first-line therapy)**

- **Short to long-term pain relief (peri-operatively up to 1 year)**
  - Peri-operative epidural anesthesia with morphine and bupivacaine
  - Mixed evidence of efficacy

- **Intermediate duration (6-8 weeks, but no significant change at 6 months)**
  - **Gabapentin 2400 - 3600 mg**
  - (Topiramate as secondary option)

- **Non-Effective Treatments (no better than placebo for long-term Tx)**
  - Botox, Tramadol, Amitriptyline
Increased Energy Expenditure of Amputee Gait

Proximal/contra-lateral muscles need to compensation for missing muscles for balance and propulsion.
### Increased Energy Expenditure of Amputee Gait

#### TABLE 6–5

**Energy Expenditure of Different Levels of Amputation**

<table>
<thead>
<tr>
<th>Level of Amputation</th>
<th>Incr'd Metabolic Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syme's</td>
<td>15%</td>
</tr>
<tr>
<td>Traumatic TT BKA</td>
<td>25%</td>
</tr>
<tr>
<td>(short BKA - 40%</td>
<td></td>
</tr>
<tr>
<td>Long BKA - 10%</td>
<td></td>
</tr>
<tr>
<td>Traumatic B/L BKA</td>
<td>41%</td>
</tr>
<tr>
<td>Traumatic TF AKA</td>
<td>60-70%</td>
</tr>
<tr>
<td>Traumatic B/L AKA</td>
<td>&gt;200%</td>
</tr>
<tr>
<td>(260% Huang)</td>
<td></td>
</tr>
<tr>
<td>Traumatic AKA and BKA</td>
<td>118% net cost</td>
</tr>
<tr>
<td>Vascular TT BKA</td>
<td>40%</td>
</tr>
<tr>
<td>Vascular TF AKA</td>
<td>100%</td>
</tr>
</tbody>
</table>

(From Traugh, 1975; Gonzalez 1974; Tan 1998; Huang, 1979.)

#### TABLE 9–9

**Energy Cost of Ambulation for the Amputee**

<table>
<thead>
<tr>
<th>Amputation</th>
<th>% Incr'd E</th>
</tr>
</thead>
<tbody>
<tr>
<td>No prosthesis w/ crutches</td>
<td>50%</td>
</tr>
<tr>
<td>Unilateral BK w/ prothesis</td>
<td>9-28%</td>
</tr>
<tr>
<td>Unilateral AK w/ prothesis</td>
<td>40-65%</td>
</tr>
<tr>
<td>Bilateral BK w/ prothesis</td>
<td>41-100%</td>
</tr>
<tr>
<td>BK plus AK w/ prothesis</td>
<td>75%</td>
</tr>
<tr>
<td>Bilateral AK w/ prothesis</td>
<td>280%</td>
</tr>
<tr>
<td>Unilateral Hip disartic w/ prothesis</td>
<td>82%</td>
</tr>
<tr>
<td>Hemipelvectomy with prothesis</td>
<td>125%</td>
</tr>
</tbody>
</table>

(Flores and Zohman, 1998.)
What is the energy expenditure of “normal” and “pathologic” gait?

Does walking speed affect energy use?

How is the increased (or normal) energy calculated?
1949, Weir

Published “New Method for Calculating Metabolic rate”

In ordinary breathing (at rest) and in open methods of indirect calorimetry, the heat output is equal to the product of the volume of expired air (ventilation) and the calorie value per litre.

This calorie value is almost exactly one-twentieth of the difference in the percentages of oxygen in inspired and expired air.
1955, Passmore and Durnin show

- linear relationship between Energy used and Velocity\(^2\)
- Similar to Kinetic energy
  - \( \approx \frac{1}{2} \text{mass} \times \text{Velocity}^2 \)

Energy calculated from analysis of collected \( \text{O}_2 \) concentrations with Beckman-Pauling oxygen analyzer.

How was this determined?
Energy\textsubscript{w} = C\textsubscript{1} + C\textsubscript{2} \times \text{velocity}\textsuperscript{2}  

Divide each side by velocity

Energy\textsubscript{m} = C\textsubscript{1}/\text{velocity} + C\textsubscript{2} \times \text{velocity}  

\text{(Energy per minute)}

\text{(Energy per meter)}
Fig. 1. Rate of O₂ consumption at rest, standing, walking at CWS and FWS.
Power requirement (rate of \textit{O}_2 \textit{consumption})

- milliliters of O2 consumed per kg body weight per minute

Physiological work (\textit{O}_2 \textit{cost}) during level walking

- Amount of oxygen consumed per kilogram body weight per unit distance.
- Determined by dividing the rate of O2 consumption by the speed of walking.
Pathologic Gait – Joint Fusion

Ankle Fusion:
- 3% greater energy use than normal gait
- 90% gait efficiency

Hip Arthrodesis
- 32% greater energy use than normal gait
- 53% gait efficiency

Table 2
Energy expenditure following hip and ankle fusion and cylinder cast immobilization of the knee*

<table>
<thead>
<tr>
<th></th>
<th>Velocity (m/min)</th>
<th>O₂ rate (ml/kg per min)</th>
<th>O₂ cost (ml/kg per m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ankle fusion</td>
<td>67</td>
<td>12.0</td>
<td>0.17</td>
</tr>
<tr>
<td>Cylinder knee cast</td>
<td>64</td>
<td>12.7</td>
<td>0.20</td>
</tr>
<tr>
<td>Hip fusion</td>
<td>67</td>
<td>14.7</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Pathologic Gait – 3-Point Crutch Gait

Average rate of Energy expenditure was 32% greater than normal

Average Energy cost (per meter) was about double

Likely an underestimate – RER 0.9 – 1.1 (Partial Anaerobic conditions)

**TABLE 1. Energy expenditure of three-point crutch gait in two groups of fracture patients and of normal subjects walking without crutches during 5-min trial**

<table>
<thead>
<tr>
<th></th>
<th>SLC ( n = 17 )</th>
<th>LLC ( n = 8 )</th>
<th>Total ( n = 25 )</th>
<th>Normal walking(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (beats/min)</td>
<td>156 ± 16</td>
<td>145 ± 18</td>
<td>153 ± 17</td>
<td>100 ± 14</td>
</tr>
<tr>
<td>Oxygen rate (ml/kg/min)</td>
<td>15.2 ± 3.1</td>
<td>16.8 ± 2.0</td>
<td>15.7 ± 2.9</td>
<td>11.9 ± 2.3</td>
</tr>
<tr>
<td>Oxygen cost (ml/kg-m)</td>
<td>0.31 ± 0.06</td>
<td>0.35 ± 0.06</td>
<td><strong>0.32 ± 0.06</strong></td>
<td><strong>0.15 ± 0.02</strong></td>
</tr>
<tr>
<td>Respiratory exchange ratio</td>
<td>1.02 ± 0.11</td>
<td>1.04 ± 0.09</td>
<td><strong>1.03 ± 0.10</strong></td>
<td><strong>0.81 ± 0.07</strong></td>
</tr>
<tr>
<td>Speed (m/min)</td>
<td>50 ± 11</td>
<td>50 ± 11</td>
<td><strong>50 ± 11</strong></td>
<td><strong>80 ± 11</strong></td>
</tr>
<tr>
<td>Stride length (m)</td>
<td>1.20 ± 0.14</td>
<td>1.18 ± 0.12</td>
<td><strong>1.19 ± 0.14</strong></td>
<td><strong>1.40 ± 0.18</strong></td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>84 ± 15</td>
<td>84 ± 13</td>
<td><strong>84 ± 14</strong></td>
<td><strong>114 ± 10</strong></td>
</tr>
</tbody>
</table>

\(^a\) Mean and 1 SD.
Aerobic Vs Anaerobic

Aerobic is 19 times more efficient than Anaerobic
Respiratory exchange ratio (RER)

- Ratio of CO₂ produced to O₂ consumption under exercise conditions
- > 0.90 is indicative of anaerobic activity
- > 1 is indicative of severe exercise
Pathologic Gait – Unilateral Amputee
Traumatic vs. Dysvascular

<table>
<thead>
<tr>
<th>Level of Amputation</th>
<th>n</th>
<th>Age (Yrs.)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>Duration of Prosthetic Use (Yrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vascular amputees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above the knee</td>
<td>13</td>
<td>60</td>
<td>1.76</td>
<td>70</td>
<td>1.2</td>
</tr>
<tr>
<td>Below the knee</td>
<td>13</td>
<td>63</td>
<td>1.71</td>
<td>71</td>
<td>1.4</td>
</tr>
<tr>
<td>Syme</td>
<td>15</td>
<td>57</td>
<td>1.69</td>
<td>79</td>
<td>1.1</td>
</tr>
<tr>
<td>Traumatic amputees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above the knee</td>
<td>15</td>
<td>31</td>
<td>1.72</td>
<td>72</td>
<td>10.0</td>
</tr>
<tr>
<td>Below the knee</td>
<td>14</td>
<td>29</td>
<td>1.77</td>
<td>80</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Waters, 1976
Pathologic Gait – Unilateral Amputee
Traumatic vs. Dysvascular

**TABLE II**

<table>
<thead>
<tr>
<th></th>
<th>Velocity (m/min)</th>
<th>Cadence (Steps/min)</th>
<th>Stride Length (m)</th>
<th>Rate of Oxygen Uptake (ml/kg-min)</th>
<th>Net Oxygen Cost (ml/kg-m)</th>
<th>Heart Rate (Beats/min)</th>
<th>Respiratory Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vascular amputees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above the knee</td>
<td>36 ± 15</td>
<td>72 ± 18</td>
<td>1.00 ± 0.20</td>
<td>12.6 ± 2.9</td>
<td>0.35 ± 0.06</td>
<td>126 ± 17</td>
<td>0.96 ± 0.13</td>
</tr>
<tr>
<td>Below the knee</td>
<td>45 ± 9</td>
<td>87 ± 7</td>
<td>1.02 ± 0.13</td>
<td>11.7 ± 1.6</td>
<td>0.26 ± 0.05</td>
<td>105 ± 17</td>
<td>0.82 ± 0.06</td>
</tr>
<tr>
<td><strong>Traumatic amputees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above the knee</td>
<td>52 ± 14</td>
<td>87 ± 13</td>
<td>1.20 ± 0.18</td>
<td>12.9 ± 3.4</td>
<td>0.25 ± 0.05</td>
<td>111 ± 12</td>
<td>0.90 ± 0.07</td>
</tr>
<tr>
<td>Below the knee</td>
<td>71 ± 10</td>
<td>99 ± 9</td>
<td>1.44 ± 0.16</td>
<td>15.5 ± 2.9</td>
<td>0.20 ± 0.05</td>
<td>106 ± 11</td>
<td>0.83 ± 0.08</td>
</tr>
</tbody>
</table>

Waters, 1976
Pathologic Gait – Unilateral Amputee
Traumatic vs. Dysvascular

Increased cadence with shorter stride length is more economical than reduced cadence with longer stride length

Waters, 1976, 1999
Pathologic Gait – Unilateral Amputee Dysvascular

V1 – self-selected/normal walking speed
V2 – Maximum walking speed
Pathologic Gait – Amputee
Traumatic vs. Dysvascular: Increased Energy Cost

- **Traumatic**
  - TT = 25% (range 6% – 45%)
  - TF = 55 - 65% (range 32% – 67%)
  - TT/TT = 40 - 45% (range 35% – 100%)

- **Dysvascular (non-amputee: 25% - 35%)**
  - TT = 50 - 60% (range 22% – 115%)
  - TF = 120% (range 67% – 168%)
  - TT/TT = (range 77% – 105%)

- 3-point Crutch Ambulation – 32% - 48.5% - 2x

Waters, 1976, 1999
Pathologic Gait – Bilateral Amputee

Traumatic

- One subject (age: late 20’s)
- Meningococcemia with purpura fulminas
- B/L transradial and b/l knee disartic
- 2 years later (after rehab and wounds heal)
  - Fitted with stubbies
- 1 year later (after more rehab)
  - Fitted with non-computerized hydraulic knees joints (Mauch)
  - Independent walking w/in 1 year
- 4 years later…..ready to be tested

Perry, 2004
<table>
<thead>
<tr>
<th>Characteristics</th>
<th>3–5 Minutes</th>
<th>19–20 Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stubbies (%% N)</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>Noncomputerized, Mauch SNS</td>
<td>42</td>
<td>45</td>
</tr>
<tr>
<td>C-Legs</td>
<td>70</td>
<td>71</td>
</tr>
</tbody>
</table>

**Table 2: Energy Consumption at Rest and During 20-Minute Energy Cost Test**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Resting</th>
<th>3–5 Minutes</th>
<th>19–20 Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of oxygen consumption (% N)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stubbies</td>
<td>30</td>
<td>94</td>
<td>102</td>
</tr>
<tr>
<td>Noncomputerized, Mauch SNS</td>
<td>26</td>
<td>118</td>
<td>148</td>
</tr>
<tr>
<td>C-Legs</td>
<td>32</td>
<td>124</td>
<td>95</td>
</tr>
<tr>
<td>Oxygen cost (% N)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stubbies</td>
<td>NA</td>
<td>212</td>
<td>225</td>
</tr>
<tr>
<td>Noncomputerized, Mauch SNS</td>
<td>NA</td>
<td>265</td>
<td>304</td>
</tr>
<tr>
<td>C-Legs</td>
<td>NA</td>
<td>167</td>
<td>120</td>
</tr>
<tr>
<td>RER (CO₂/O₂)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stubbies</td>
<td>0.85</td>
<td>0.93</td>
<td>0.88</td>
</tr>
<tr>
<td>Noncomputerized, Mauch SNS</td>
<td>0.83</td>
<td>1.06</td>
<td>1.03</td>
</tr>
<tr>
<td>C-Legs</td>
<td>0.99</td>
<td>1.17</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Abbreviation: NA, not applicable because oxygen cost is based on distance traveled.
Pathologic Gait – Bilateral Amputee

Important

- All studies of bilateral AKA amputees are:
  - Young
  - Not due to Vascular dz (trauma, CA, congenital)
  - Relatively healthy
  - RER > 1.0 (Energy cost may be much higher)

Increased Energy - Walking speed is usually slower

- Per Perry, 2004 (% of normal, 1 subject): 120% - 304%
- Per Huang, 1979: (4 subjects) 300% greater energy cost per unit distance
- Per Corcoran et al, 1994: (2 subjects) 186% higher than predicted for normal
- Per Hoffman, 1997: (5 subjects) 55% - 83% higher aerobic demands

Range - 83% - 304% (that’s a rather large range)
Pathologic Gait – Bilateral Amputee

- **What’s next?**
  - More studies to further detail energy cost ??? - Probably No
  - Very rare that a bilateral, trans-fem, dysvascular patient walks

- **Why does any of this matter?**
  - To educate/prepare your patients and to give perspective for future activity
  - To caution (scare) them to monitor their stump and contra-lateral foot skin
  - Estimated 50% 5-year mortality rate for dysvascular amputees
  - Of those still alive after 5 years, 50% will have had a second amputation
Pathologic Gait – Amputee

Increased Energy Cost
(Approximations that you should remember)

- **Traumatic**
  - TT = 25%
  - TF = 65%
  - TT/TT = 45%

- **Dysvascular**
  - Multiply above: x1.5 - x2

- **Bilateral Transfemoral**
  - Traumatic – 100 – 150 % (at least)
  - Dysvascular – very unlikely to be ambulating

- **3-point Crutch Ambulation ~ 50%**

Waters, 1976, 1999
Take Home Points

“What I think you should know for patient care and your boards”

- **Skin Care**
  - Optimize hygiene
  - Proper socket fit (Volume mgmt - ACE wrap with Fig 8 or shrinker)

- **Phantom Pain**
  - Complex, exact mechanism unknown
  - No perfect treatment, but with time usually improves or resolves
  - Gabapentin (and likely Morphine) - good options for treatment

- **Energy cost of Amputee Gait (see previous slide)**
  - Increases with level of amputation, compensated slower walking speeds
  - More proximal amputation level estimates may be low
  - unaccounted anaerobic activity