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.
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

Dermatologic Conditions

- Dermatitis (most common in traumatic)
- Ulcer/pressure sites (most common in vascular disease)
- Verrucous Hyperplasia
- Fungal/Bacterial Infection
- Callus
- Cyst
## Dermatologic Conditions – Traumatic

<table>
<thead>
<tr>
<th>Dermatologic condition</th>
<th>Total patients Number (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant contact dermatitis</td>
<td>32 (30.4)</td>
</tr>
<tr>
<td>Allergic contact dermatitis</td>
<td>25 (23.9)</td>
</tr>
<tr>
<td>Infected infant 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>Epidermolysis cyst</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>Keloid</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td>Haematomata</td>
<td>1 (0.9)</td>
</tr>
<tr>
<td>Total</td>
<td>105 (100)</td>
</tr>
</tbody>
</table>

## Dermatologic Conditions – PVD

<table>
<thead>
<tr>
<th>Patient demographic and amputation information for five most common skin problems</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Table 1</strong></td>
</tr>
<tr>
<td><strong>Ulcér</strong></td>
</tr>
<tr>
<td><strong>Irritation</strong></td>
</tr>
<tr>
<td><strong>Inclusion Cyst</strong></td>
</tr>
<tr>
<td><strong>Callus</strong></td>
</tr>
<tr>
<td><strong>Verrucous Hyperplasia</strong></td>
</tr>
<tr>
<td><strong>All Skin Problems</strong></td>
</tr>
<tr>
<td><strong>Age</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Age at amputation</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Transtibial</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Reason for amputation</strong></td>
</tr>
<tr>
<td>Peripheral vascular disease ± diabetes, diabetes</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td><strong>Trauma</strong></td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Female</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:
Ulcer/pressure sores

Dermatologic Conditions:
Dermatitis

http://www.dermnetnz.org
Choke Stump Syndrome

Dermatologic Conditions:
Verrucous Hyperplasia
Dermatologic Conditions: Fungal Infection

http://www.dermnetnz.org

Etiology of common Skin problems

TABLE 2 Recorded etiology of the five most common skin problems

<table>
<thead>
<tr>
<th></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>Prosthesis</td>
<td>117 (83.9%)</td>
<td>74 (79.5%)</td>
<td>65 (81.0%)</td>
<td>57 (95.0%)</td>
<td>43 (91.5%)</td>
<td>442 (85.7%)</td>
</tr>
<tr>
<td>Socks</td>
<td>23 (16.3%)</td>
<td>15 (16.7%)</td>
<td>5 (6.3%)</td>
<td>8 (13.4%)</td>
<td>5 (10.5%)</td>
<td>67 (12.7%)</td>
</tr>
<tr>
<td>airy limb</td>
<td>4 (2.3%)</td>
<td>6 (6.5%)</td>
<td>7 (8.9%)</td>
<td>2 (3.3%)</td>
<td>1 (2.1%)</td>
<td>21 (4.0%)</td>
</tr>
<tr>
<td>± sweating</td>
<td>7 (4.9%)</td>
<td>2 (2.2%)</td>
<td>0 (0.0%)</td>
<td>1 (1.7%)</td>
<td>4 (8.6%)</td>
<td>18 (3.4%)</td>
</tr>
<tr>
<td>Weight change</td>
<td>6 (4.3%)</td>
<td>6 (6.5%)</td>
<td>1 (1.3%)</td>
<td>0 (0.0%)</td>
<td>1 (2.1%)</td>
<td>17 (3.2%)</td>
</tr>
<tr>
<td>Limb shape</td>
<td>6 (4.3%)</td>
<td>6 (6.5%)</td>
<td>1 (1.3%)</td>
<td>0 (0.0%)</td>
<td>1 (2.1%)</td>
<td>17 (3.2%)</td>
</tr>
<tr>
<td>Other</td>
<td>22 (15.6%)</td>
<td>6 (6.5%)</td>
<td>4 (5.0%)</td>
<td>1 (1.7%)</td>
<td>1 (2.1%)</td>
<td>50 (9.5%)</td>
</tr>
</tbody>
</table>

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>Verrueous Hyperplasia (n = 47)</th>
<th>All Skin Problems (n = 528)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prosthetic adjustment or new prosthesis</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>Modify prosthetic use</td>
<td>33 (22.7%)*</td>
<td>2 (2.3%)*</td>
<td>9 (11.4%)</td>
<td>3 (5.0%)</td>
<td>3 (6.4%)</td>
<td>57 (10.0%)</td>
</tr>
<tr>
<td>Sock change</td>
<td>25 (17.7%)</td>
<td>22 (23.0%)</td>
<td>7 (8.9%)</td>
<td>8 (13.1%)</td>
<td>12 (25.5%)</td>
<td>109 (20.6%)</td>
</tr>
<tr>
<td>Medication (topical and/or oral)</td>
<td>60 (42.2%)</td>
<td>7 (7.6%)*</td>
<td>13 (16.4%)*</td>
<td>6 (10.8%)*</td>
<td>7 (14.2%)</td>
<td>141 (26.7%)</td>
</tr>
<tr>
<td>Cream (nonmedicinal)</td>
<td>11 (7.8%)</td>
<td>8 (8.6%)</td>
<td>16 (20.2%)</td>
<td>12 (20.4%)</td>
<td>7 (14.9%)</td>
<td>71 (13.4%)</td>
</tr>
<tr>
<td>Dressing</td>
<td>16 (11.2%)</td>
<td>4 (4.3%)*</td>
<td>8 (10.2%)</td>
<td>5 (8.3%)</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%)</td>
<td>2 (3.3%)</td>
<td>1 (2.1%)</td>
<td>44 (8.3%)</td>
</tr>
</tbody>
</table>

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

**Gel Liners**

Silicone vs. Urethane
Pressure Sensitive Areas

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

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
- Non-Pharmacological
  - Mirror therapy
  - Biofeedback
  - Mental Imagery
  - Hypnosis
  - Meditation
- Optimal socket fit / proper fit
- 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 compensate for missing muscles for balance and propulsion.

### 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></td>
<td>(short BKA - 40%</td>
</tr>
<tr>
<td></td>
<td>Long BKA - 10%)</td>
</tr>
<tr>
<td>Traumatic R/L BKA</td>
<td>41%</td>
</tr>
<tr>
<td>Traumatic TF AKA</td>
<td>60-70%</td>
</tr>
<tr>
<td>Traumatic R/L AKA</td>
<td>&gt;200%</td>
</tr>
<tr>
<td></td>
<td>(260% Huang)</td>
</tr>
<tr>
<td>Traumatic AKA and BKA</td>
<td>118% net cost</td>
</tr>
<tr>
<td>Vascular TT BKA</td>
<td>45%</td>
</tr>
<tr>
<td>Vascular TF AKA</td>
<td>100%</td>
</tr>
</tbody>
</table>

(From Traugh, 1975; Gonzalez 1974; Tan 1998; Huang, 1978.)

### 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/ prosthesis</td>
<td>9-28%</td>
</tr>
<tr>
<td>Unilateral AK w/ prosthesis</td>
<td>40-65%</td>
</tr>
<tr>
<td>Bilateral BK w/ prosthesis</td>
<td>41-100%</td>
</tr>
<tr>
<td>BK plus AK w/ prosthesis</td>
<td>75%</td>
</tr>
<tr>
<td>Bilateral AK w/ prosthesis</td>
<td>280%</td>
</tr>
<tr>
<td>Unilateral Hip disartic w/ prosthesis</td>
<td>82%</td>
</tr>
<tr>
<td>Hemipelvectomy with prosthesis</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?

---

**Energy Expenditure - Approximation**

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.
Energy Expenditure - Normal

- 1955, Passmore and Durnin show linear relationship between Energy used and Velocity
- Similar to Kinetic energy $E = \frac{1}{2} \text{mass} \times \text{Velocity}^2$
- Energy calculated from analysis of collected O$_2$ concentrations with Beckman-Pauling oxygen analyzer.
- How was this determined?

Energy $w = C_1 + C_2 \times \text{Velocity}^2$ (Energy per minute)

Divide each side by velocity

Energy $m = \frac{C_1}{\text{velocity}} + C_2 \times \text{velocity}$ (Energy per meter)
### Energy-Speed Relationship Tables

#### TABLE 3. Energy expenditure of customary normal, slow, and fast walking

<table>
<thead>
<tr>
<th>Age Group (yr)</th>
<th>Heart rate (beat/min)</th>
<th>Rate O₂ consumption (ml/kg-min)</th>
<th>O₂ Cost (ml/kg-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Children (6–12)</td>
<td>F</td>
<td>109.3^*</td>
<td>120.6^*</td>
</tr>
<tr>
<td>M</td>
<td>111.3^*</td>
<td>122.6^*</td>
<td>105.1^*</td>
</tr>
<tr>
<td>T</td>
<td>119.1^*</td>
<td>130.9^*</td>
<td>113.7^*</td>
</tr>
<tr>
<td>Teens (13–19)</td>
<td>F</td>
<td>102.7^*</td>
<td>114.1^*</td>
</tr>
<tr>
<td>M</td>
<td>104.2^*</td>
<td>116.7^*</td>
<td>100.1^*</td>
</tr>
<tr>
<td>T</td>
<td>112.1^*</td>
<td>123.6^*</td>
<td>106.8^*</td>
</tr>
<tr>
<td>Adults (20–59)</td>
<td>F</td>
<td>103.2^*</td>
<td>115.7^*</td>
</tr>
<tr>
<td>M</td>
<td>105.0^*</td>
<td>117.5^*</td>
<td>101.3^*</td>
</tr>
<tr>
<td>T</td>
<td>114.9^*</td>
<td>127.3^*</td>
<td>113.1^*</td>
</tr>
<tr>
<td>Seniors (60–80)</td>
<td>F</td>
<td>105.8^*</td>
<td>120.4^*</td>
</tr>
<tr>
<td>M</td>
<td>108.3^*</td>
<td>123.1^*</td>
<td>104.9^*</td>
</tr>
<tr>
<td>T</td>
<td>119.7^*</td>
<td>134.7^*</td>
<td>118.5^*</td>
</tr>
</tbody>
</table>

* Values are means and 1 SD.

* Significant (p < 0.05) difference between male and female subjects.

* Significant (p < 0.05) difference between preceding value in younger age group.

(Waters, 1988)

---

**Fig. 1. Rate of O₂ consumption at rest, standing, walking at CWS and FWS.**
Power requirement (rate of O₂ consumption)
- milliliters of O₂ consumed per kg body weight per minute

Physiological work (O₂ 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

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Energy expenditure following hip and ankle fusion and cylinder cast immobilization of the knee*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Velocity (m/min)</td>
</tr>
<tr>
<td>Ankle fusion</td>
<td>67</td>
</tr>
<tr>
<td>Cylinder knee cast</td>
<td>64</td>
</tr>
<tr>
<td>Hip fusion</td>
<td>67</td>
</tr>
</tbody>
</table>

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

- Hip Arthrodesis
  - 32% greater energy use than normal gait
  - 53% gait efficiency
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 |
|-----------------|------------|-----------------|-----------------|
|                 | SLC        | LLC             | Total           | Normal walking* |
| Heart rate      | n = 17     | n = 8           | n = 25          |                |
| (beats/min)     | 156 ± 16   | 145 ± 18        | 153 ± 17        | 100 ± 14       |
| Oxygen rate     | 15.2 ± 3.1 | 16.8 ± 2.0      | 15.7 ± 2.9      | 11.9 ± 2.3     |
| (ml/kg-min)     |            |                |                |                |
| Oxygen cost     | 0.31 ± 0.06| 0.35 ± 0.06     | 0.32 ± 0.06     | 0.15 ± 0.02    |
| ml/kg/m         |            |                |                |                |
| Respiratory     | 1.02 ± 0.11| 1.04 ± 0.09     | 1.03 ± 0.10     | 0.81 ± 0.07    |
| exchange ratio  |            |                |                |                |
| Speed (m/min)   | 50 ± 11    | 50 ± 11         | 50 ± 11         | 80 ± 11        |
| Stride length (m)| 1.20 ± 0.14| 1.18 ± 0.12     | 1.19 ± 0.14     | 1.40 ± 0.18    |
| Cadence (steps/min)| 84 ± 15 | 84 ± 13         | 84 ± 14         | 114 ± 10       |

* Mean and 1 SD.
Aerobic Vs Anaerobic

\[ \text{Aerobic: } \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \xrightarrow{\text{oxygen, many steps}} 6\text{CO}_2 + 6\text{H}_2\text{O} + 38 \text{ATP} \]

\[ \text{Anaerobic: } \text{C}_6\text{H}_{12}\text{O}_6 \xrightarrow{\text{oxygen, fewer steps}} 2\text{Lactic Acids} + 2\text{ATP} \]

Aerobic is 19 times more efficient than Anaerobic

Respiratory exchange ratio (RER)

- Ratio of CO\(_2\) produced to O\(_2\) 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 I

<table>
<thead>
<tr>
<th>Subjects</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>Unrestrained Walking in Amputees (Mean Values and Standard Deviation)</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>Velocity (m/min)</td>
<td>Cadence (Steps/min)</td>
<td>Stride Length (m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vascular amputees</td>
<td>Above the knee</td>
<td>36</td>
<td>±15</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Below the knee</td>
<td>45</td>
<td>±9</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>Syme</td>
<td>52</td>
<td>±14</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>Traumatic amputees</td>
<td>Above the knee</td>
<td>52</td>
<td>±14</td>
</tr>
<tr>
<td></td>
<td>Below the knee</td>
<td>71</td>
<td>±19</td>
<td>99</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** = 56% (range 32% – 67%)
  - **TT/TT** = 41% (range 35% – 100%)

- **Dysvascular (non-amputee: 25% - 35%)**
  - **TT** = 60% (range 22% – 115%)
  - **TF** = 118% (range 67% – 168%)
  - **TT/TT** = (range 77% – 105%)

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

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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

---

Waters, 1976, 1999

Perry, 2004
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
  - 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%
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

Works Cited

- Perry, Jacqueline, et al. "Energy expenditure and gait characteristics of a bilateral amputee walking with C-Leg prostheses compared with stubby and conventional articulating prostheses." Archives of physical medicine and rehabilitation 85.10 (2004): 1711-1717.
Works Cited

- http://www.physio-pedia.com/Prosthetics
- http://books.elsevier.com.br/special_topics/respiration.htm
- http://amazonaws.com/thoughts2/eimages/la-c/la-90/dle9x/9a36c6a689b95302-520.jpg