Traumatic Amputation: Where are We Going with Research?

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University of Miami School of Medicine
Department of Physical Therapy
1930’s and 1940’s
Sports for Amputees

Race Walkers Britain

Major MP Leahy
Traditional Decision-Making Process

- Experience and Judgment
- Patient Preference
- Clinical Circumstance
Evidence-Based Decision-Making Process

Scientific Evidence

Experience and Judgment

Patient Preference

Clinical Circumstance
Oxford Centre of Evidence-based Medicine Levels of Evidence (2001)

1) Randomized Control Trials
2) Systematic Review (with homogeneity) of cohort studies or Outcomes research
3) Systematic Review of case-control studies or individual case-controlled study
4) Case-series
5) Expert opinion or consensus without explicit critical appraisal
Surgical Procedures and Outcomes
Posterior Flap  Ertl Osteoplastic Procedure
Ankle Disarticulation or Long Transtibial Amputation
Knee Disarticulation Amputation
Basic Components of TTA Prosthesis

- suspension
- socket
- shank or pylon
- foot-ankle assembly
Prosthetic Socket Comparison

PTB  PTB SC  PTB SC/SP
Pin and Lock Doffing
One-way Suction Valve System
Negative Pressure Sockets
Socket Design and Wound Healing
Liner Sleeve Functions

- Absorption of shear stress
- Dispersal of Compressive forces
- Suspension of prosthesis

**Shear Stress** - The intensity of force parallel to the surface on which it acts.

**Compressive Force** - A force that tends to shorten a material.
Quadrilateral Socket
Ischial Containment Socket
## TFA Socket Designs

- **Norm v. IC**
  - % Change: +18%
  - Level Sig.: P<0.01

- **Norm v. Quad**
  - % Change: +28%
  - Level Sig.: P<0.01

- **IC v. Quad**
  - % Change: +12%
  - Level Sig.: n/s

- **Norm v. IC**
  - % Change: +27%
  - Level Sig.: P<0.01

- **Norm v. Quad**
  - % Change: +42%
  - Level Sig.: P<0.01

- **IC v. Quad**
  - % Change: +20%
  - Level Sig.: P<0.01

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*Gailey et al 1993*
TFA Suspensions
CAD-CAM Fabrication
Consensus suggests that sockets are the most critical component of a prosthesis.

- Little Evidence suggesting differences between sockets
- No standardized method of assessment
- No evidence to determine functional value of the socket
- No evidence concerning fabrication techniques
Prosthetic Knee Systems
Hydraulic SNS
1968 Hans Mauch

Components:
- Stance Adjustment
- Selector Switch
- Cylinder
- Piston Rod
- Pendulum
- Counterweight
- Control Insert
- Spring
- Valve (Open)
- Control Insert

Illustration shows the internal components of a hydraulic system.
Microprocessor Knees
Adaptive C-Leg
Rheo Knee
Victhom Knee
1861 JE Hanger
Lost leg in Civil War
feet using rubber bumpers
1958 SACH Foot designed by Howard Eberhart & Charles Radcliffe
Seattle Foot and Carbon Copy II
Flex Foot
Flex Foot vs. SACH

- The Flex Foot had significantly longer late stance phase and a longer duration of early and late swing with the uninvolved limb. Macfarlane, Nielsen, Shurr, Meier 1991

- The difference of the aft shear impulse on the prosthetic side and the fore shear impulse on the sound side showed the smallest value for the Flex Foot and the greatest value for the SACH foot. Lehman J, Price R, Boswell-Bessette S, Dralle A, Questad K, deLateur B 1993
Symmetry of Gait

• Flex Foot asymmetries were less pronounced than with SACH foot. Schneider, Hart et al. 1993

• A longer stride was noted with the Flex Foot with fewer steps per minute than with the SACH foot, yet walked at similar speed. Macfarlane, Nielsen, Shurr, Meier 1991
Shock Absorption & Torsion Control
Tests and Measures of Prosthetic Components
Amputee Walking Energy Cost

O₂ COST (ml/kg·meter)

- TP
- HD
- TF
- KD
- TT
- Normal

SPEED (meters/minute)

- TP
- HD
- TF
- KD
- TT
- Normal

AMPUTATION LEVEL

Waters, 1992
<table>
<thead>
<tr>
<th>Level / Cause</th>
<th>VO2</th>
<th>Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTA: Trauma</td>
<td>15%</td>
<td>10%</td>
</tr>
<tr>
<td>TTA: Vascular</td>
<td>30%</td>
<td>30%</td>
</tr>
<tr>
<td>TFA: Trauma</td>
<td>40%</td>
<td>20%</td>
</tr>
<tr>
<td>TFA: Vascular</td>
<td>65%</td>
<td>40%</td>
</tr>
</tbody>
</table>
Dynamic vs. Nondynamic Prosthetic Feet

Only a 4% difference in energy expenditure exists between dynamic response and non dynamic response prosthetic feet.

Gailey 1994 / Perry 1993 / Lehmann 1993
Effect of Prosthetic Weight


• Function may have greater value than reduced weight.
Factors Influencing the Metabolic Cost of Walking

- Length of the residual limb
  - Between levels of amputation
  - Within levels of amputation

- Cause of amputation
  - Traumatic vs. Vascular

- Age
  - Linear regardless of disability
Dynamic Response Feet Have a Limited Mechanical Energy Return

- SACH Foot: 39%
- Seattle Foot: 71%
- Flex Foot: 89%
- Human Foot: 246%

Gitter et al, 1991

- SACH Foot: 20%
- Flex Foot: 70%

Schneider, Hart, Zernike, Setoguchi and Oppenheim 1993
Gait Lab Analysis
Posterior Pelvic Rotation
COM Remains Over Heel
## Traditional Prosthetic Training vs. Resistive Gait Training

Yigiter K 2002

<table>
<thead>
<tr>
<th></th>
<th>Resist. Gait</th>
<th>Traditional</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt bearing%</td>
<td>16.59 ± 8.87</td>
<td>8.35 ± 3.47</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Stride Length</td>
<td>7.86 ± 3.89</td>
<td>1.32 ± 0.56</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Amp. Side</td>
<td>3.88 ± 1.86</td>
<td>5.42 ± 2.27</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Step Length (cm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sound Side Step Length</td>
<td>11.74 ± 3.62</td>
<td>6.74 ± 2.65</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Step Width</td>
<td>4.72 ± 2.80</td>
<td>2.60 ± 1.04</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>SSCG (step/ min)</td>
<td>16.44 ± 4.58</td>
<td>9.96 ± 2.26</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Self selected cadence</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FG (step/ min)</td>
<td>21.6 ± 4.36</td>
<td>14.72 ± 2.46</td>
<td>p&lt;.05</td>
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<tr>
<td>Fast cadence</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Velocity (cm/ s)</td>
<td>14.72 ± 3.81</td>
<td>9.60 ± 3.60</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>SL/ LEL (stride length/ limb length)</td>
<td>0.08 ± 0.01</td>
<td>0.02 ± 0.03</td>
<td>p&lt;.05</td>
</tr>
<tr>
<td>Abducted Prosthetic Limb</td>
<td>Adducted Sound Limb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------------</td>
<td></td>
<td></td>
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<tr>
<td>Increased walking width may be the result of hip abductor weakness requiring greater lateral stability.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- James 1973 / Jaegers 1995</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>In the frontal plane the COM remains over the sound limb in children.</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>- Engsburg 1992</td>
<td></td>
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</table>
Sound Side Knee Degeneration

Patellofemoral Arthritis

- 63% TFA
- 41% TTA
- 22% nonamputee
  - Hungerford 1975

Similar findings
Burke 1978
Powers 1994
Self-Report Assessment Instruments Applied to LLA

- **Amputee Activity Survey** *(Day, 1981)*
- **Prosthetic Profile of the Amputee** *(Gauthier-Gagnon, 1992)*
- **SF-36 Health Status Profile** *(McHorney, 1993)*
- **Prosthesis Evaluation Questionnaire** *(Legro, 1998)*
- **Orthotics and Prosthetics National Office Outcome Tool** *(Hart, 1999)*
Amputee Activity Survey (AAS) (Day 1981)

- Administered to 2,400 amputees.
- Subjective assessment of daily activity level and step rate.
- Amputees with higher AAS scores walked more.
- Reliability and validity never statistically addressed.
Prosthetic Profile of the Amputee
(Gauthier-Gagnon, 1992)

- PPA has shown to have moderate to good reliability and validity in determining factors that are potentially related to prosthetic use by the amputee after discharge from rehabilitation.

- The PPA-LCI was prone to high ceiling effects (40%) that would limit its ability to detect improvement. (Miller WC et al. 2002)

- The questionnaire is lengthy
SF-36 (Smith 1995)

- SF-36 may provide insight into many areas of functioning, but does not appear to be a good predictive tool nor is it designed specifically for the amputee.

- The SF-36 appears to have a floor effect for lower functioning amputees.
Prosthesis Evaluation Questionnaire (PEQ) (Legro 1998)

- 41 questions
- Prosthesis Function, Mobility, Psychosocial Experiences and Well being
- Evaluate the prosthesis and life with the prosthesis
- Moderate correlations with standard tests
Performance Based Assessment Instruments

- **Functional Independence Measure (Davidoff, 1990)**
- **Functional Ambulation Profile (Nelson, 1974)**
- **Prosthetic Goal Achievement Test**
- **Barthel’s Index (Mahoney, 1965)**
Functional Independence Measure (FIM)

- Muecke’s (1992) modified amputation FIM sub-score eight ambulation activities
- Low scores at admission demonstrated greater improvement at discharge
- High scores at admission resulted in perfect scores by discharge
FIM’s Ability to Discriminate Level of Function in Amputees

- FIM was unsuccessful in predicting prosthetic rehabilitation \textit{Leung, 1996}

- Limited portion of FIM correlated with the use of a prosthesis according to Houghton scale 1992

- No significant differences between vascular and traumatic amputees \textit{Melchiorre, 1996}
A comparison of three measures of progress in early lower limb amputee rehabilitation.
(Panesar BS et al. 2001)

- In vascular amputees, the FIM showed significant change between admission and discharge ($p < 0.0001$) but only the AAS showed change between discharge and follow-up ($p < 0.0001$).
Six-minute Walk (Cooper, 1968)

- Cooper (1968) first introduced the 12-minute run performance test.
- McGavin et al. (1976) 12-minute walk test to measure exercise tolerance in chronic bronchitis.
- The 12-minute walk test was found to be a useful and measurable indication of exercise tolerance.
- Butland (1982) had a series of elderly patients perform the 3, 6 and 12-minute walk test concluded that the 6-minute walk test is the sensible compromise.
Two Minute Walk Test
(Brooks D et al 2001)

- 2-minute walk test was responsive to change with rehabilitation in LLA
- Measured at discharge and follow-up: 2-minute walk test showed adequate correlation with measures of physical functioning (SF-36 and Houghton score) and prosthetic use in this population.
Activities-specific Balance Confidence Scale
(Miller WC, et al. 2003)

- ABC Scale (ICC = .91)
- 2MWT (ICC = .72)
- TUG (ICC = -.70)
- The ABC Scale discriminated between all groups except those based on amputation level.
Physical, mental, and social predictors of functional outcome in unilateral lower-limb amputees. (Schoppen et al 2003)

- For the SIPS-68 scores, age, comorbidity, 1-leg balance, and the 15-word test predicted functional outcome in 69% of amputees.
- For the GARS score, age, 1-leg balance, and the 15-word test predicted functional outcome in 64%.
- For the TUG test (mean, 23.9s), age and 1-leg balance predicted functional outcome in 42% of amputees.
- After correction for age, the only significant predictor for prosthetic use was 1-leg balance.
Amputee Mobility Predictor

**AMPnoPRO:** performed without a prosthesis

**AMPPRO:** performed with a prosthesis

20 item performance-based measure
Amputee Mobility Predictor

- Determine Functional Level
- Predict the distance walked in 6 min.
- Determine the contribution of functional ability
- Determine what physical systems need to be addressed
- Measure change over time
# Means for Variables

<table>
<thead>
<tr>
<th>MFCL</th>
<th>6-min (meters)</th>
<th>AAS</th>
<th>AMPno PRO</th>
<th>AMP PRO</th>
</tr>
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<tbody>
<tr>
<td><strong>K1 Household</strong></td>
<td>49.86</td>
<td>-36.05</td>
<td>15.37</td>
<td>25.0</td>
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<tr>
<td><strong>K2 Limited Community</strong></td>
<td>189.89</td>
<td>-7.51</td>
<td>25.28</td>
<td>34.65</td>
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<tr>
<td><strong>K3 Community Ambulator</strong></td>
<td>298.64</td>
<td>11.23</td>
<td>31.36</td>
<td>40.5</td>
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<tr>
<td><strong>K4 High Activity</strong></td>
<td>419.76</td>
<td>27.77</td>
<td>38.49</td>
<td>44.67</td>
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## Estimated AMP Cut Scores

<table>
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<tr>
<th>AMPno</th>
<th>AMP</th>
<th>K0</th>
<th>K1</th>
<th>K2</th>
<th>K3</th>
<th>K4</th>
</tr>
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<tbody>
<tr>
<td>AMPno</td>
<td>AMP</td>
<td>0-8</td>
<td>9-20</td>
<td>21-28</td>
<td>29-36</td>
<td>37-43</td>
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<tr>
<td>PRO</td>
<td></td>
<td>N/ A</td>
<td>15-26</td>
<td>27-36</td>
<td>37-42</td>
<td>43-47</td>
</tr>
</tbody>
</table>
The Base Equation

\[ Y(6 \text{ minute distance}) = -12.239 - 1.226 \text{ (age)} + 7.956 \text{ (AMPnoPRO)} - 6.235 \text{ (comorbidity score)} + 0.129 \text{ (time after amp.)} \]
4. Arises from a chair

Unable without help = 0
Able, uses arms/assist device = 1
Able, without using arms = 2

**System Challenged**
- Organizational skills
- Momentum strategies
- Dynamic balance
- Concentric postural extensors
4. Arises from a chair

- Organizational planning
- Seated forward weight shifts for momentum
- Sit-to-stand progression
- Concentric strengthening LE
- Partial wall squats to full wall squats
Variables related to functional outcomes:

- Institutionalization
- Residual limb pain
- Psychological profile
- Motivation

- Perception of health
- Mobility
- Ulcers
- Prosthetic use
- Self care

- Level of amputation has not been consistently found to be representative of functional capacity.
What do we need:

- Determine the appropriate measurement tools
- Determine the appropriate level of evidence-based research
- Identify research programs that will have the most significant impact on the greatest number of amputees
- Create a mechanism for continued research to address future advancements in prosthetics and amputee rehabilitation
<table>
<thead>
<tr>
<th>Name</th>
<th>Time</th>
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<tbody>
<tr>
<td>Maurice Green</td>
<td>9.79</td>
</tr>
<tr>
<td>Florence Joyner</td>
<td>10.49</td>
</tr>
<tr>
<td>Marlon Shirley</td>
<td>10.89</td>
</tr>
<tr>
<td>Joe Gaetani</td>
<td>12.22</td>
</tr>
<tr>
<td>Earle Conner</td>
<td>12.56</td>
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