Traumatic Amputation: Where are We Going with Research?

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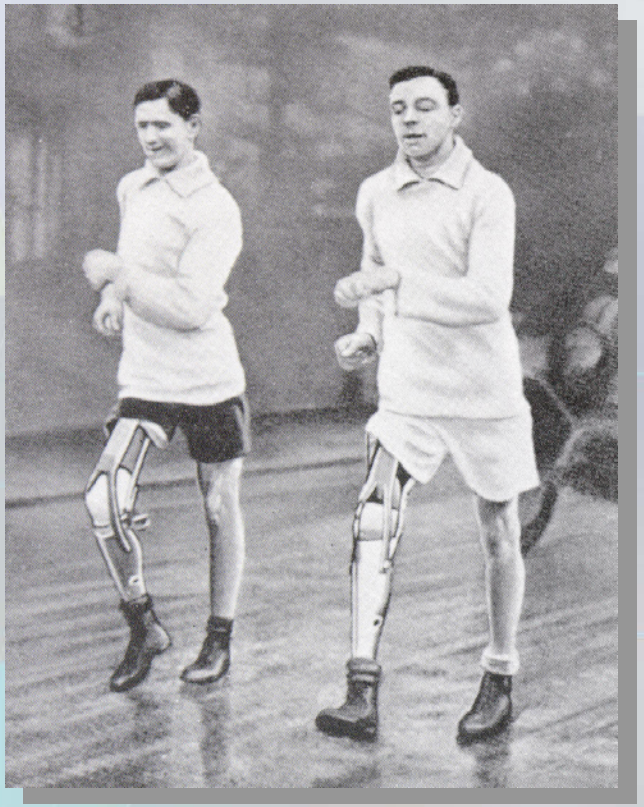
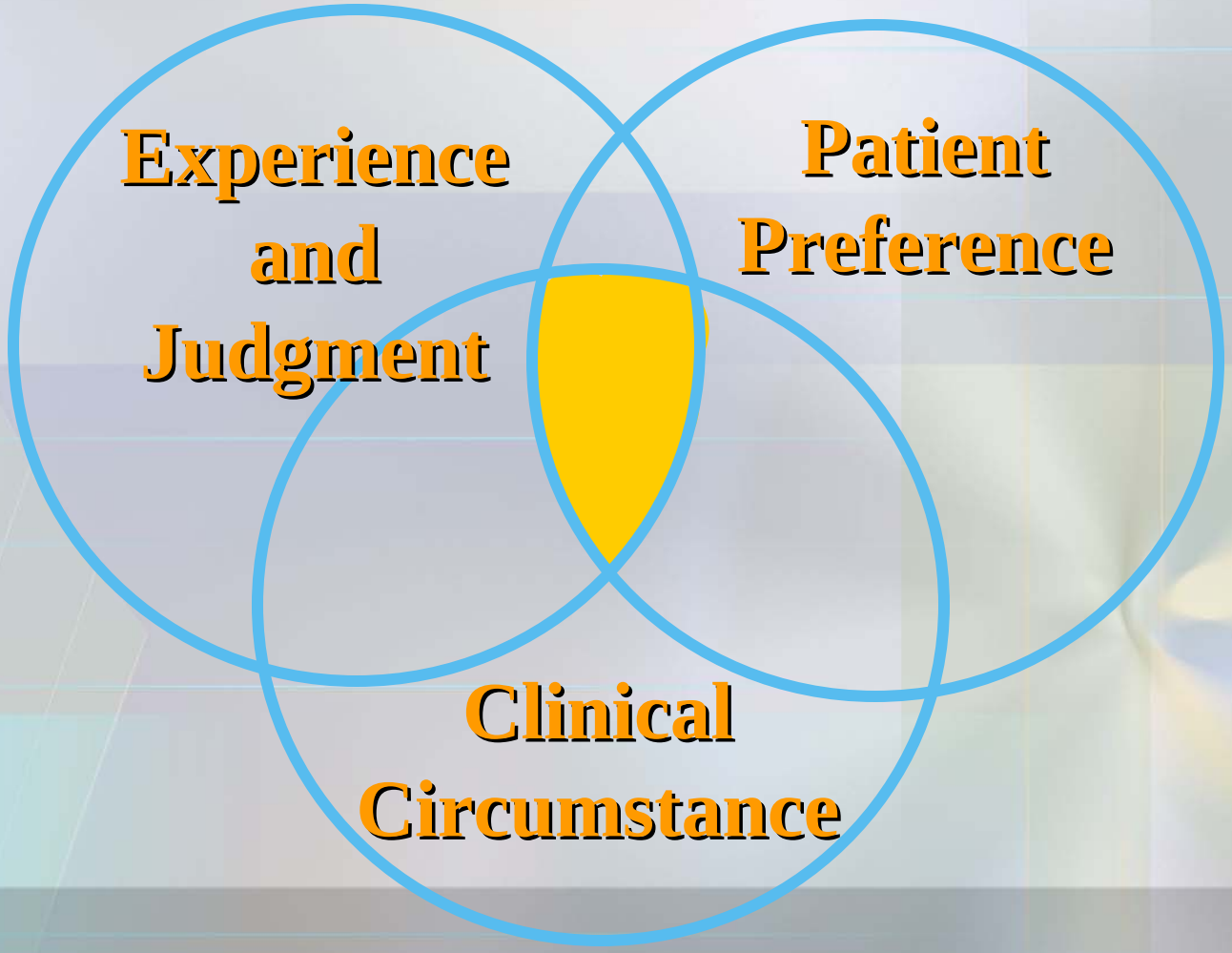
1930's and 1940's Sports for Amputees



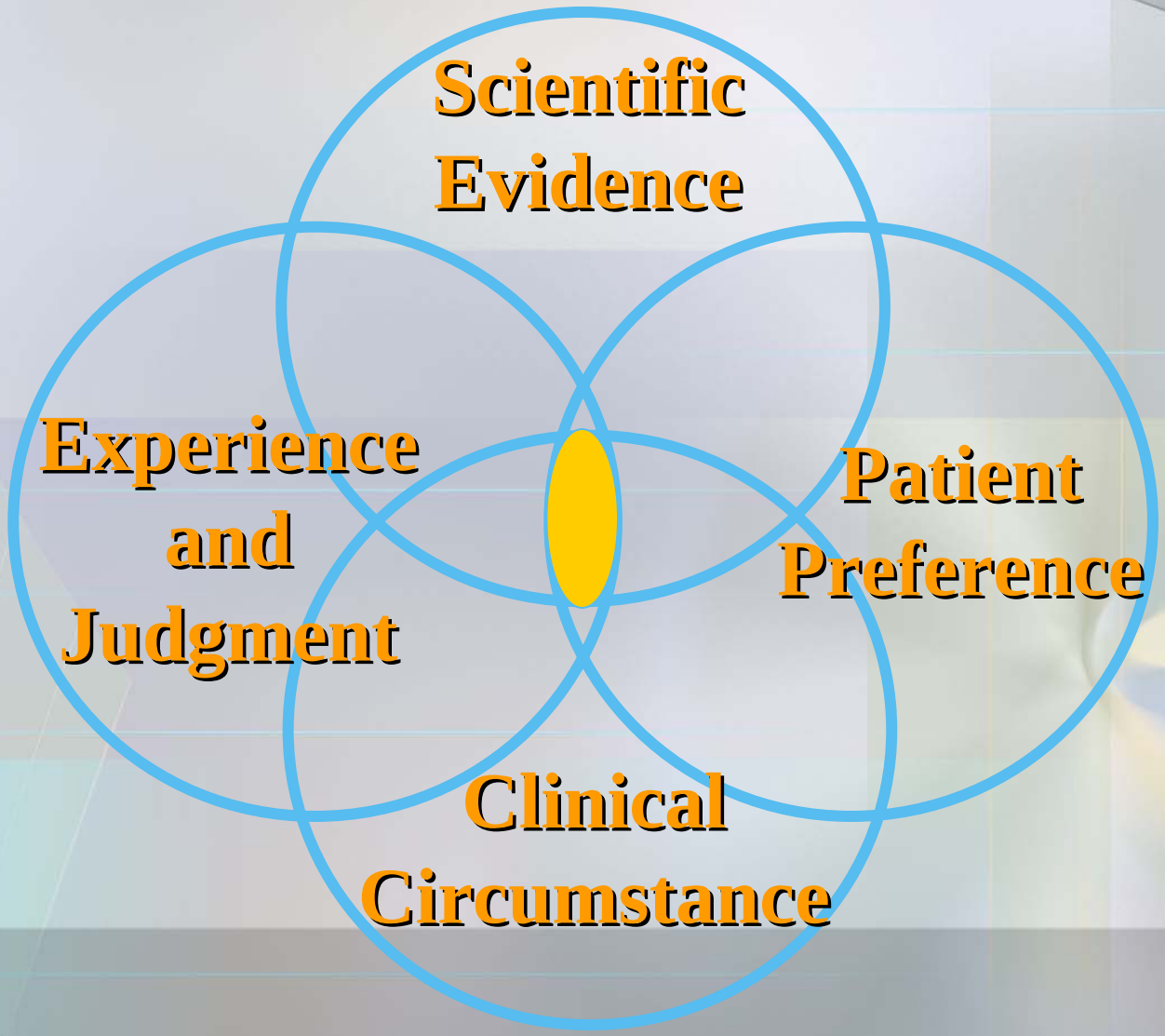
Race Walkers Britain

Major MP Leahy

Traditional Decision-Making Process



Evidence-Based Decision-Making Process



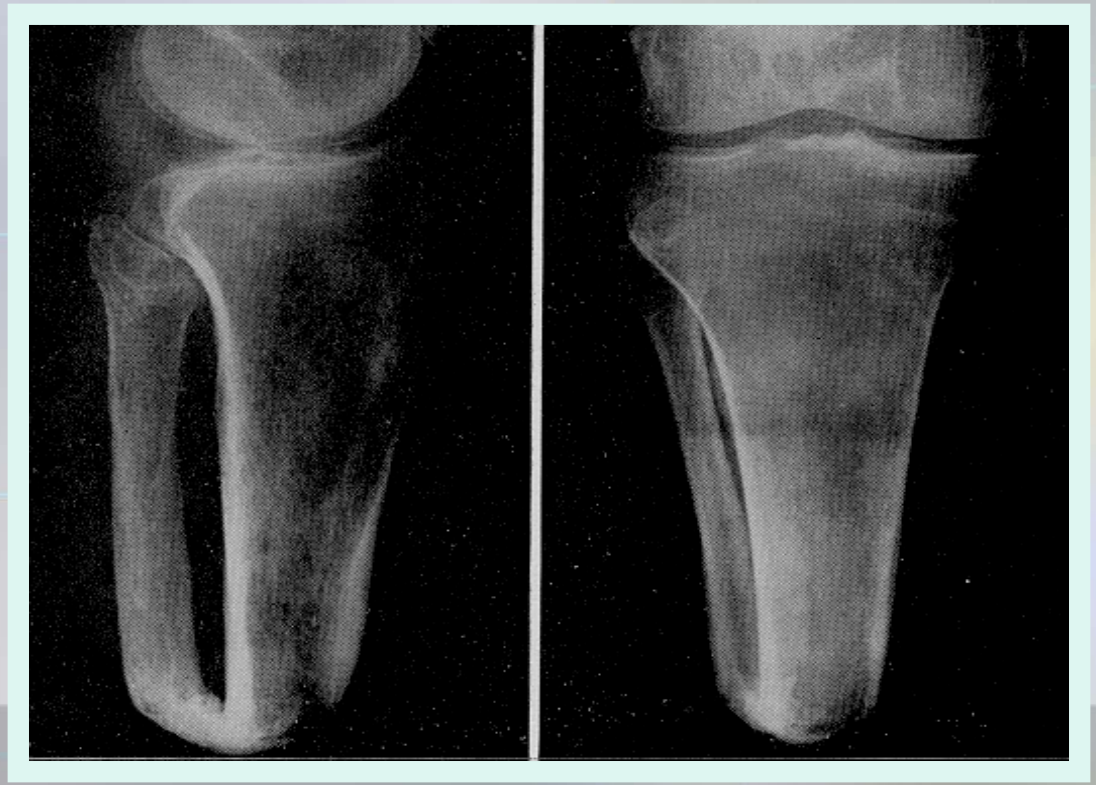
Oxford Centre of Evidence-based Medicine Levels of Evidence (2001)

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



Anterior Posterior Flap

Myocuntaneous Flap

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

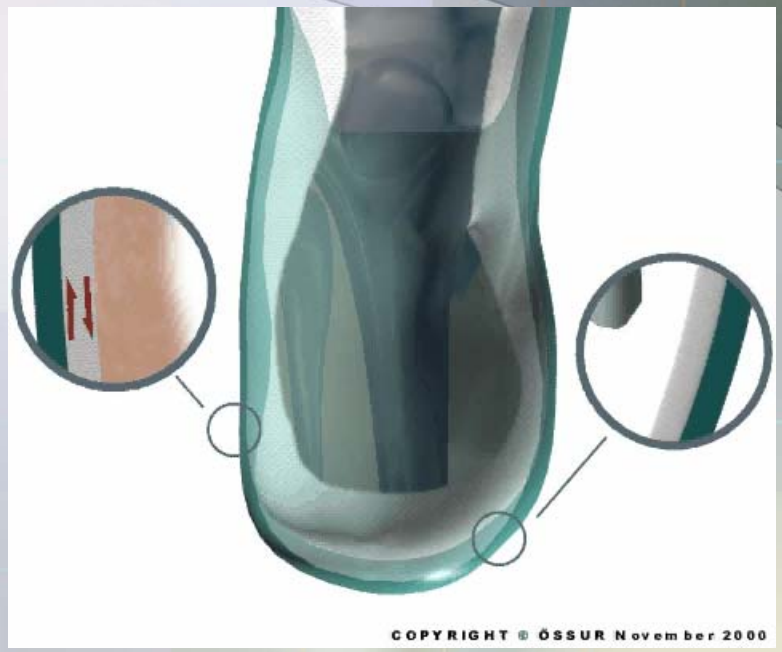
One-way Suction Valve System

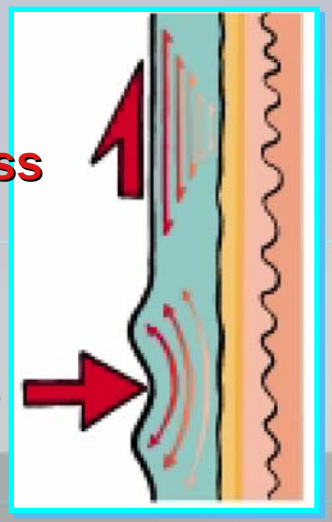
Negative Pressure Sockets

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

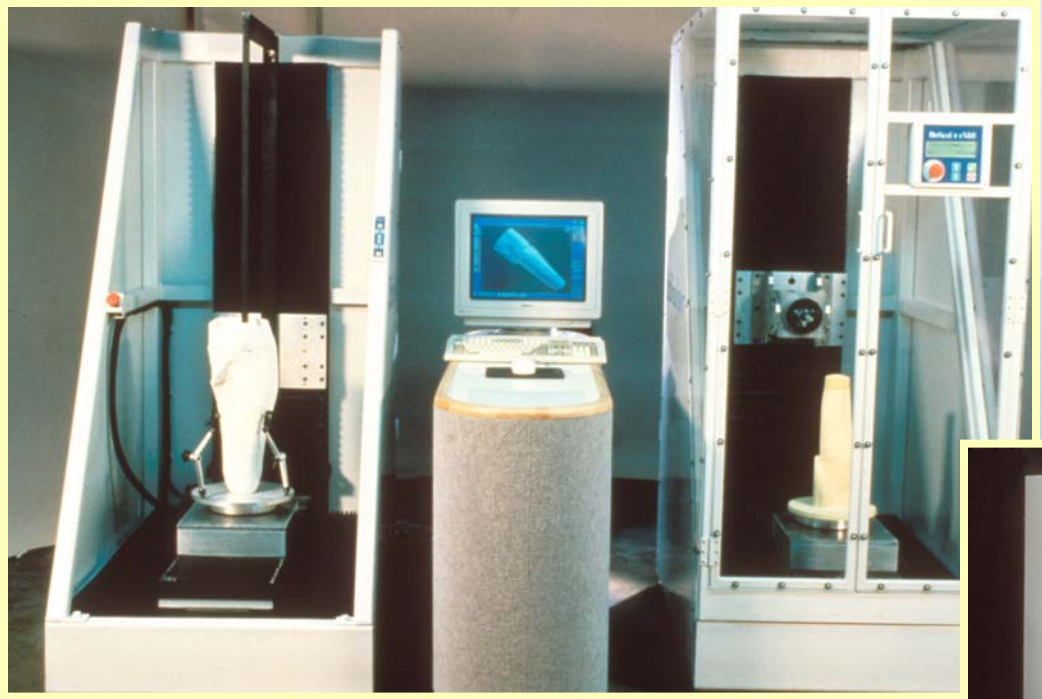
TFA Socket Designs

	% Change	Level Sig.
Norm v. IC	+18%	P<0.01
Norm v. Quad	+28%	P<0.01
IC v. Quad	+12%	n/s
Norm v. IC	+27%	P<0.01
Norm v. Quad	+42%	P<0.01
IC v. Quad	+20%	P<0.01

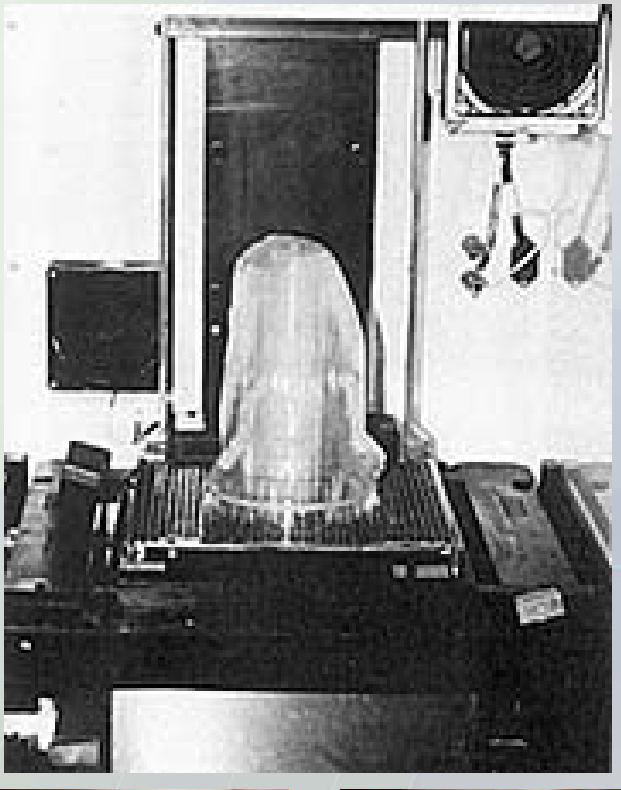
Gailey et al 1993

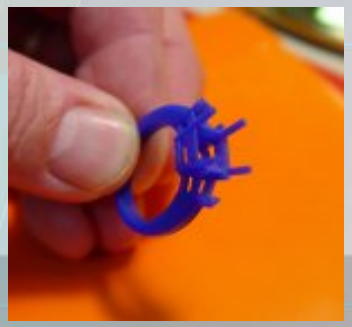
TFA Suspensions

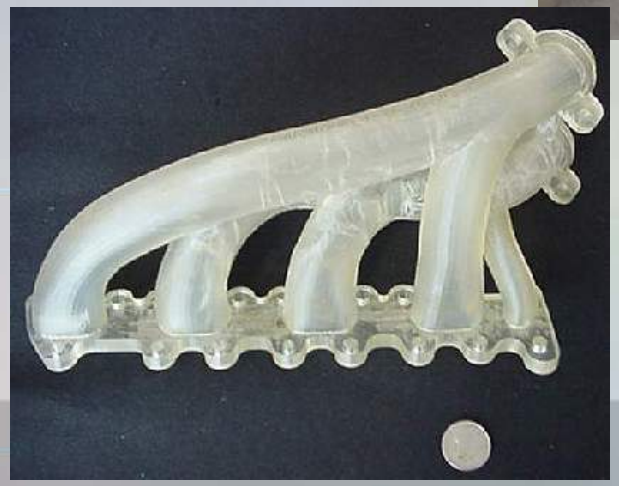
CAD-CAM Fabrication



Stereolithgraphy Technology





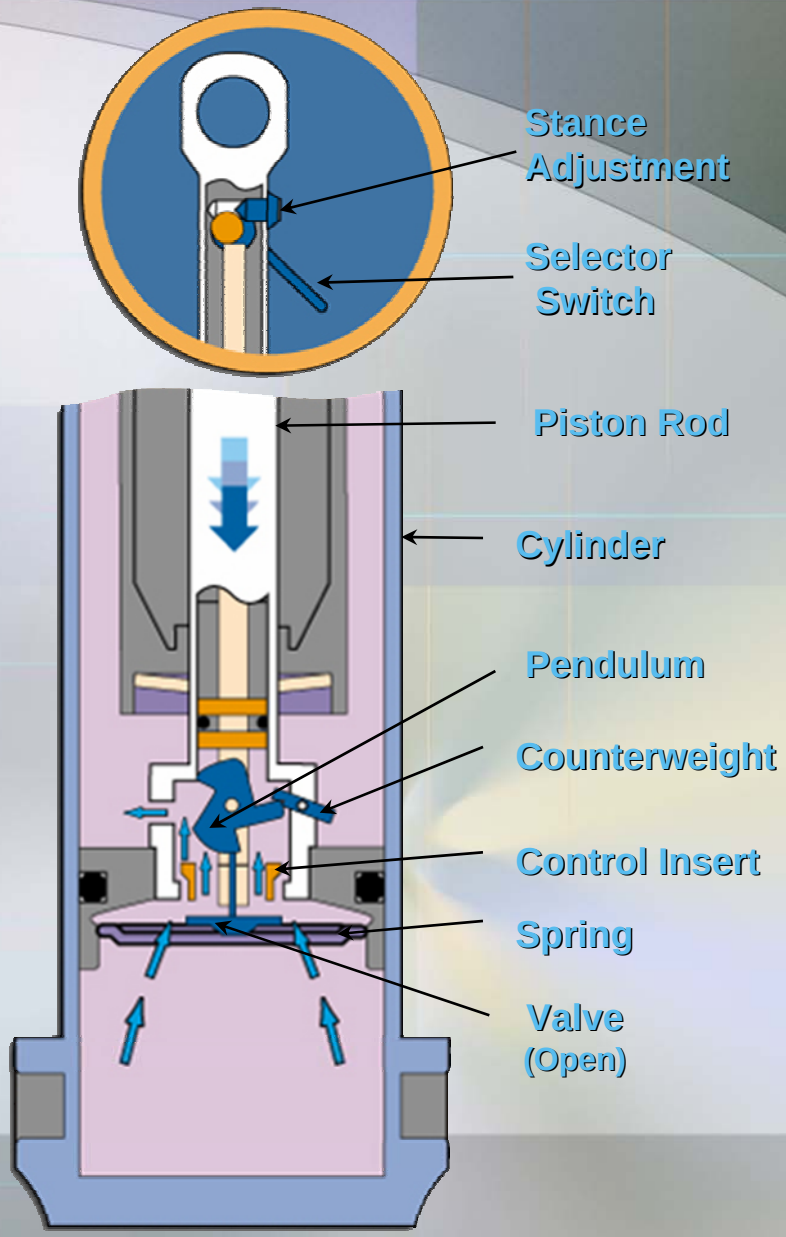


Consensus suggests that sockets are the most critical component of a prosthesis

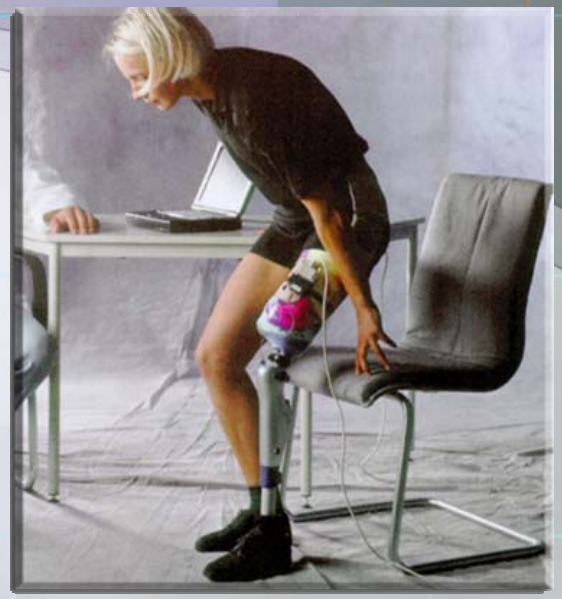
- Little Evidence suggesting differences between sockets
- No standardized method of assessment
- No evidence to determine functional value of the socket
- No evidence concerning fabrication techniques

Prosthetic Knee Systems

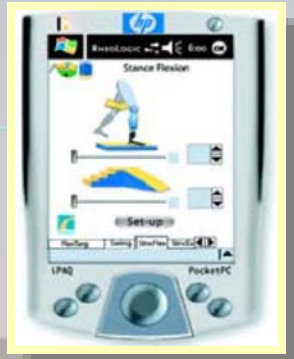
Hydraulic SNS
1968 Hans Mauch



Microprocessor Knees
Adaptive C-Leg



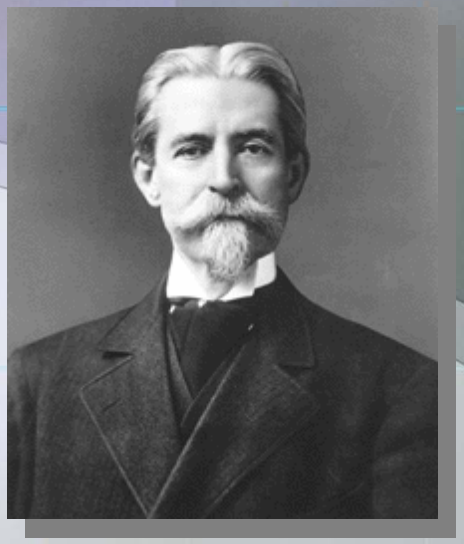
Rheo Knee



Victhom Knee

1861 JE Hanger

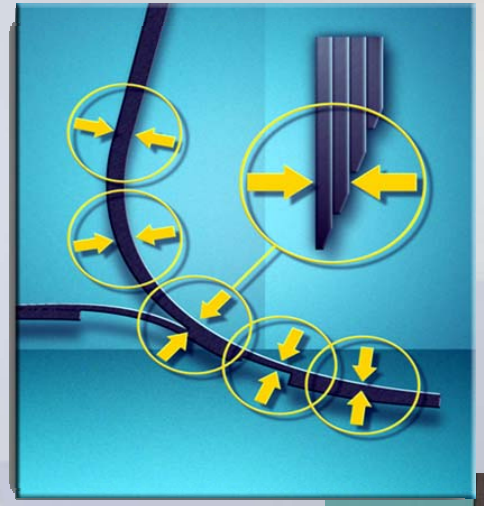
Lost leg in Civil War
feet using rubber bumpers

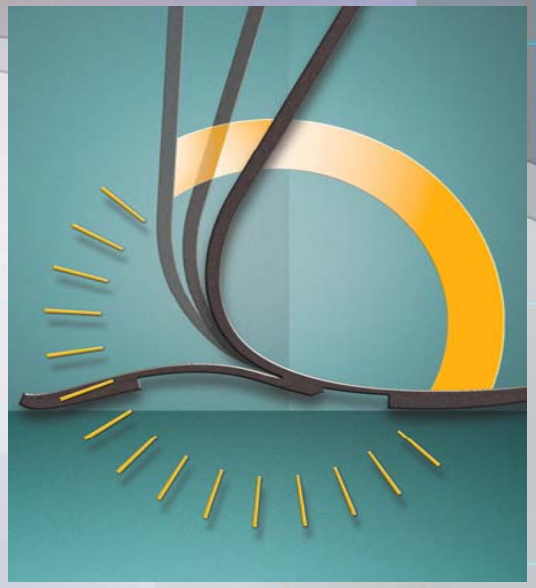


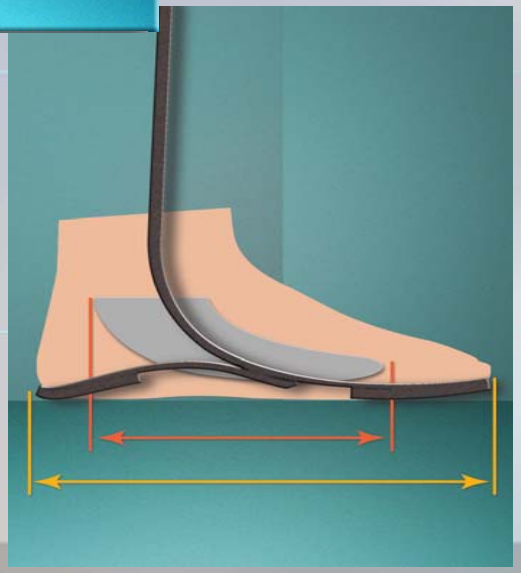
1958 SACH Foot designed by Howard Eberhart & Charles Radcliffe

Seattle Foot and Carbon Copy II

Flex Foot







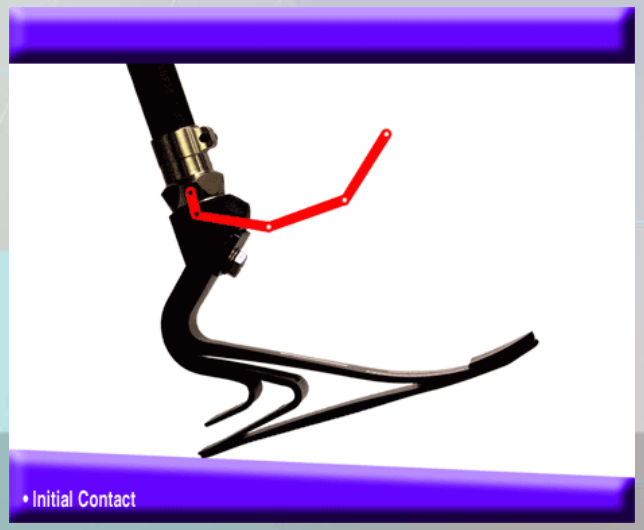
Flex Foot vs. SACH

- 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

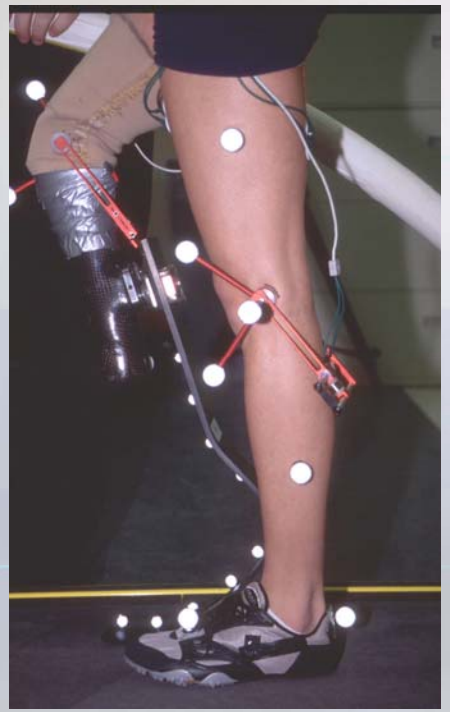
Symmetry of Gait

- 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

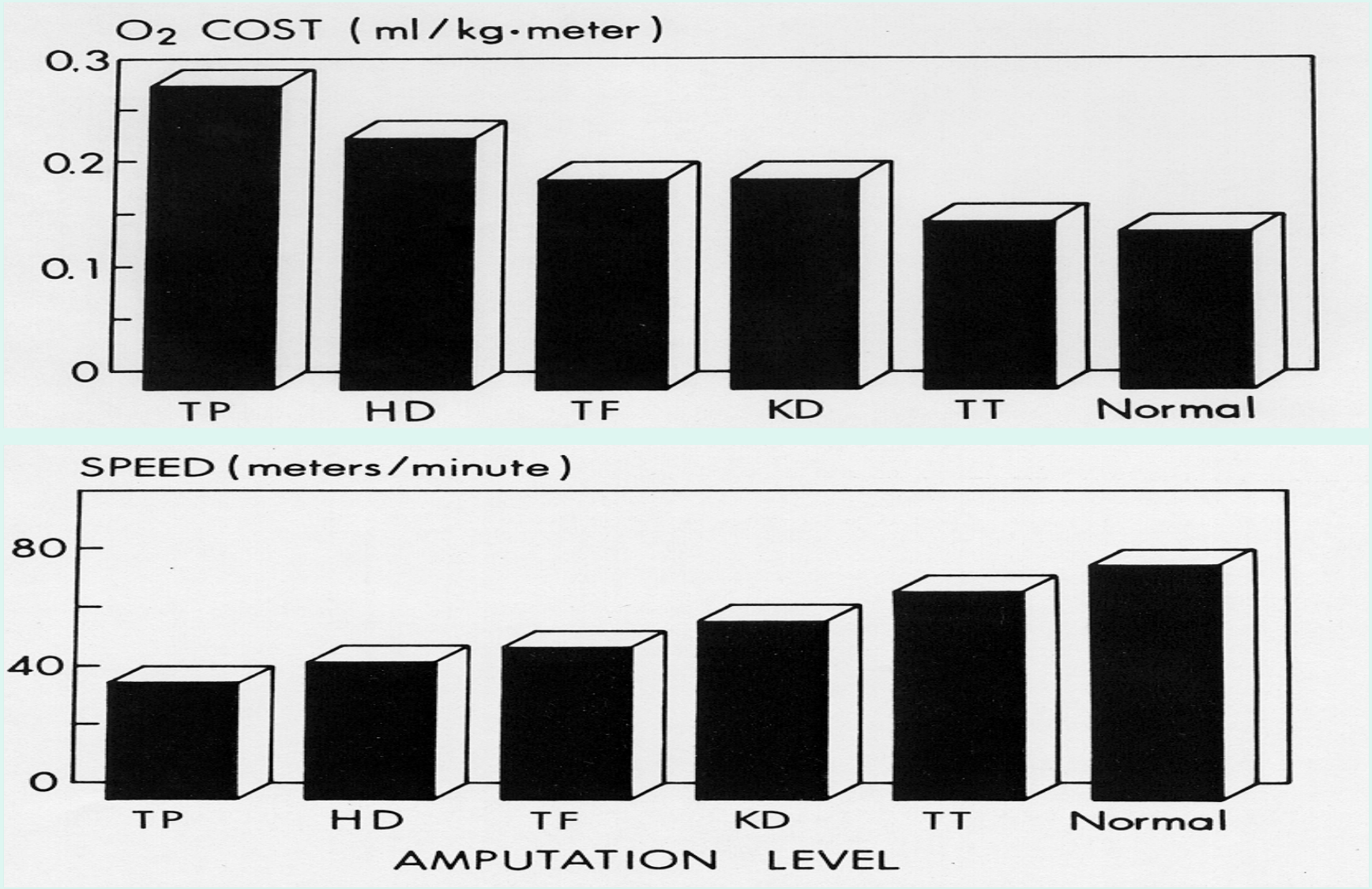
Shock Absorption & Torsion Control



Tests and Measures of Prosthetic Components



Amputee Walking Energy Cost Waters, 1992



Relative Amputee Energy Cost

Level / Cause	VO2	Velocity
TTA: Trauma	15%	10%
TTA: Vascular	30%	30%
TFA: Trauma	40%	20%
TFA: Vascular	65%	40%

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

- Weight of the prosthesis does not influence the metabolic cost of ambulation.
  Czerniecki 1994 / Gailey 1994 / Lehmann 1998 / Gitter 1997
- 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

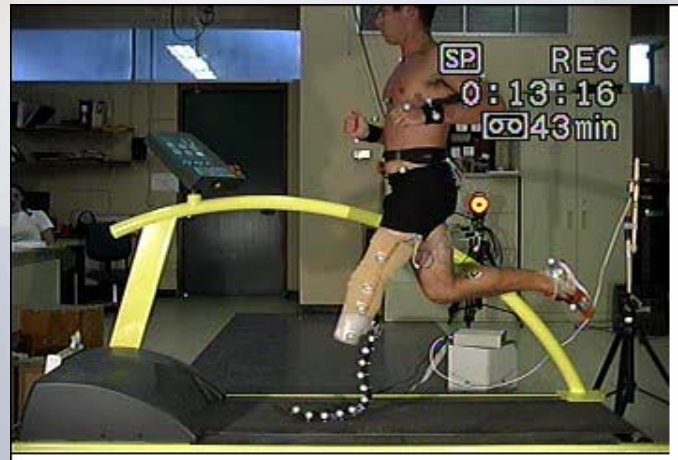
SACH Foot	39%
Seattle Foot	71%
Flex Foot	89%
Human Foot	246%

Gitter et al, 1991

SACH Foot	20%
Flex Foot	70%

Schneider, Hart, Zernike, Setoguchi and Oppenheim 1993

Gait Lab Analysis



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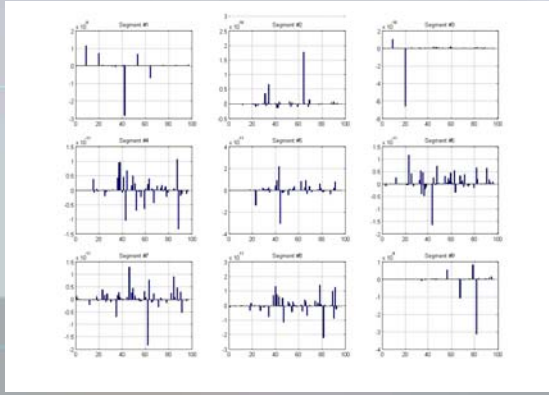
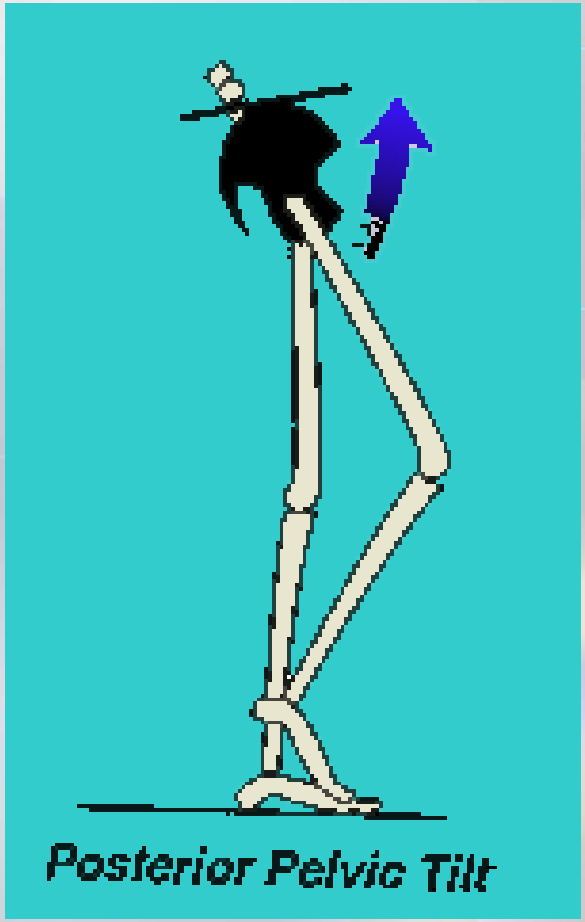


Posterior Pelvic Rotation
COM Remains Over Heel



Traditional Prosthetic Training vs. Resistive Gait Training Yigiter K 2002

	Resist. Gait	Traditional	Sig.
Wt bearing %	16.59 ± 8.87	8.35 ± 3.47	p<.05
Stride Length	7.86 ± 3.89	1.32 ± 0.56	p<.05
Amp. Side	3.88 ± 1.86	5.42 ± 2.27	p<.05
Step Length (cm)			
Sound Side Step Length	11.74 ± 3.62	6.74 ± 2.65	p<.05
Step Width	4.72 ± 2.80	2.60 ± 1.04	p<.05
SSCG (step/min)	16.44 ± 4.58	9.96 ± 2.26	p<.05
Self selected cadence			
FG (step/min)	21.6 ± 4.36	14.72 ± 2.46	p<.05
Fast cadence			
Velocity (cm/s)	14.72 ± 3.81	9.60 ± 3.60	p<.05
SL/LEL (stride length/limb length)	0.08 ± 0.01	0.02 ± 0.03	p<.05

Altered Walking BOS

- Increased walking width may be the result of hip abductor weakness requiring greater lateral stability.

- James 1973 / Jaegers 1995

- In the frontal plane the COM remains over the sound limb in children.

- Engsburg 1992

Abducted Prosthetic Limb

Adducted Sound Limb

Sound Side Knee Degeneration

Patellofemoral Arthritis

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

Similar findings

Burke 1978
Powers 1994

Increased Double Support Time

Jaegers 1992
Murray 1981
James 1973

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 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 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 t et al 2003)

- For the SIP-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

MFCL	6-min (meters)	AAS	AMPno PRO	AMP PRO
K1 Household	49.86	-36.05	15.37	25.0
K2 Limited Community	189.89	-7.51	25.28	34.65
K3 Community Ambulator	298.64	11.23	31.36	40.5
K4 High Activity	419.76	27.77	38.49	44.67

Estimated AMP Cut Scores

	AMPnoPRO	AMPPRO
K0	0-8	N/A
K1	9-20	15-26
K2	21-28	27-36
K3	29-36	37-42
K4	37-43	43-47

The Base Equation

Y(6 minute distance) =

-12.239 -1.226 (age)

+ 7.956 (AMPnoPRO)

– 6.235 (comorbidity score)

+ .129 (time after amp.)

4. Arises from a chair

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

<u>System Challenged</u>

- 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

Maurice Green	9.79
Florence Joyner	10.49
Marlon Shirley	10.89
Joe Gaetani	12.22
Earle Conner	12.56

Questions?

Thank You

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