Objective Assessment of Function: Using Gait Analyses to Detect Objective Differences

Kenton Kaufman, PhD, PE
Motion Analysis Laboratory
Mayo Clinic
Rochester, MN

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The Human Gait
Braune and Fischer, ~1895
U C – Berkeley
~ 1950

- Verne Inman, MD, PhD
  Orthopedic Surgeon & Anatomist
- Howard Eberhart, PhD
  Civil Engineer
- Charles Radcliffe, PhD
  Mechanical Engineer
- Henry Ralston, PhD
  Physiologist

Monumental Studies
Affected every area of gait analysis
Ford et al, 1995

• Prosthetic clinicians rating video footage of transtibial amputees

• Intentional misalignment in sagittal and coronal plane

• Between rater reliability
  • Coronal plane: $k=0.36$
  • Sagittal plane: $k=0.08$
Saleh & Murdoch, 1985

- Experienced observers
- Gait of transtibial amputees
- Prosthetic limbs intentionally misaligned in sagittal plane
- Agreement of observers with biomechanical model was 22%
Motion Measurement

- Real-time analysis
- Digital cameras
  - Up to 300 Hz
  - Infrared strobe lighting

Eagle Digital System
Knee Extensor Moment

**External Demand**
- Force (F)
- Center of Mass (COM)
- Lever arm (LA)

**Internal Response**
- Ground Reaction Force (F)
- Muscle contraction
- Moment

**Ground Reaction Force (F)**
- Muscle contraction
- COM
- Lever arm (LA)
c-leg User

- Ext
- Flx

GAIT CYCLE (%)

MOMENT (%BW-HT)
Balance
Computerized Dynamic Posturography

- Sensory Organization Test (SOT)
- Motor Coordination Test (MCT)
SOT

Visual and proprioceptive inputs are altered to evaluate their effect on balance.
C-leg User

Sensory Organization Test

Equilibrium Score

Sensory Analysis

Strategy Analysis

COG Alignment
Motor Coordination Tests

Motor Control Test

Adaptation Test

Translation

Rotation
c-leg User

Motor Control Test

Weight Symmetry

Latency (msec)

Backward Translations

Latency (msec)

Forward Translations
Mauch SNS Knee

SUBJECT 1
Motor Control Test

SUBJECT 2
Motor Control Test

SUBJECT 3
Motor Control Test

SUBJECT 4
Motor Control Test
c-leg User

Adaptation Test

TOES UP

TOES DOWN
Mauch SNS Knee

SUBJECT 1

Adaptation Test

TOES UP

TOES DOWN

SUBJECT 2

Adaptation Test

TOES UP

TOES DOWN

SUBJECT 3

Adaptation Test

TOES UP

TOES DOWN

SUBJECT 4

Adaptation Test

TOES UP

TOES DOWN
Objective Analyses of Gait Efficacy

- Oxygen consumption measurements
- Evaluate metabolic efficiencies

n = 6

Schmalz et al, 2002
Total Activity

- Doubly-labeled Water
- Step Counter
StepWatch™

• Pager-size molded urethane case worn on ankle
• Continuously records number of steps extended monitoring periods
• Time-sequenced data allow patterns of activity and rest to be visualized
Mauch SNS Knee Steps/Day

SUBJECT 1

* not worn in am

Avg = 4264 steps/day

SUBJECT 2

Avg = 2545 steps/day

SUBJECT 3

Avg = 2706 steps/day

1 millions steps/yr = 2700 steps/day
Activity Level
StepWatch™ Data
10 day Average

Percent of Time Spent at Activity Level

- No Activity
- Low (1-15 steps/min)
- Med (16-40 steps/min)
- High (>40 steps/min)

Subject 1 | Subject 2 | Subject 3
StepWatch Data™

Typical Work Day

Time of Day

Steps/min

0:00 3:00 6:00 9:00 12:00 15:00 18:00 21:00 0:00
StepWatch™ Data

Typical weekend?

Friday

Time of Day

Steps per Minute

0:00 3:00 6:00 9:00 12:00 15:00 18:00 21:00 0:00
StepWatch™ Data

Saturday

Time of Day

Steps per Minute

0:00 3:00 6:00 9:00 12:00 15:00 18:00 21:00 0:00
Pathophysiology → Functional Limitations → Disability

Amputation → Gait Balance Energy Consumption → Activity Limitations
Prosthetic Evaluation Questionnaire (PEQ)

Ambulation (AM), Appearance (AP), Frustration (FR), Perceived Response (PR), Residual Limb Health (RL), Social Burden (SB), Sounds (SO), Utility (UT), Well Being (WB)
Outcome Assessment

RECOMMENDATIONS

Mechanistic

- Questionnaire
  - SF-36
  - Prosthesis Evaluation Questionnaire
- Instrumented Measures
  - Gait
  - Balance

Metabolic

- Energy Expenditure
- Total Activity
Thank you!