



# Palo Alto Rehabilitation Research and Development Center





# Multi-Site Movement Analysis



- Why we want to do multi-site trials
- Why we can't do exactly what we'd like to do
- Current VA multi-site technology development research
- What we can do
  - Near term – two years
  - Immediate future – six months
  - Right now – right now

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# Why we want to do multi-site trials

- Multiple site outcome measures for rehabilitation treatments and protocols, disseminate “best practices”
- Our original interest was in osteoarthritis (OA) of the knee
  - Large population studies needed for statistically significant results
  - Reduce patient load on any one site
  - Increase diversity of subject population
  - Foster collaboration between centers



# Amputee Healthcare in the VA

- Some of the same reasons apply to amputee related research
- Additionally, interest in clinical monitoring
  - Veterans all over the country
  - 10 central, 26 satellites fabrication sites
- Function and changes in function can be quantified using motion capture technologies



# Why we can't do exactly what we'd like to do

- We don't have motion analysis systems everywhere
- Motion analysis systems are expensive
- Motion analysis systems are not standardized
  - Hardware
  - Protocols
  - Personnel training



# Shriners multi-site experiment

- Motion analysis primarily for surgical planning for children with cerebral palsy
- 10 Vicon, 2 Motion Analysis Systems
- 1 machined test object at all sites
- 1 subject, 1 lab, 1 tester, 6 consecutive days
- 1 test subject at 12 labs, average 2 testers/site





# Shriners multi-site results

- Absolute accuracy from machined rod – 3 degrees, 3 mm; standard deviation less than 1 deg
- Repeatability within site (marker placement controlled) – std dev < 1 deg, range < 4 deg
- Across clinicians, sites

	pelvic tilt	hip flexion	knee flexion	dorsiflexion
Std Dev	3.5	5.0	4.6	2.7
Range	14.8	23.9	17.3	12.1
	pelvic rotation	hip rotation	foot progression	pelvic obliquity
Std Dev	1.6	7.3	2.6	1.3
Range	5.9	28.3	10.9	6.0



# Current VA multi-site technology development research



- Research program designed to address some of these questions
  - Survey VA motion capture labs
  - Design protocols, software, and training programs to improve standardization across sites
  - Develop new technologies for human motion capture that bypass some of these issues
  - Study 10 normal subjects at two sites
  - Study 20 osteoarthritic subjects, 10 at both sites



# Current motion capture systems

- Systems purchased to address very different research questions
- Different Hardware
- Different Protocols

	Walter Reed	Seattle	Cleveland	Palo Alto
System	Motion Analysis	Vicon	Vicon	Qualisys
	Atlanta	Pittsburgh	Miami	Stanford
System	Peak	Optotrak	Motion Analysis	Qualisys



# Revised Research Plan

- Too soon for OA portion of research, may not get these tests in during the two year grant proposal time
- Need to test normal subjects at more of the sites
  - Sending a group of seven subjects to various sites when traveling for other purposes
  - Travel funding for some tests from outside sources



# Current Status

- Have software and a protocol, no consensus
- Central data server with backup system
- Visited Miami for scientific meeting, moving lab and not ready for testing
- Visited Cleveland, ran seven test subjects
- Running same group at Stanford and Palo Alto VA
- Scheduled to visit Seattle Dec 8
- Good progress on markerless techniques



# Gait Parameters of Interest



## **Time Distance**

SPEED  
STRIDE LENGTH (normalized to height)  
STEPS PER MINUTE  
SWING TIME (seconds)  
SUPPORT TIME (seconds)  
% SWING TIME

## **Kinetics**

KNEE FORCE RESULTANT MIN  
KNEE FORCE RESULTANT MAX  
FIRST PEAK OF KNEE FLEX/EXT MOMENT  
SECOND PEAK OF KNEE FLEX/EXTENSION  
FIRST PEAK OF KNEE ADDUCTION MOMENT  
SECOND PEAK OF KNEE ADDUCTION MOMENT

## **Kinematics**

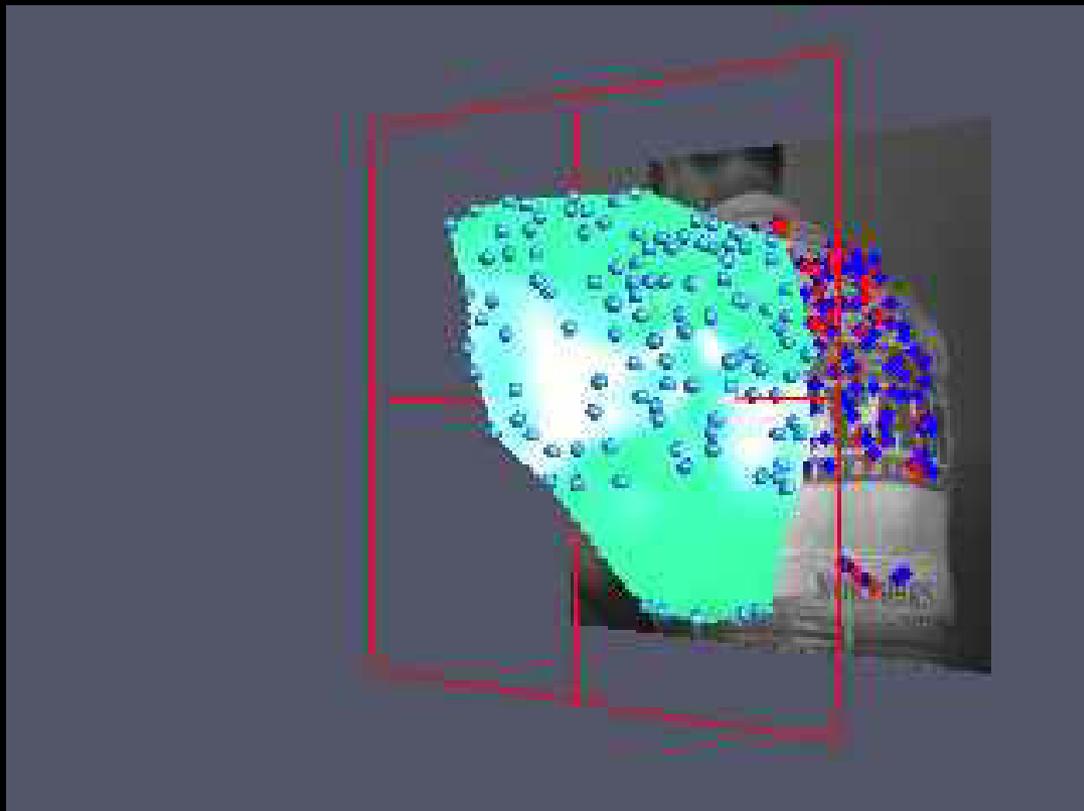
HIP RANGE OF MOTION  
HEEL STRIKE KNEE FLEXION ANGLE  
MINIMUM KNEE FLEXION  
MIDSTANCE KNEE FLEXION ANGLE  
TOE-OUT ANGLE  
KNEE RANGE OF MOTION  
TOE-OFF KNEE FLEXION ANGLE  
TERMINAL EXTENSION KNEE FLEXION ANGLE

- Based on osteoarthritis related research questions
- New set of parameters from breakout sessions based on amputee related clinical and research questions



# What we can do - near term

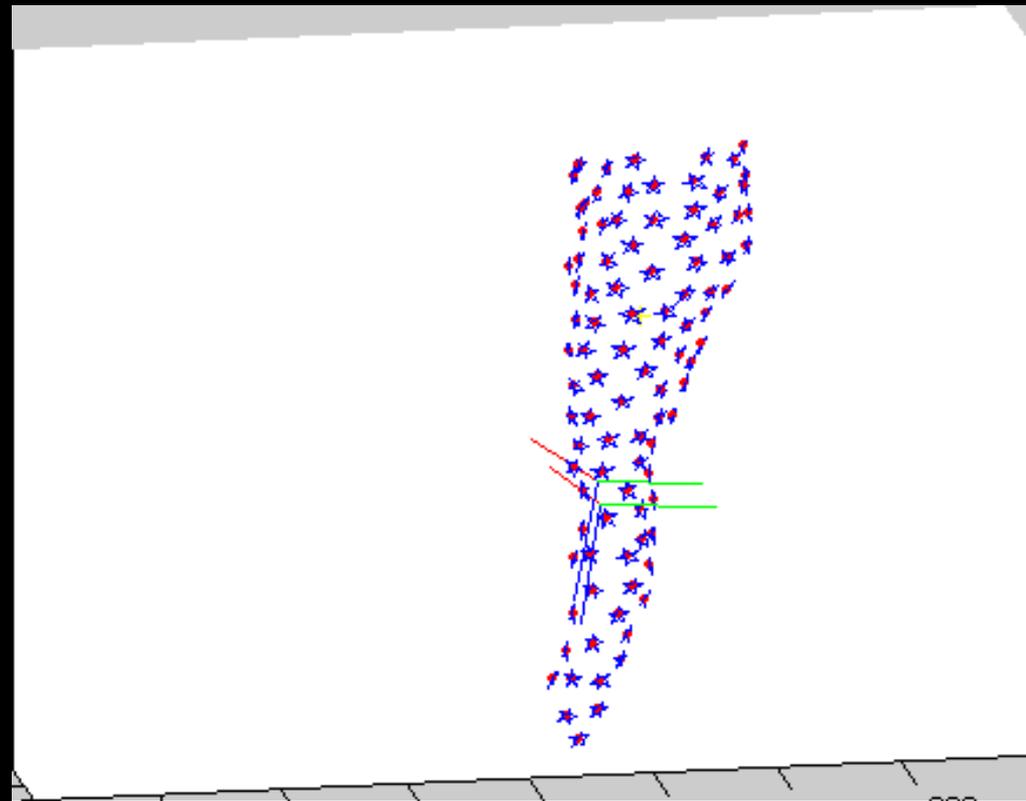
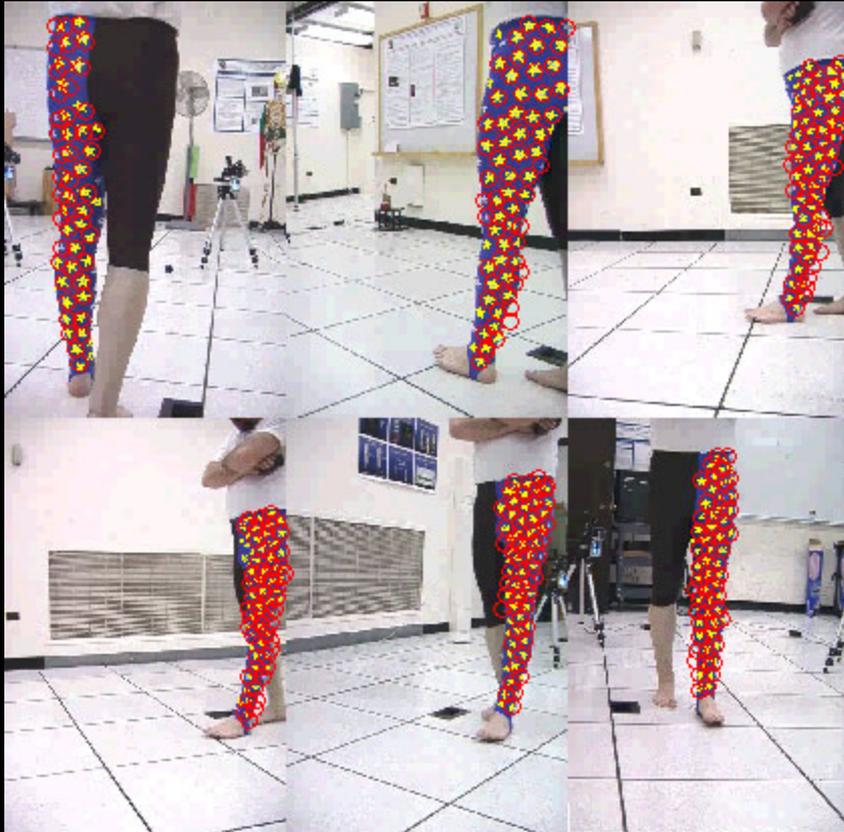
- Drive on with markerless motion capture research
  - As with prosthetics research, tremendous advances in computation, networking, electronics, optics have not been fully incorporated into human motion capture





# What we can do - near term

High resolution feature based multiple color camera motion capture  
- two orders of magnitude more data than marked techniques





# What we can do - Immediate future

- Develop some collaborations to define future research questions
- Transfer expertise from groups focused on amputee motion capture
- Finish the existing multi-site research
  - Test the rest of the subjects
  - Statistical analysis for biases
  - Achieve consensus on protocols



# What we can do - Immediate future

- Standard gait tests?
  - Our modus is to establish experiments as driven by clinical or research questions
  - May be enthusiasm for a standard gait test, always run the subjects through as much of the standard protocol as the sites technology permits



## What we can do - right now

- Define some research questions
- May be able to answer these across multiple sites depending on required accuracy
- Clinicians could begin prescribing motion capture of the amputee population for clinical monitoring purposes
  - Know limitations, can still be important data
  - As research protocols and standardization techniques improve we may be able to incorporate this data



# Time Distance Measurements

- AMP Pod



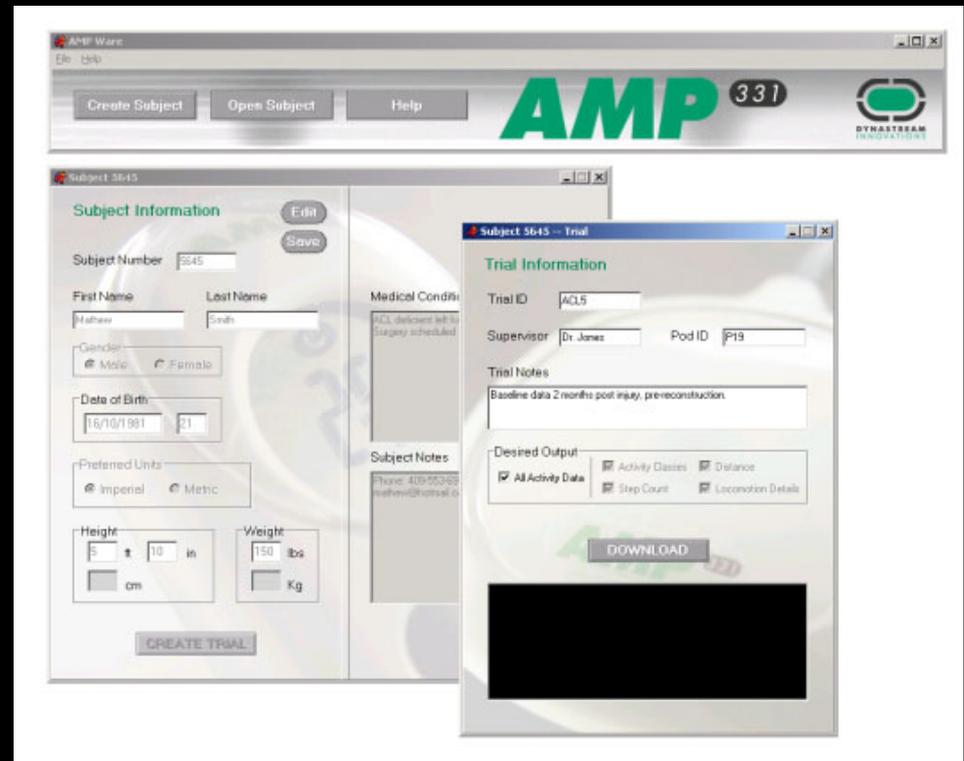
- AMP Ankle Sleeve



- AMP Link



- AMP Ware





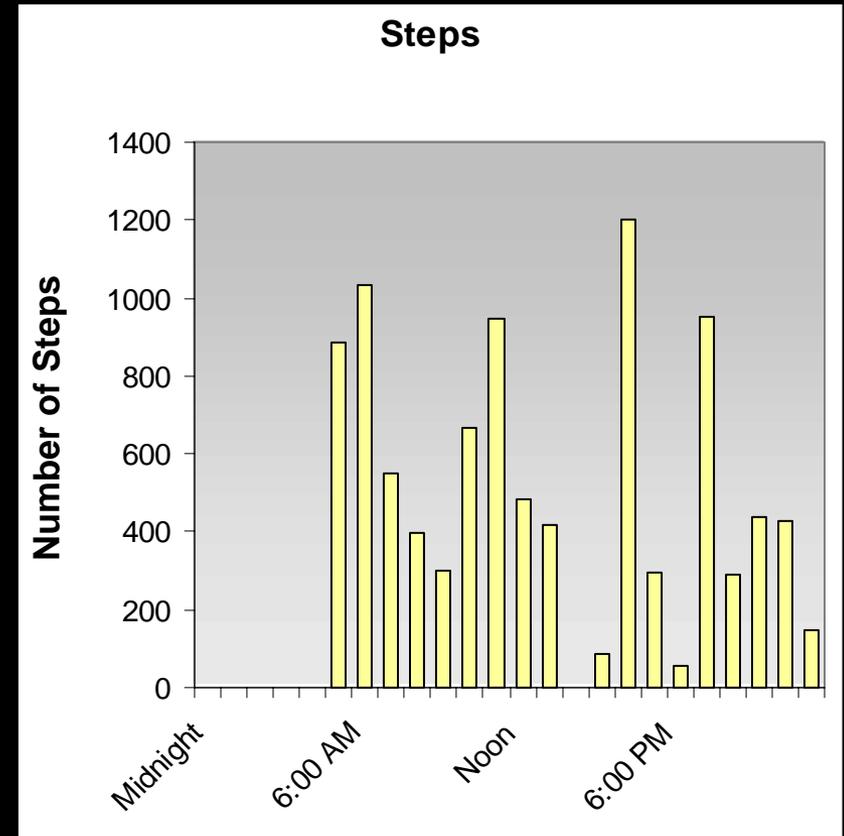
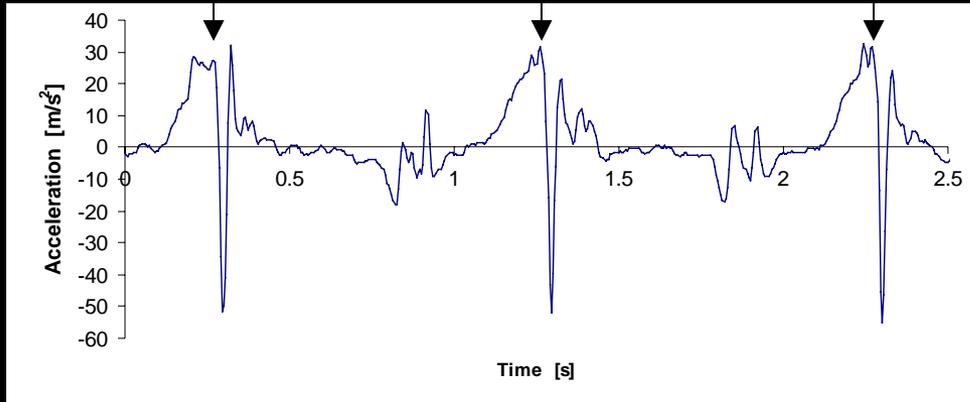
# Major phases of gait are identified from inertial sensor signals



HS1

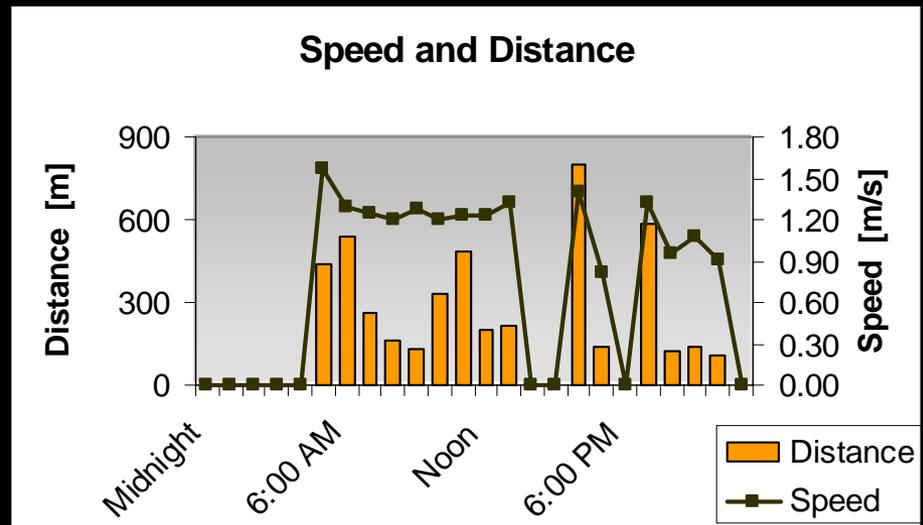
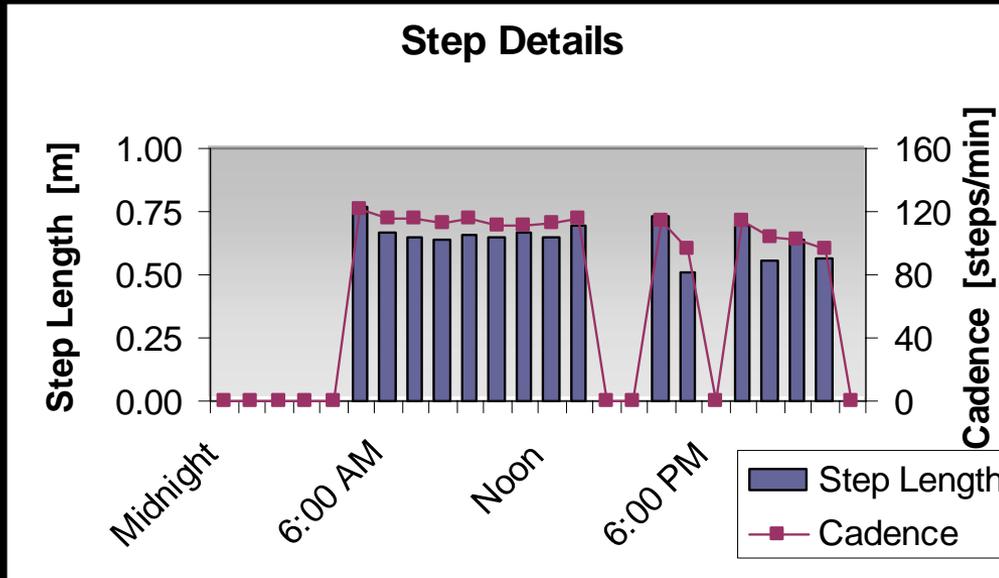
HS2

HS3





# True angular position is calculated and time/ distance measurements derived and stored



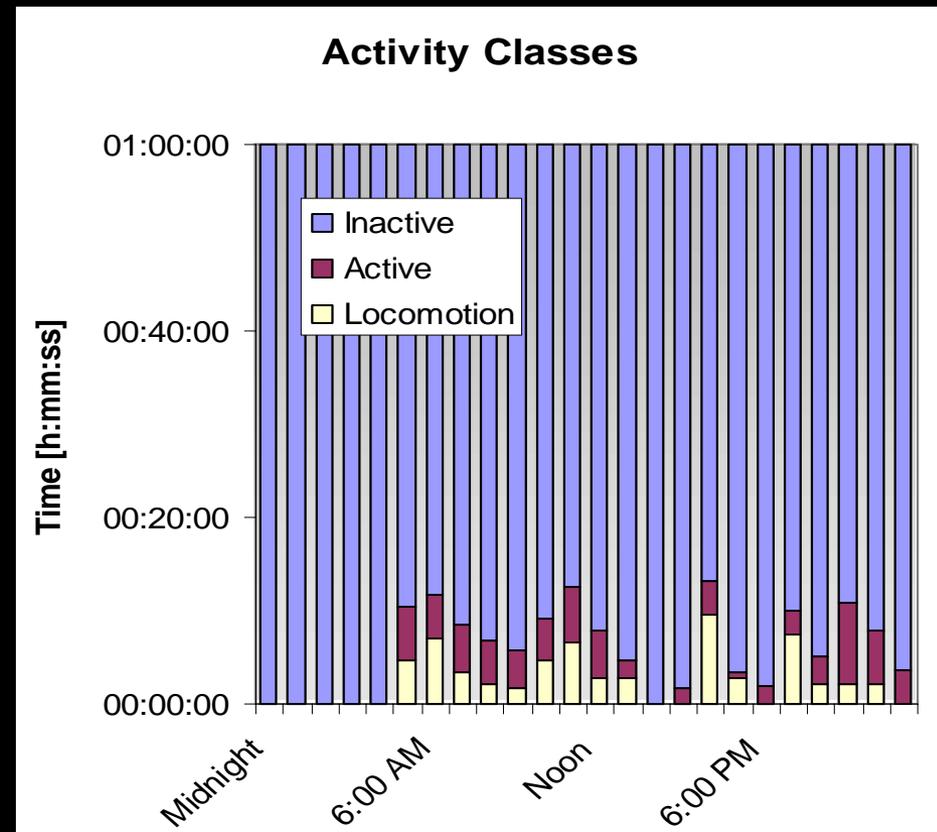


# Subject activity level monitored for a week



## Three Activity Classes

- Inactive Class: “lying or sitting”
- Active Class: “up and about”
- Locomotion Class: “going somewhere”





# Summary

- Research and clinical questions to be addressed across multiple sites are limited by biasing introduced by different hardware, protocol, and training
- Some questions can be addressed, error level
- Full kinematic/kinetic analysis for clinical monitoring is currently available
- Off the shelf technologies are available if the research and clinical questions warrant



# Acknowledge our Funding Sources

- Veteran's Administration
- National Institutes of Health
- National Science Foundation
- Defense Advanced Research Projects Agency



# AMP Pod



FEATURE	BENEFIT
patented speed and distance algorithm	measurement of kinematics in proven and accurate technology included in many other products containing Dynastream Technology
easy to use UI with LCD display	simple user interaction and function indicator
mechanically robust	impact resistant and durable
waterproof	can be worn in shower or during unfavorable weather conditions
data collection for up to nine days on one power source	multiple day objective data collection for weekdays and weekends
tamper-proof	research subject cannot interrupt sensitive data collection
fool-proof	no false step detects
secured data in non-volatile memory	data will not be lost if power interrupted





# Ankle Sleeve



FEATURE	BENEFIT
custom designed for AMP Pod	secure fit of Pod in sleeve provides accurate data
medical grade mesh	comfortable and breathable
S, M, L, and XL sizing available	fits many different research populations (children to obese)
washable	can keep clean and are re-usable





# AMP Link



FEATURE	BENEFIT
connects to USB port	quick download (2 sec/day)
simple Tiny Area Network	works in ISM band
operating range is 3m	user can download at range with no wired connections
mechanically robust	impact resistant and durable





# AMP Ware



FEATURE	BENEFIT
subject and trial information associated with Pod data	data management is made easy
data stored in Excel format	data can be viewed, analyzed and shared with ease
full help features and support	all help is available online or customer support
ability to enter notes for each subject and trial	specific research needs addressed in text fields
database of all subjects created	data management is made easy

