Physical Activity Assessment Using Accelerometers

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Overview

- Why use accelerometers
- How accelerometers work
- What accelerometers tell us
- Practical matters and logistics
- Data summarization and interpretation
- NHANES experience

Why Consider Accelerometers?

- Activities we are interested in may be routine and occur throughout the day
  - transportation, including short trips
  - walks for pleasure
- This type of behavior is difficult to report – frequency/intensity/duration
  - not discrete units, e.g. packs of cigarettes
  - intensity is highly subjective
- Reporting is subject to “desirability” - bias
- Qx. have limited reliability/validity
- Diaries have fairly high subject burden

Benefits of Accelerometers

- Remove cognitive aspect of data collection
  - provide objective data
- Primarily measure locomotor activity
- Can monitor multiple days with low burden
- Captures “real-time” intensity, duration, and can derive frequency of bouts
- Non-reactive measurement possible

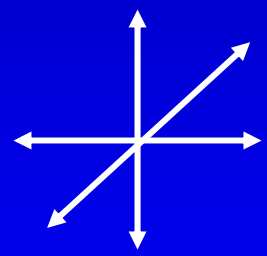
Accelerometer Caveats

- Does not provide context of activity
- Primarily measures locomotor activity
  - not total activity or energy expenditure
  - misses upper body movement with usual placement
  - cannot distinguish load-carrying vs. not
- BUT walking/running is a primary source of activity, and may be your focus

How Accelerometers Work

Accelerometer Methods

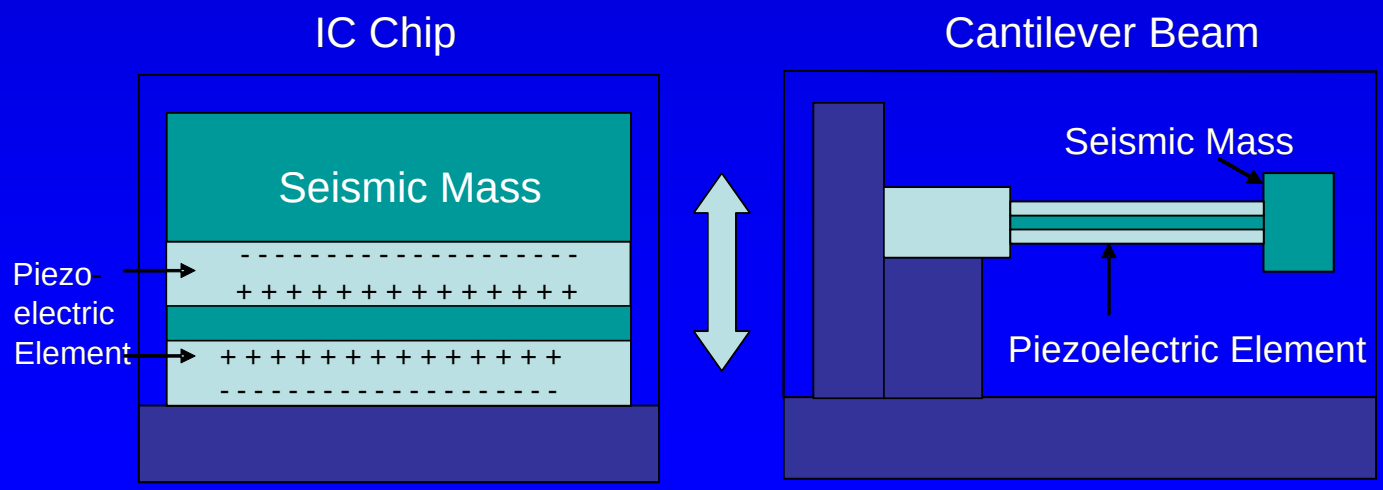
- Measures body movement in terms of acceleration
  - related to intensity of physical activity
  - measured in 1 to 3 orthogonal planes
    - » anterior-posterior
    - » medial-lateral
    - » vertical



  - Data stored for later download/analysis

Acceleration

- Proportional to net external force
  - reflects energy cost of activity
- Measured by piezoelectric sensors
  - piezoelectric element plus seismic mass
  - measure tension/compression (IC) or bending (beam) upon acceleration
  - generates voltage signal proportional to acceleration



Schematic from Chen and Bassett

More Electronic Factors

- Sampling frequency
  - determines motions that can be detected
  - related to frequency of movement, e.g. arm frequency > leg frequency
- Bandwidth filtering
  - increases linearity of the output relative to movement
  - reduces artifacts (noise)
    - » temperature changes, electronic noise
    - » external factors e.g. vehicular movement
  - if excessive (band is too narrow), reduces valid data collection

Accelerometer Output

- Counts
  - generated based on sampling frequency
    - » range of 1-64 Hz
  - usually summed up over epoch period – often 1 min, may be user-defined
  - NOT comparable across devices
    - » different sensors,
    - » conversion parameters,
    - » amplification

Additional Output Available

- Device dependent
  - Steps
  - Estimated energy expenditure
    - » usually calculated by external software
    - » generally not accurate at individual level
  - Behavior or gait characterization
    - » e.g., stroll vs. walk vs. run
    - » distance traveled, speed

Data Obtained

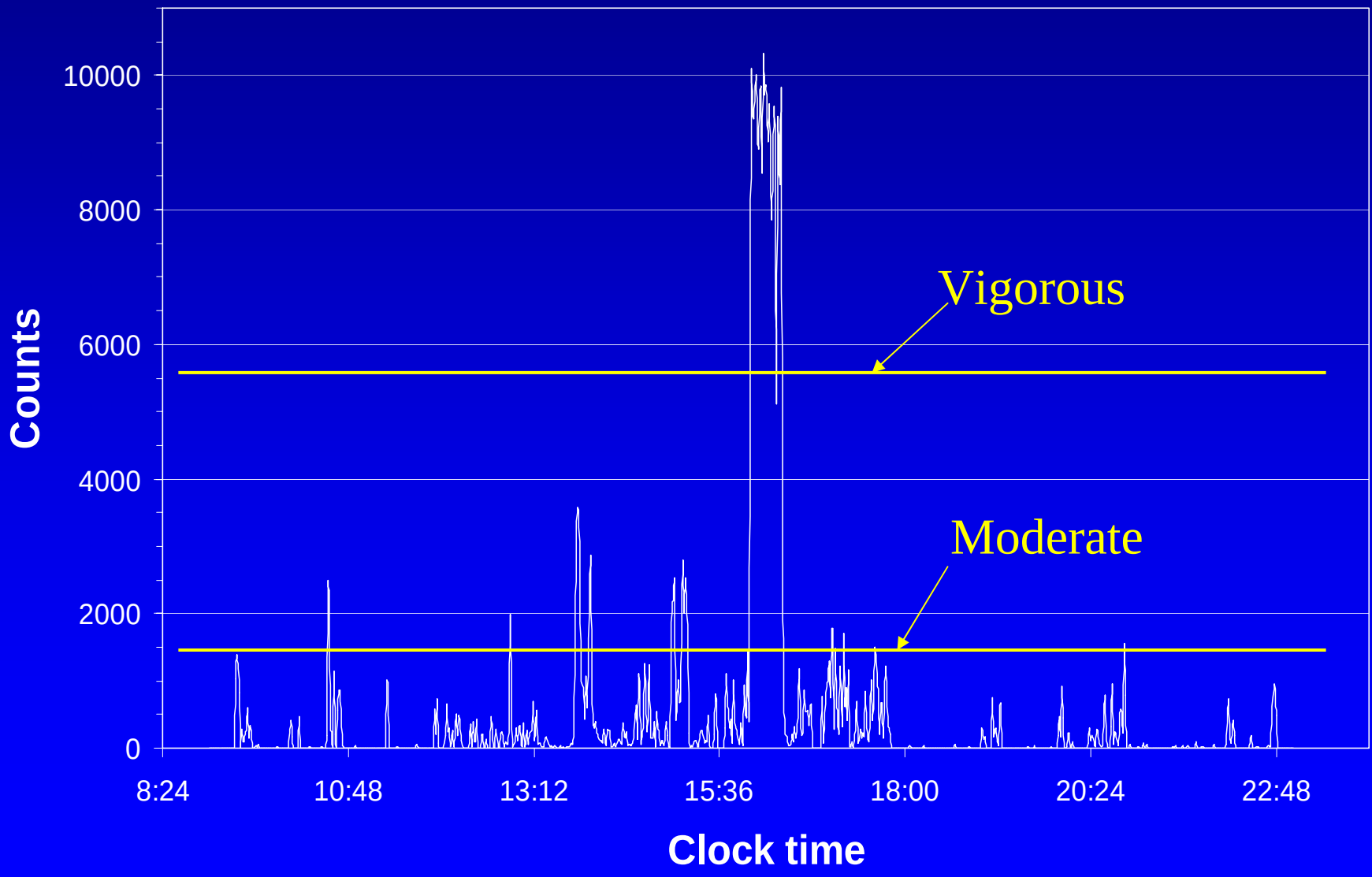
- Pattern of counts over time
  - cumulative counts
  - average counts/min
  - time spent within given count criteria
    - » sedentary, light, moderate, vigorous, etc.
- Pattern of steps over time (some devices)

Data Example (Actigraph)

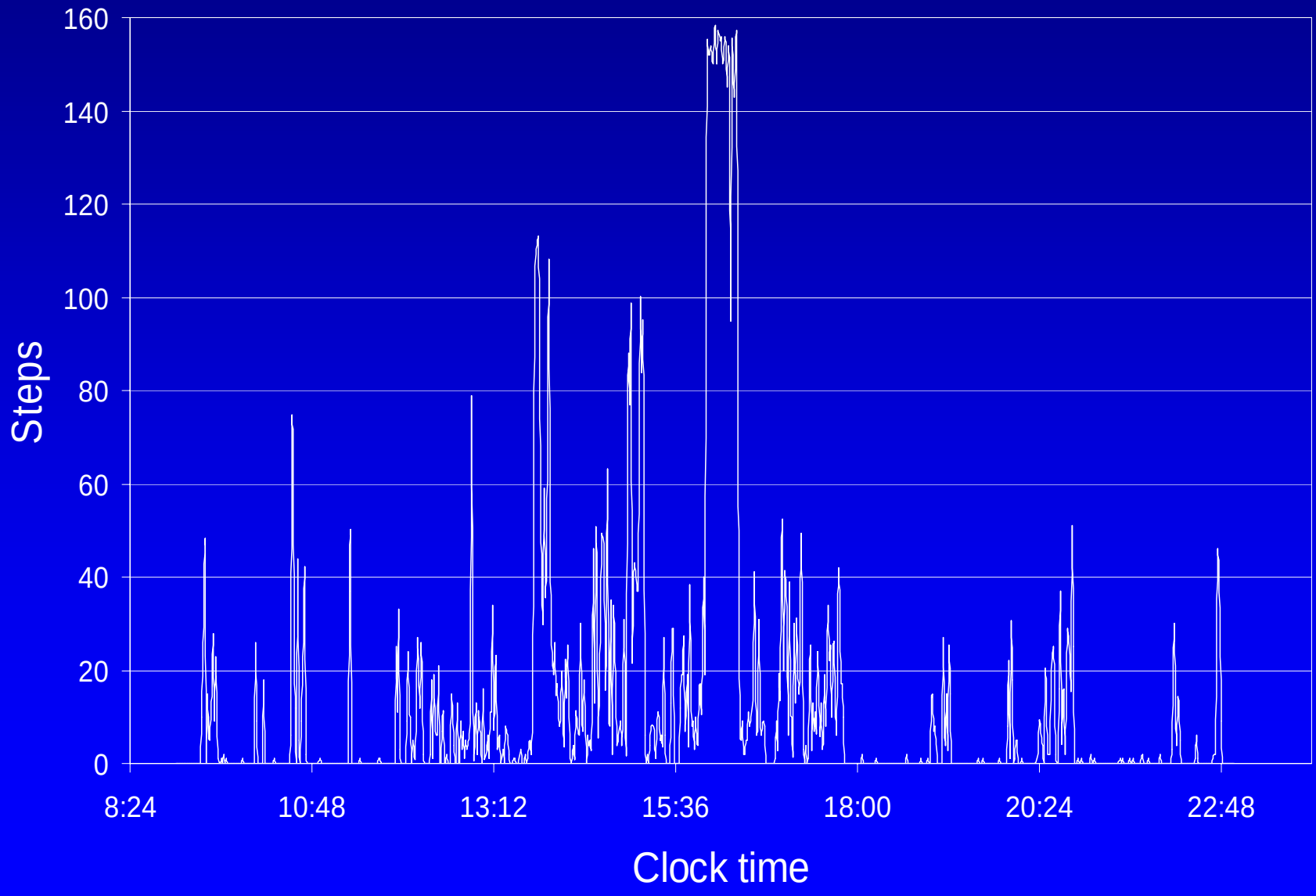
SN:14823 Ver 2.2
Start Time 05:00:00
Start Date 04-14-2004
Epoch Period (hh:mm:ss) 00:01:00
Download Time 15:01:36
Download Date 04-21-2004
Current Memory Address: 21362
Battery Life Remaining: 3805 hrs MODE= 1

0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	565	8	1047	52	53	4	9	0	0	0
541	19	0	0	61	2	383	33	831	67	148	6	85	
4	59	2	30	3	76	3	7	0	13	1	11	0	100
3	43	3	15	0	2	0	98	2	92	2	0	0	0
0	0	0	39	1	6	0	10	1	122	6	0	0	0
0	0	0	0	0	3	1	76	3	17	1	43	3	44
2	153	5	29	3	184	3	59	2	123	5	52	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	1	12	2	128	4
10	1	1	0	0	0	45	1	15	1	36	2	14	0

Activity counts



Weekend Steps (total=10,700)



Practical Matters & Logistics

Implementation Issues

- Device selection
- Monitor number and placement
- Distribution and collection
- Compliance
- Data interpretation

Wearable Accelerometers

Activity + Heart-Rate Monitor

Movement + HR + Posture

5 sensors attached to body parts – chest, each leg, each foot

Selection Factors

- Uni-axial vs. tri-axial or omni-directional
  - comparable estimates of free-living PA
  - slight improvement in some validity estimates with > 1 axis
  - output of tri-axial and uni-axial highly correlated
- Focus on cost, practicality, reliability, and desired comparability

Monitor Number & Placement

- Wrist, ankle, hip, lower back
  - For locomotion, hip or back is preferred
  - close to center of mass
- Multiple monitors?
  - capture movement of extremities
  - marginal improvement not worth practical costs

Number of Days to Monitor

- Trade-off between
  - cost and compliance (burden) vs.
  - better estimate of “usual activity”
- For adults, seven days is best
  - especially for patterns of inactivity
  - 3-4 days gives ICC of 0.8 (Matthews, et al., 2002)
- For youth, 4-9 days suggested

Distribution & Collection

- In-person is best
  - relationship increases compliance
  - demonstrate fit and wear
  - answer questions
  - maximize useful data collection days
- Mail-back return
  - prepaid, padded envelopes
  - used in NHANES
  - environmental effects – X-ray, cold, etc.

Promoting Compliance

- Daily activity log
  - time on/off, wake/sleep
  - supplemental activity information
- Written instructions with FAQ
- Anticipate barriers to wear – fashion, work-belts
- Provide information to employers, coaches, camp counselors, etc.
- Provide incentives contingent upon compliance

Data Interpretation

- Compliance-related decisions
  - determining wear-time
  - “complete” day of wear
  - sufficient number of days
  - impute missing days?
- Choice of outcome measure
  - mean counts per minute
  - compliance with recommendations
    - » cutpoints
    - » bouts?

Cutpoint choice (MTI adult)

Author	Moderate (3 MET)	Vigorous (6 MET)
Freedson et al., 1998	1952	5725
Yngve et al., 2003	2260 treadmill 2743 track	5896 6403
Hendelman et al., 2000	2191 walk 191 mixed	6893 7526
Swartz, et al., 2000	574 mixed	4945

Cutpoints

- Often based on small samples
- Often limited age ranges
  - University students, faculty and staff well characterized
- Depend on type of activities included

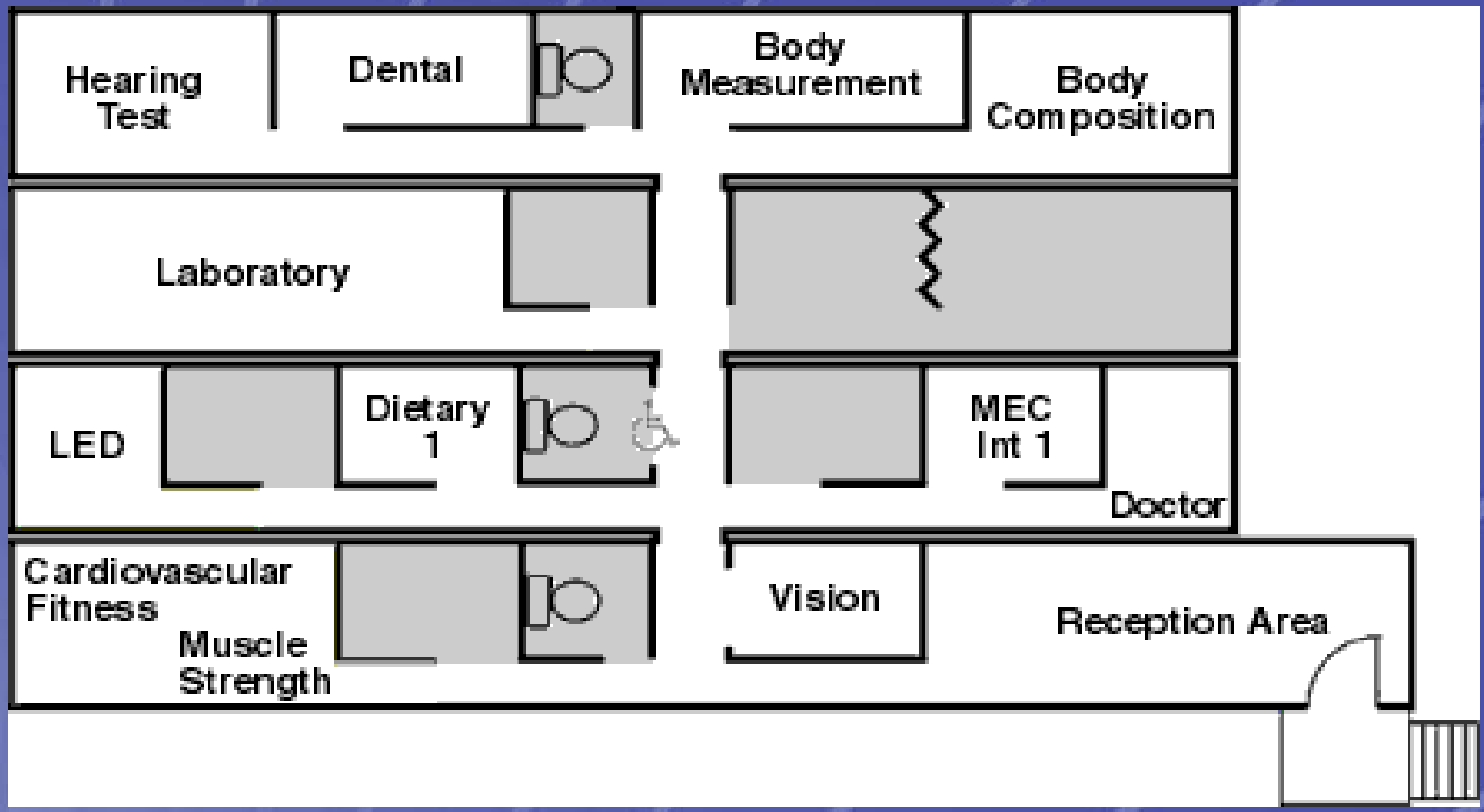
NHANES Example

NHANES

- Nationally representative sample
  - Household interview
  - Biomedical examination
- Oversamples on age/race/income
  - vary by particular survey
- Response rates >70%

NHANES Mobile Exam Center

NHANES


Hearing Test
Dental
Body Measurement
Body Composition
Laboratory
LED
Dietary 1
MEC Int 1
Doctor
Cardiovascular Fitness
Muscle Strength
Vision
Reception Area

Activity Monitors in NHANES

PA Monitors in NHANES

- Began in 2003
- Ages 6 y +
  - Wheelchair-bound/non-ambulatory excluded
- Ask for 7 d of wear while awake
  - Take off for water activities (swim, bathe)
- Mail back monitor

- Recruitment rate ~93%
- Monitor return rate ~97%

Accelerometer Considerations

- Removes cognitive reporting aspect
- Captures steps and intensity
- Primarily measures locomotor activity
  - Primary source of physical activity
  - No measure of load-bearing
  - Misses upper body and other movements
  - Question of intensity cutoffs for various ages
- No information on sources of activity
- Not a complete measure of total physical activity or energy expenditure

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- **Watch for MSSE Supplement**

Thank you – Questions?

http://riskfactor.cancer.gov

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