

Methods to Measure Physical Activity

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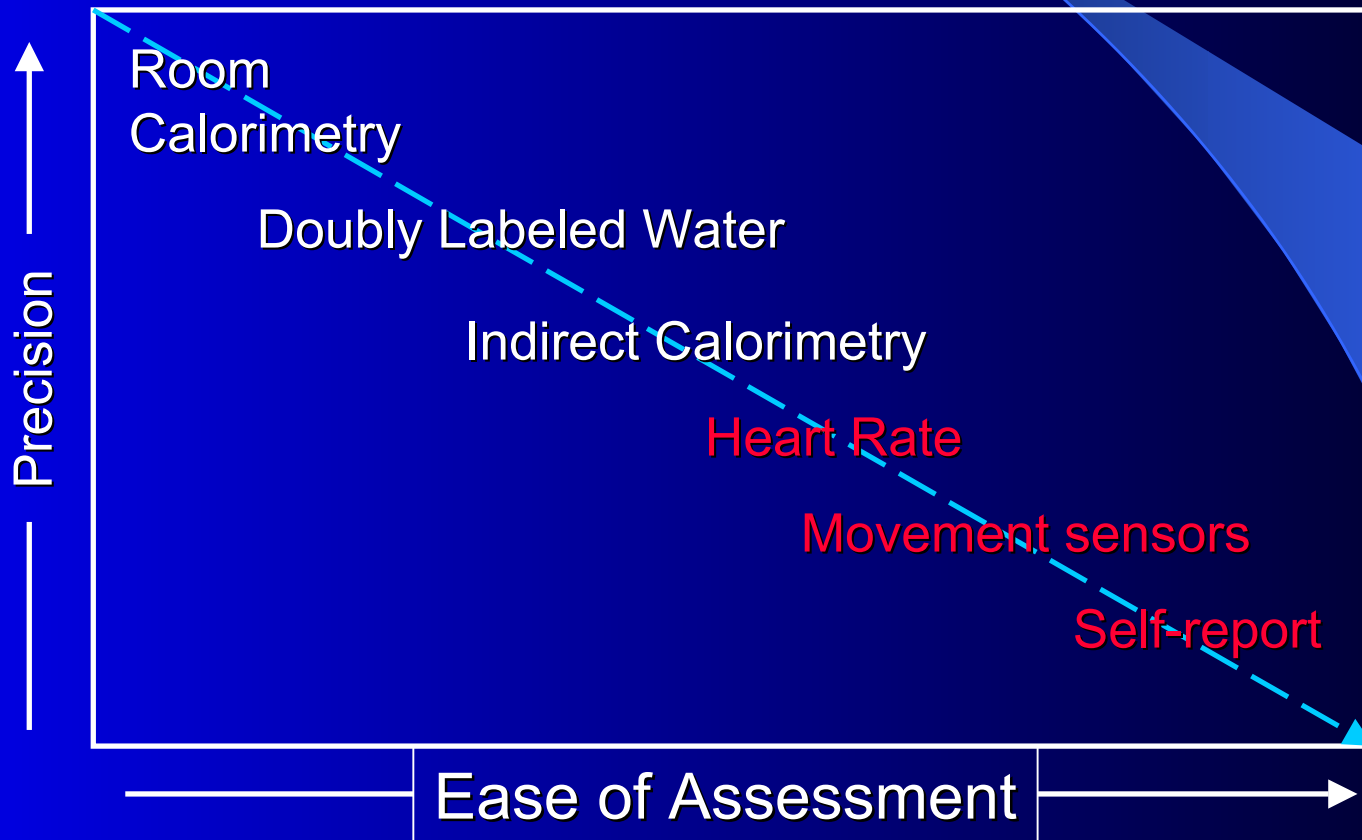
Definitions of physical activity

- ★ *Physical Activity* is "any bodily movement produced by skeletal muscles that results in energy expenditure"
- ★ **The energy cost of physical activity may not necessarily be equivalent to body movement**
- ★ *Exercise* is "a specific type of PA that is planned, structured and repetitive done to improve or maintain physical fitness"
- ★ *Physical fitness* is "a set of attributes either health- or performance related" and is not synonymous with physical activity

Why bother to measure physical activity better ?

- To estimate the true effect size
- To specify which dimension of physical activity is of most importance for a particular health outcome
- To make cross-cultural comparisons
- To monitor temporal trends within populations
- To measure the effect of interventions

Measuring Physical Activity - Levels of Sophistication



Measuring Physical Activity – Methods and Outcomes

| <u>Method</u> | | <u>Measurement</u> | | <u>Outcome</u> |
|-----------------------|---|---|---|------------------------|
| Room Calorimetry | → | CO ₂ and VO ₂ | → | EE |
| Doubly Labeled Water | → | CO ₂ production | → | EE |
| Indirect Calorimetry | → | CO ₂ and VO ₂ | → | EE |
| Accelerometry | → | Acceleration (i.e. body movement) | → | Counts |
| Heart Rate monitoring | → | HR | → | EE |
| Self-Report | → | Intensity, Frequency, Duration, (Type) | → | Activity score, EE, |

Validity of physical activity assessment methods

- Does the method measure what it is supposed to measure?
- Direct validation: Provides measures of energy cost, types, and patterns of body movement and/or physiological responses to body movement
- Indirect validation: Using measures that is likely to reflect habitual physical activity; i.e. fitness, body composition

Self-report Methods

- Questionnaires
- Activity Diaries

Objective Methods

- HR monitoring
- Accelerometry

Criterion methods

- Indirect calorimetry
- Doubly Labelled Water

Validity terminology I

- Criterion validity:

a questionnaire is validated against an objective method.

The relationship is frequently reported as a correlation coefficient (Pearson, Spearman)

Validity terminology II

- Absolute validity:
- The absolute outcome (i.e. EE or time spent in activity) is compared to data from an objective instrument which provides the same outcome measure.

The association is usually reported as the degree of agreement (Bland and Altman method).

Validity terminology III

- Concurrent validity:

A questionnaire is compared to another self-report instrument (i.e. diary or another questionnaire).

Although a high correlation between two subjective instruments suggest validity, the instruments are not of a different type and may be subject to correlated error.

Self-Report Methods

- Questionnaires
- Activity Diaries
- Recall interviews

Questions to be asked of any questionnaire

- What true exposure is it trying to assess ?
- What is the frame of reference of the questionnaire ?
- Is the validation sample representative of the study population?
- Has the questionnaire been validated against an appropriate comparison method ?
- Is the instrument reliable?

PAQs used in the general population

- Aerobic Center Longitudinal Study PAQ
- Baecke PAQ
- Bouchard 3-day physical activity record
- CARDIA physical activity history
- Framingham Physical activity index
- Godin Leisure-time exercise questionnaire
- HIP activity questionnaire
- Historical leisure activity questionnaire
- Kuopio Ischemic Heart Disease Study Q's
- Lipid research clinics questionnaire
- Minnesota Leisure-time PA
- Modifiable Activity Questionnaire
- Paffenbarger Physical Activity Questionnaire
- Seven-Day Physical Activity Recall
- Stanford Usual Activity Questionnaire
- Tecumseh Occupational PAQ

Validity of the EPIC physical activity questionnaire (EPAQ2)

2002

01/04/02

epic
European Prospective Investigation of Cancer

Physical Activity Questionnaire

This questionnaire is designed to find out how frequently you are in your everyday life.

Please try to answer every question, except when there is a separate request to skip a question.

If you are uncertain about how to answer a question then do the best you can. If you have any problems with the questionnaire the nurse will help you when you come for your health check or please telephone 02000 616611. If in a few phone calls time you will not be engaged for the call. You can call it any time of day or night or make an answering machine. Someone will call with you again and come back to you as soon as they can.

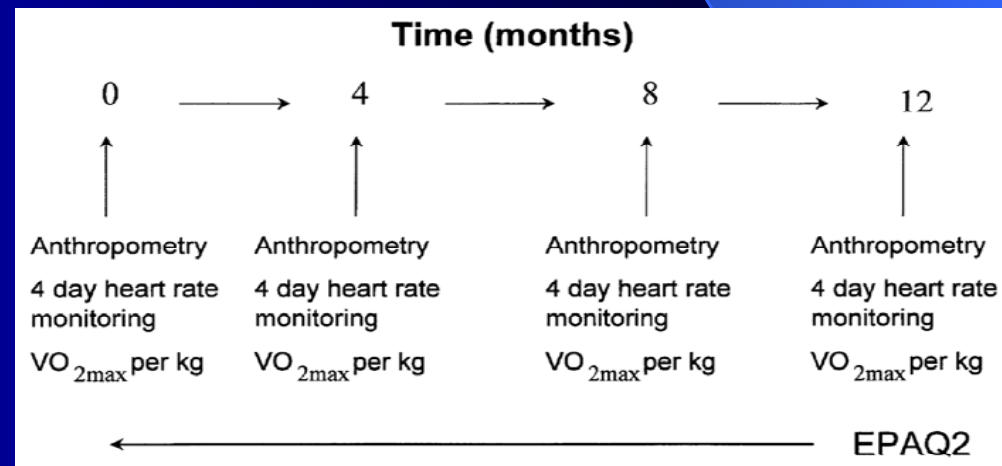
Your answers will be treated as strictly confidential and will be used only for medical research.

If you are unable to come to your health check, will you please complete this questionnaire and mail it in the freepost envelope.

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Collects information on last-year PA in 4 different domains

- DOMESTIC
- OCCUPATIONAL
- TRAVEL
- RECREATIONAL



Reliability of EPAQ2

| Reliability coefficients | Men (n=187) | Women (n=212) |
|-------------------------------------|------------------------|--------------------------|
| TV time (hr/wk) | 0.75 | 0.78 |
| Activity at home (MET-hr/wk) | 0.77 | 0.74 |
| Activity at work (MET-hr/wk) | 0.57 | 0.37 |
| Recreational activity (MET-hr/wk) | 0.69 | 0.64 |
| Vigorous activity (hr/wk) | 0.75 | 0.41 |
| Physical activity index (MET-hr/wk) | 0.74 | 0.72 |

Validity of EPAQ2

| | PAEE (kJ/hr) | VO _{2max} (ml/min/kg) |
|-------------------------------------|--------------|--------------------------------|
| TV viewing (hr/wk) | -0.07 | -0.19‡ |
| Activity at home (MET-hr/wk) | -0.04 | -0.09 |
| Activity at work (MET-hr/wk) | 0.17‡ | 0.01 |
| Recreational activity (MET-hr/wk) | 0.13 | 0.16‡ |
| Vigorous activity (hr/wk) | 0.01 | 0.16‡ |
| Physical activity index (MET-hr/wk) | 0.28§ | 0.15‡ |

Reliability and Validity of the International Physical Activity Questionnaire (IPAQ)

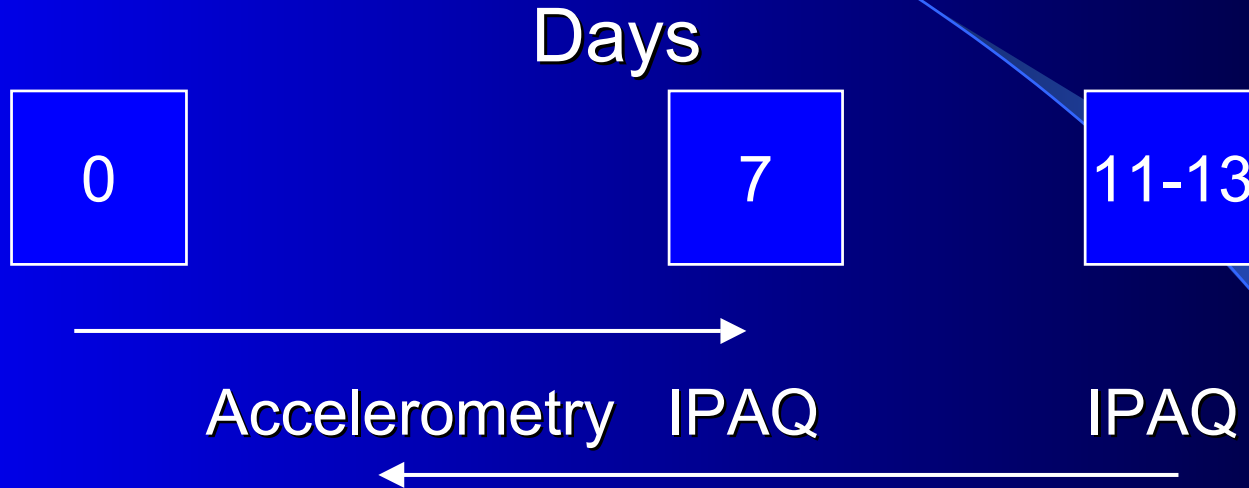


(www.ipaq.ki.se)

- 8 forms
- 14 centres in 12 countries
- Test-retest reliability (n=2632)
- Criterion validity (n=1854)
- Accelerometry as comparison instrument



Test-retest Reliability of IPAQ



All forms demonstrated a acceptable to excellent test-retest reliability ($r = 0.7 - 0.95$)

Criterion validity of IPAQ in comparison with other questionnaires

| | IPAQ* CSA | SDR Caltrac | MNLTPA Caltrac | Baecke Caltrac, LSI | MOSPA Caltrac | Godin Caltrac |
|-----|--------------|----------------|-------------------|------------------------|------------------|------------------|
| S7T | .07 | .33 | .21 | .17, .32 | .30 | .45 |
| SUT | .42 | | | | | |
| S7S | .25 | | | | | |
| SUS | .30 | | | | | |
| L7T | .36 | | | | | |
| LUT | .33 | | | | | |
| L7S | .33 | | | | | |
| LUS | .21 | | | | | |

Overall correlations IPAQ

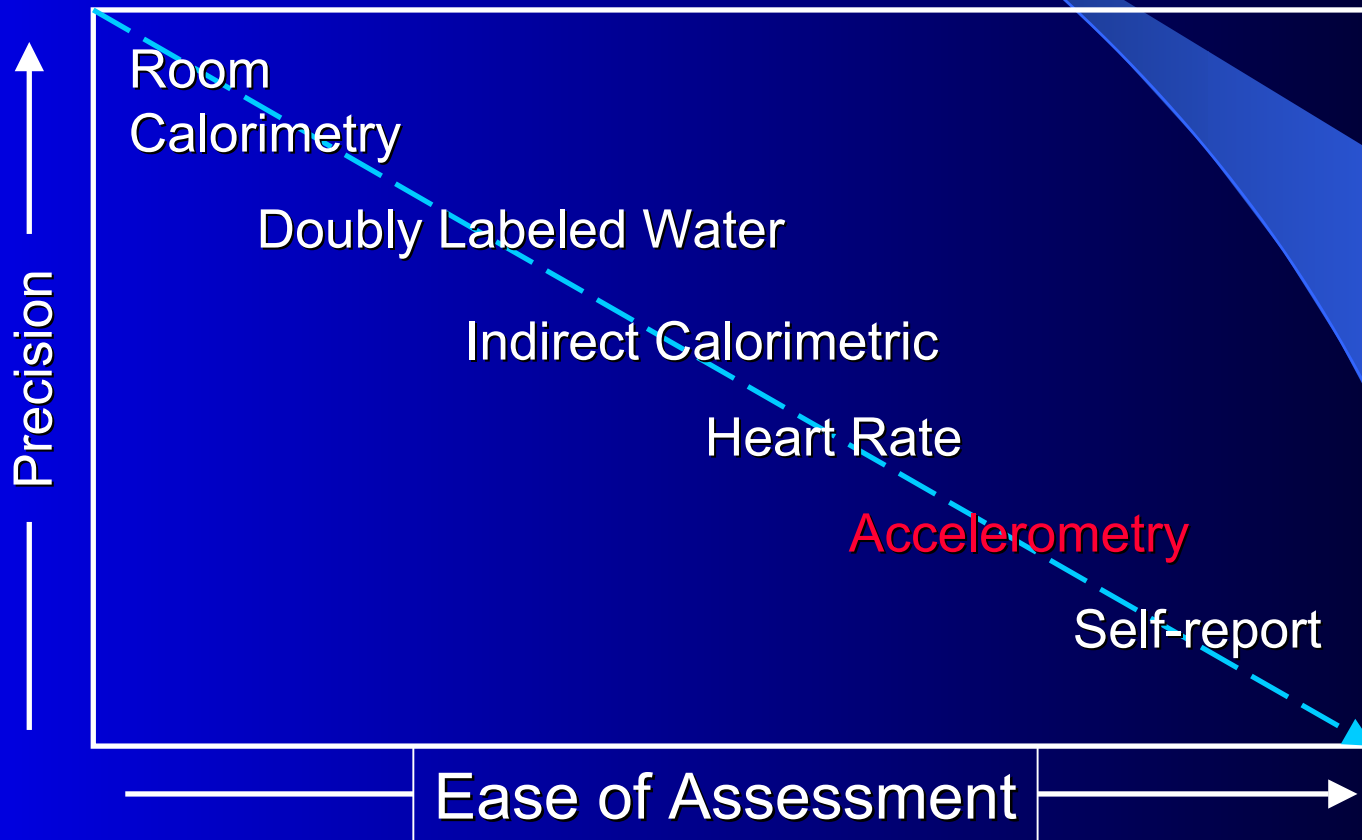
Short forms = 0.32

Long forms = 0.36

Summary; Questionnaires

- Reliability; usually good to excellent
- Criterion validity; poor to moderate (although significant)
- Absolute validity; questionable
- Questionnaires provide prevalence estimates of physical activity
- Questionnaires provide the possibility to categorise respondents into activity categories
- Questionnaires provide a poor measure of the absolute time spent at different intensity levels and the associated energy expenditure
- Questionnaires should be used with caution in children

Measuring Physical Activity - Levels of Sophistication



Assessment of body movement based on accelerometry

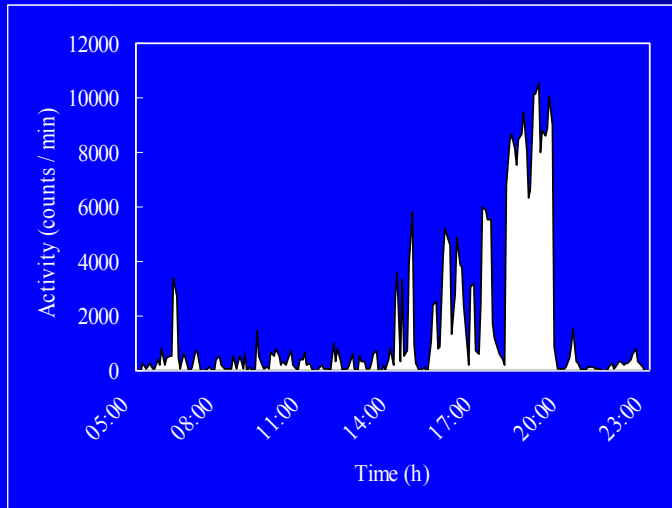
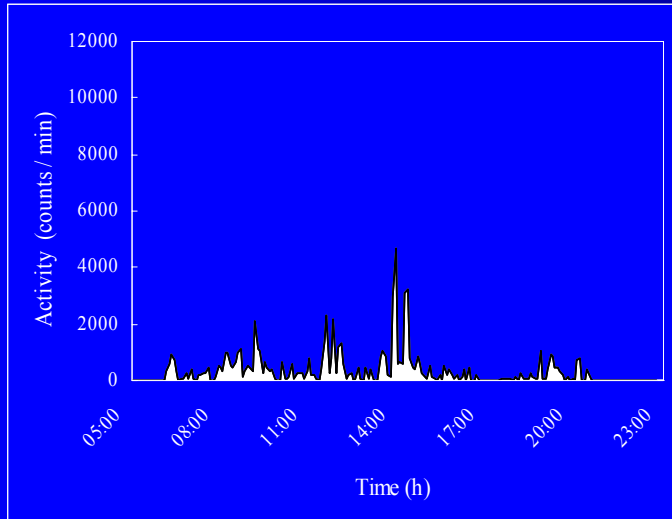
- **Principle:**

Direct measure of body movement (acceleration). When a person moves, the body is accelerated in relation to the muscular forces responsible for the acceleration of the body, and in theory to EE.

The acceleration can be measured in one (vertical), two (vertical + medio-lateral) or three (vertical + medio-lateral+anterior-posterior) directions.



Physical activity assessment by the MTI Actigraph accelerometer



- Provide a detailed description of activity patterns
- User specific epoch intervals
- Excellent data storage capacity
- Extensively validated
- EE from complex movements are not reflected by acceleration of the body (i.e. bicycling, upper body work, walking up/down, carrying goods etc.)
- Accelerometer data needs careful interpretation

Examples of validation studies using short-term protocols

REFERENCE

- Trost *et al.* MSSE (1998)
- Freedson *et al.* MSSE (1998)
- Eston *et al.* JAP (1998)
- Hendelman *et al.* MSSE (2000)
- Swartz *et al.* MSSE (2000)
- Welk *et al.* MSSE (2000)
- Nichols *et al.* RQES (2000)
- Nilsson *et al.* Ped Exer Sci (2002)
- Ekelund *et al.* Clin Physiol (2002)
- Puyau *et al.* Obes Res (2002)
- Yngve *et al.* MSSE (2003)
- Brage *et al.* MSSE (2003)
- Brage *et al.* Ped Exer Sci (2003)
- Reilly *et al.* Obes Res (2003)

PURPOSE

- Validity, (treadmill, children)
- Validity, cut-offs (treadmill, adults)
- Validity, (various activities, children)
- Validity, cut-offs (various activities, adults)
- Validity, cut-offs (various activities, adults)
- Validity, (treadmill, adults)
- Validity, cut-offs (treadmill + track, adults)
- Epoch length, (free-living, children)
- Validity, cut-offs (treadmill, CHD patients)
- Validity, cut-offs, (various activities, children)
- Placement (treadmill/track, free-living, adults)
- Validity, (treadmill + track, adults)
- Validity, (track, children)
- Cut-off sedentary, (free-living, children)

Cut-off points for different intensity levels

ACTIVITY CUT-OFF POINTS

(example: 10 y)

| | Trost <i>et al</i> | Puyau <i>et al</i> |
|-------------------------------------|--------------------|--------------------|
| Sedentary (cnts·min ⁻¹) | | < 800 |
| Light (cnts·min ⁻¹) | < 906 | 801 - 3200 |
| Moderate (cnts·min ⁻¹) | 906 – 3700 | 3200 – 8199 |
| Vigorous (cnts·min ⁻¹) | > 3700 | > 8200 |

$$\text{METs} = 0.0015 \text{ cnts}\cdot\text{min}^{-1} - 0.08957 \text{ age (yrs)} - 0.000038 \text{ cnts}\cdot\text{min}^{-1} \cdot \text{age (yrs)} + 2.757$$

(Trost *et al*, *MSSE*, 2002)

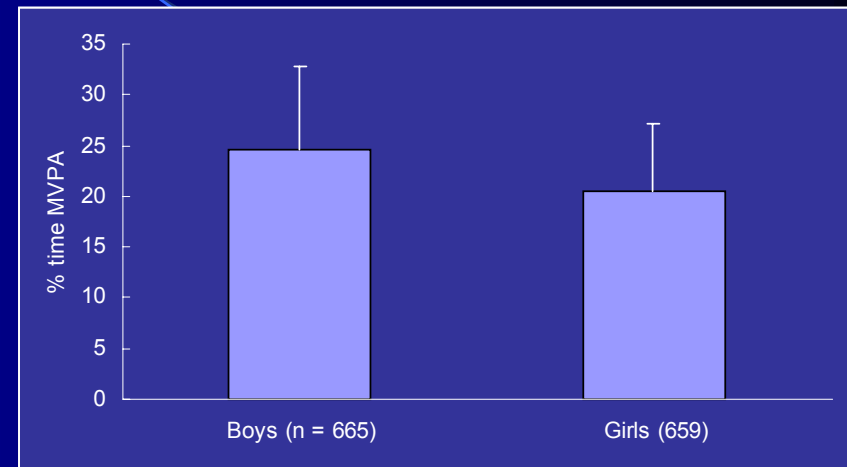
$$\text{PAEE (kcal}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = 0.000010 \text{ cnts}\cdot\text{min}^{-1} + 0.0183$$

(Puyau *et al*, *Obes Res*, 2002)

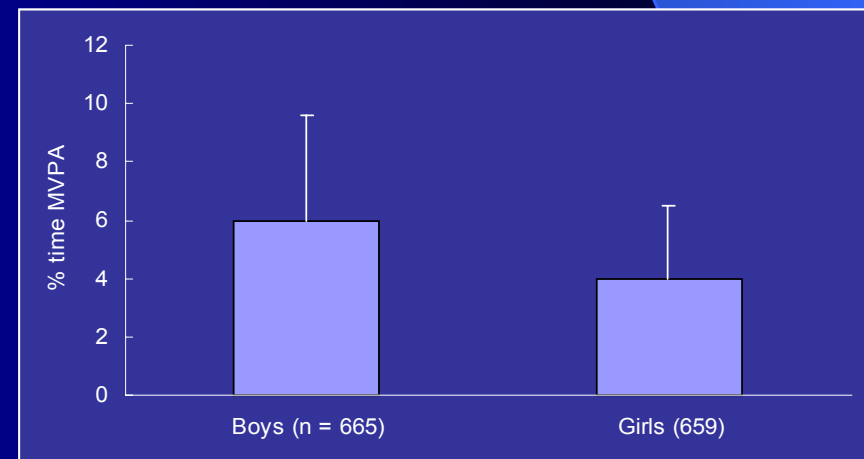
Application of different 'cut-off' points

- Time spent in MVPA in 9-10 year old children (n = 1324) from the EYHS study (Riddoch *et al.* MSSE, 2004) according to two different published cut-off points
- How to conclude whether children are active or not?

Cut-offs from Trost *et al.*

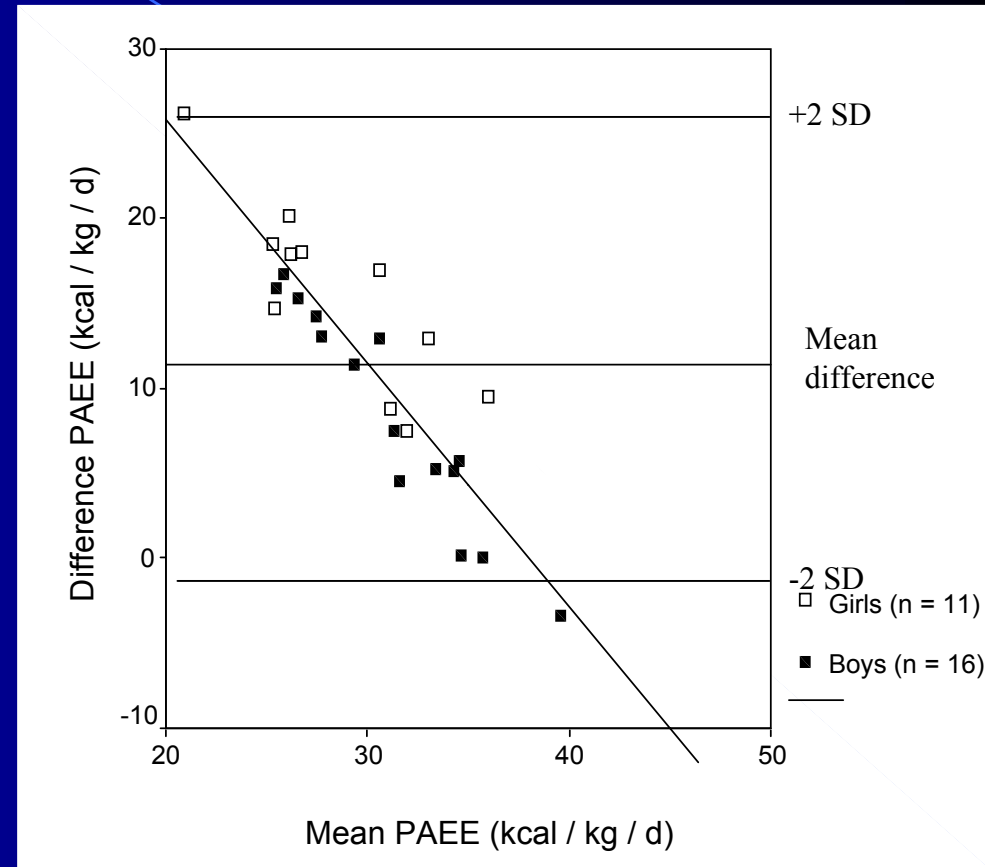


Cut-offs from Puyau *et al.*



Validity of a laboratory derived PAEE equation

- 26 children (9-10 y), simultaneous measurements of TEE by DLW and body movement by accelerometry
- Mean difference: 11.4 ± 7.0 kcal·kg⁻¹·d⁻¹ (P < 0.0001)
- Limits of agreement: + 25.4 and -2.6 kcal·kg⁻¹·d⁻¹
- $r = -0.90$ (P < 0.0001)
- The laboratory derived PAEE equation overestimated free-living PAEE by ~47%



Source: Ekelund et al. Lancet, 2004;363:1163

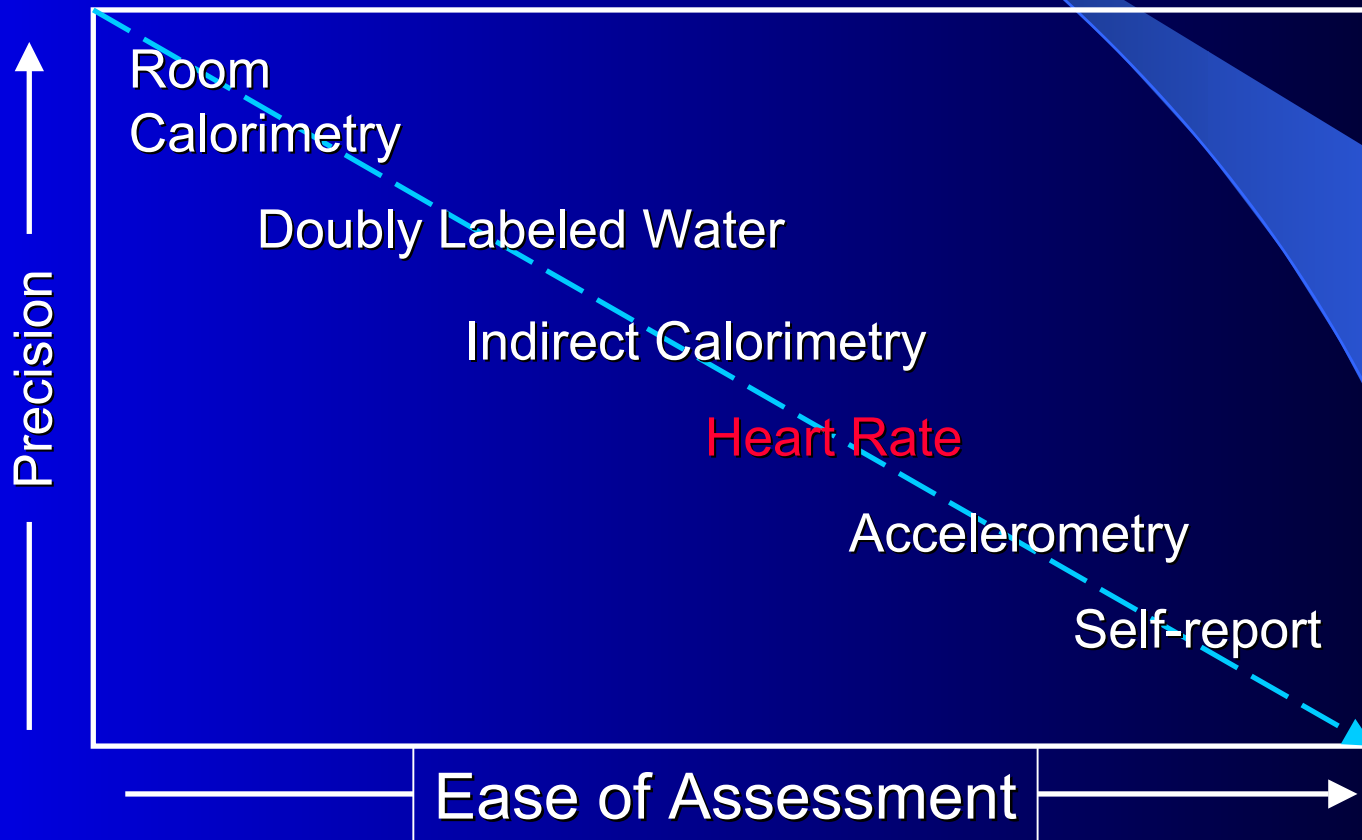
Summary of laboratory based validation studies

- Strong association ($r > 0.75$) between EE and activity counts in controlled settings
- EE prediction equations and thus, cut-off points for different intensity levels, differ depending on the calibration activities performed and the setting of these activities
- Published cut-off points are highly variable, ranging from $190 \text{ cnts}\cdot\text{min}^{-1}$ (Hendelman *et al.* MSSE, 2000) to $> 3000 \text{ cnts}\cdot\text{min}^{-1}$ (Puyau *et al.* 2002) for moderate intensity activity
- Prediction equations established in the laboratory are not valid for free-living PAEE prediction

Summary; Activity Monitors

- Extensively validated
- Applicable to children and adults
- Provide data on patterns of physical activity
- Valid for assessing the total amount of PA
- Cut-off points are arbitrary
- Laboratory based EE prediction equations are not valid for free-living
- Applicable in relatively large studies (n=4000)

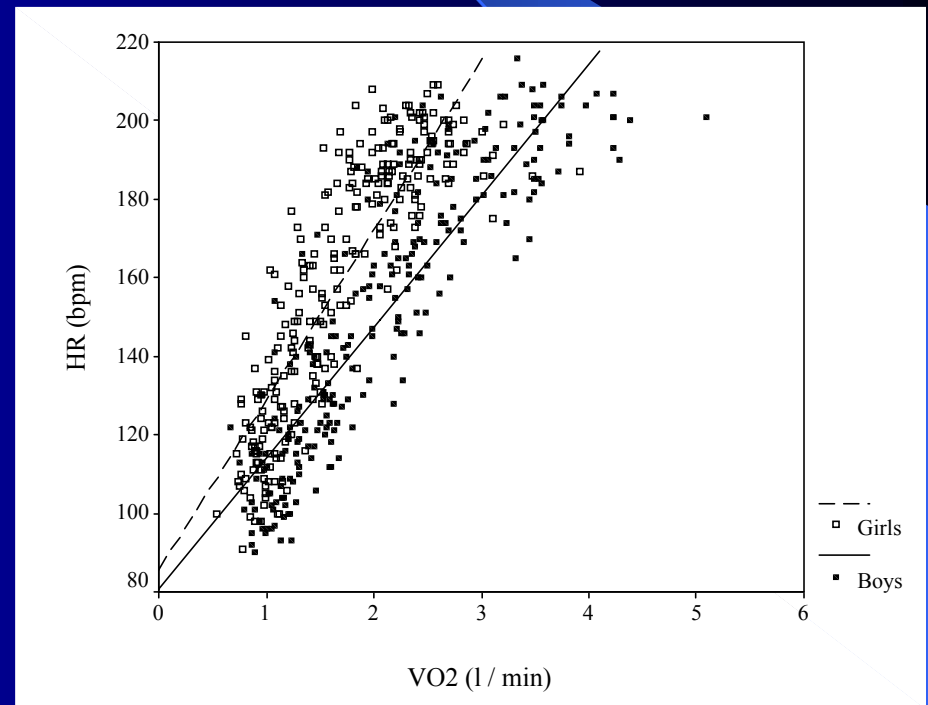
Measuring Physical Activity - Levels of Sophistication



Heart Rate Monitoring

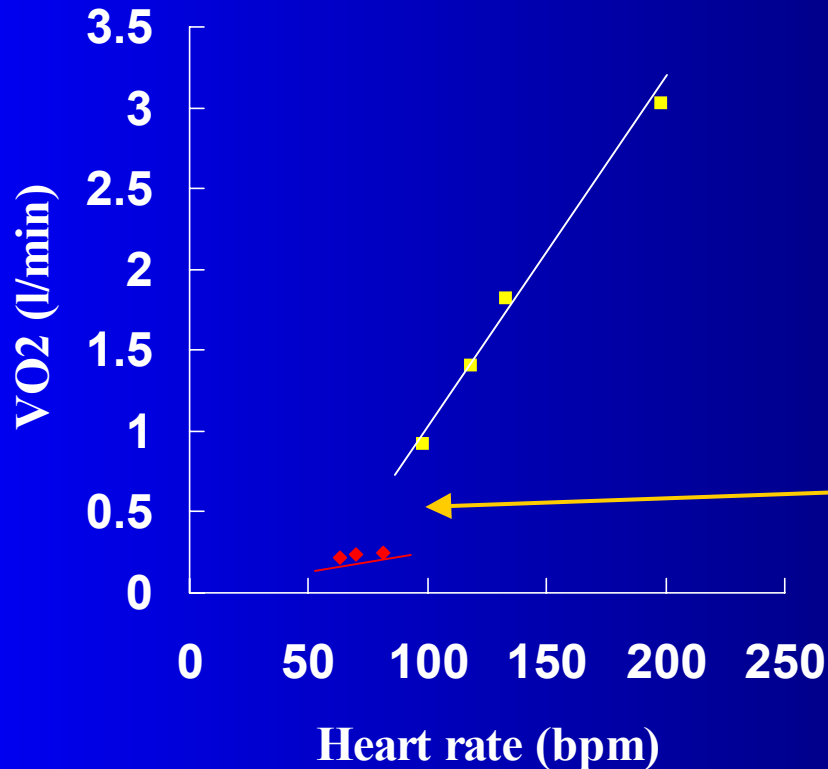
Principle:

Linear relationship between heart rate and energy expenditure during steady state work loads with large muscle groups



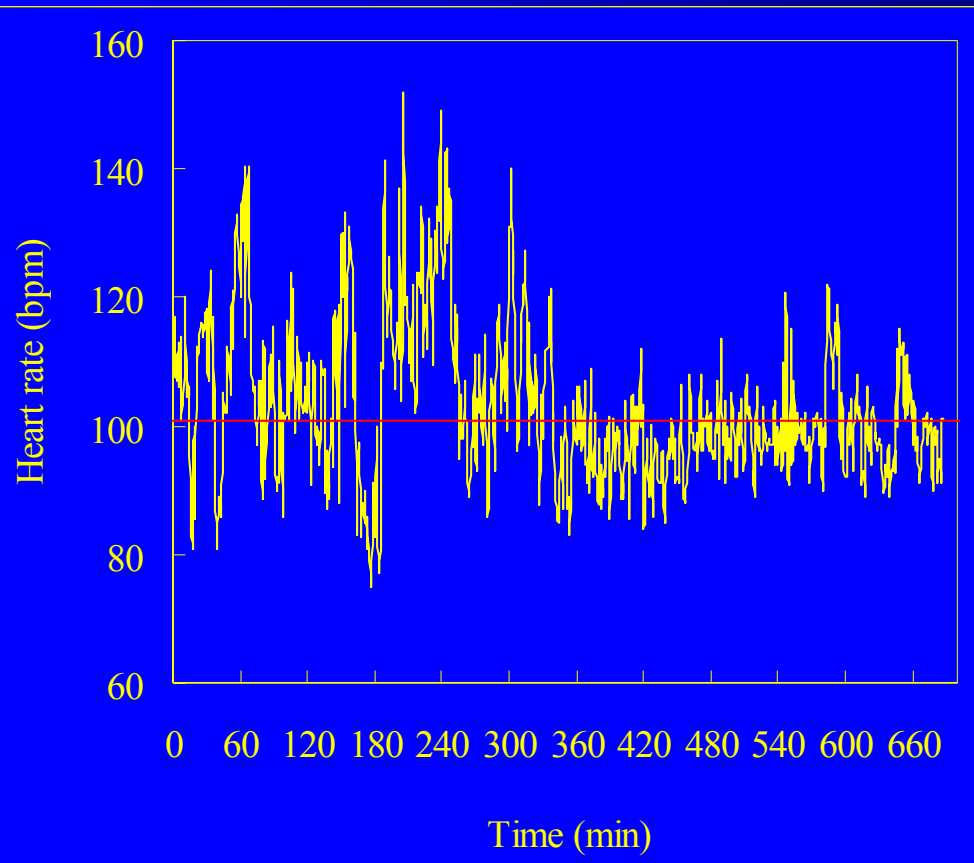
The FLEX HR Method

(Spurr *et al.* 1988)



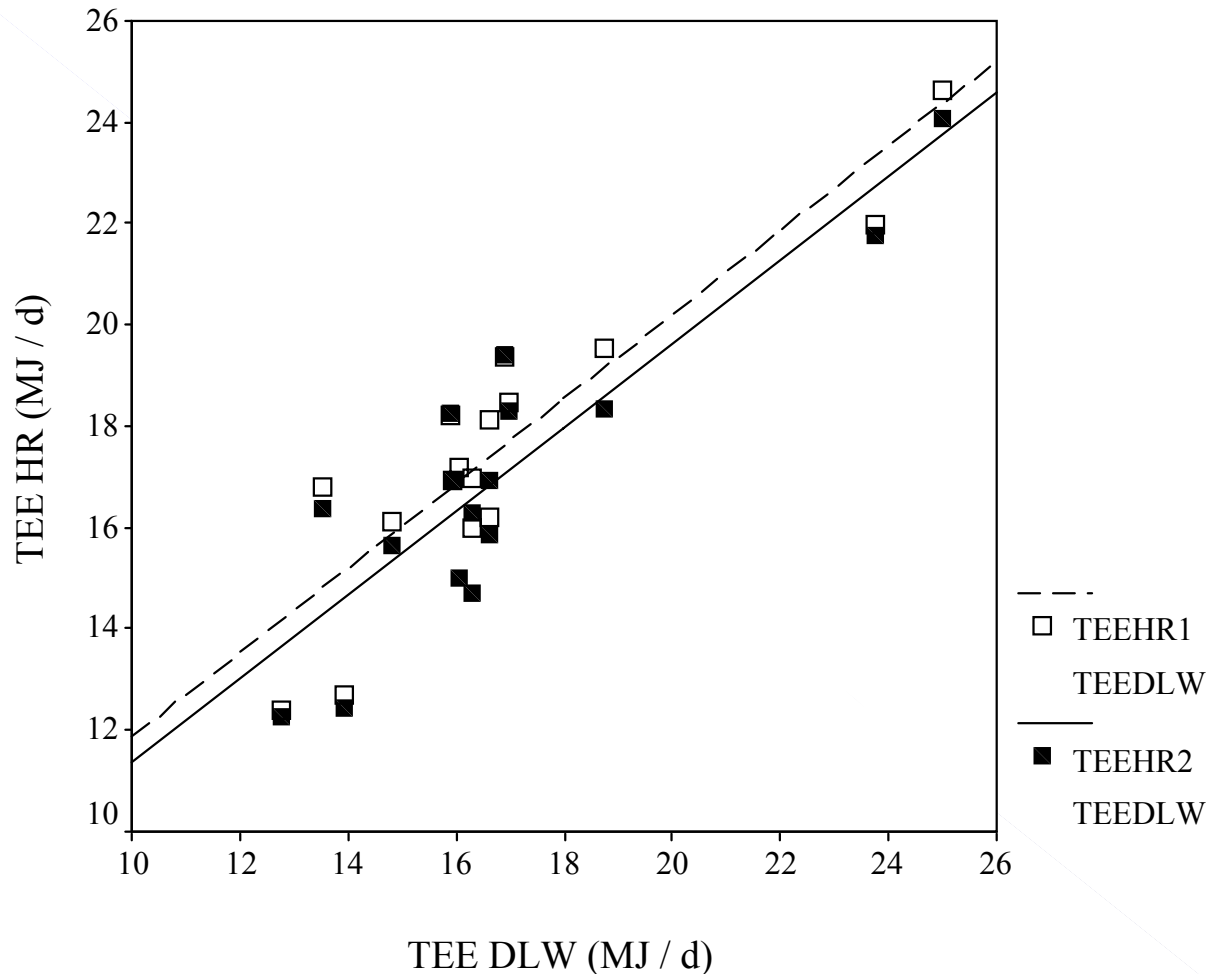
- Measurement or prediction of basal metabolic rate (BMR)
- Measurement of resting energy expenditure (REE; supine, sitting, standing)
- Individually determined FLEX HR
- min-by-min HR monitoring (4 d)

Calculation of TEE from HRM



- $TEE = EE_{\text{sleep}} + EE_{\text{rest}} + EE_{\text{act}}$
- $EE_{\text{sleep}} = BMR$
- $EE_{\text{rest}} = REE$ (HR < FLEX HR)
- $EE_{\text{act}} = EE$ from regression equations (HR \geq FLEX HR)

The relationship between TEE measured by the DLW-method and estimated by the FLEX HR method



$r = 0.90, P < 0.001$

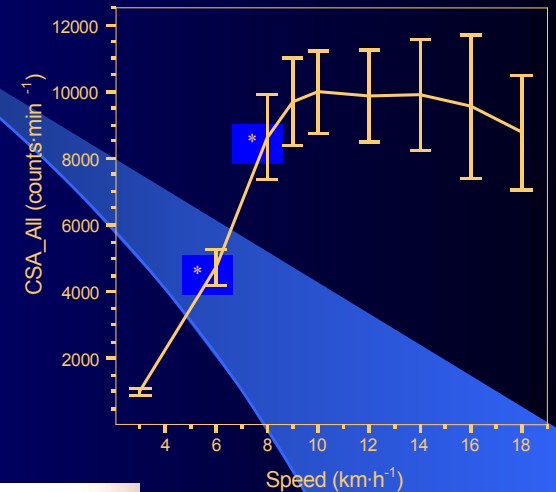
$r = 0.88; P < 0.001$

Summary; Heart Rate monitoring

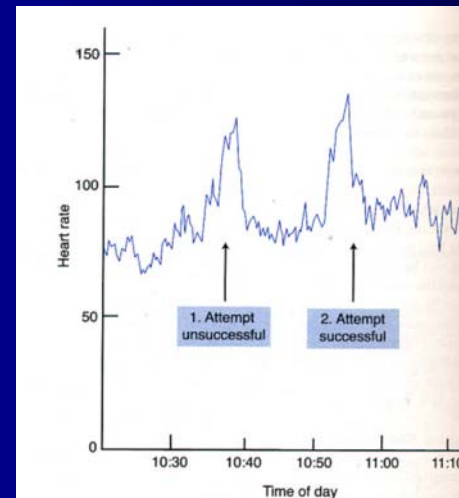
- The FLEX HR method is extensively validated in adults, children athletes, and obese
- Applicable in relatively large studies ($n = 1000$)
- Provide data on EE and pattern of PA
- Require individual calibration
- HR is affected by other factors than PA

The next generation of free-living physical activity assessment

- Accelerometry has limitations (e.g. bicycling, carrying goods, walking uphill etc.)
- Heart rate monitoring has limitations (e.g. elevated HR due to stress and environmental factors)
- Measurement errors from the two methods are not positively correlated
- **Combination of movement and HR-monitoring**

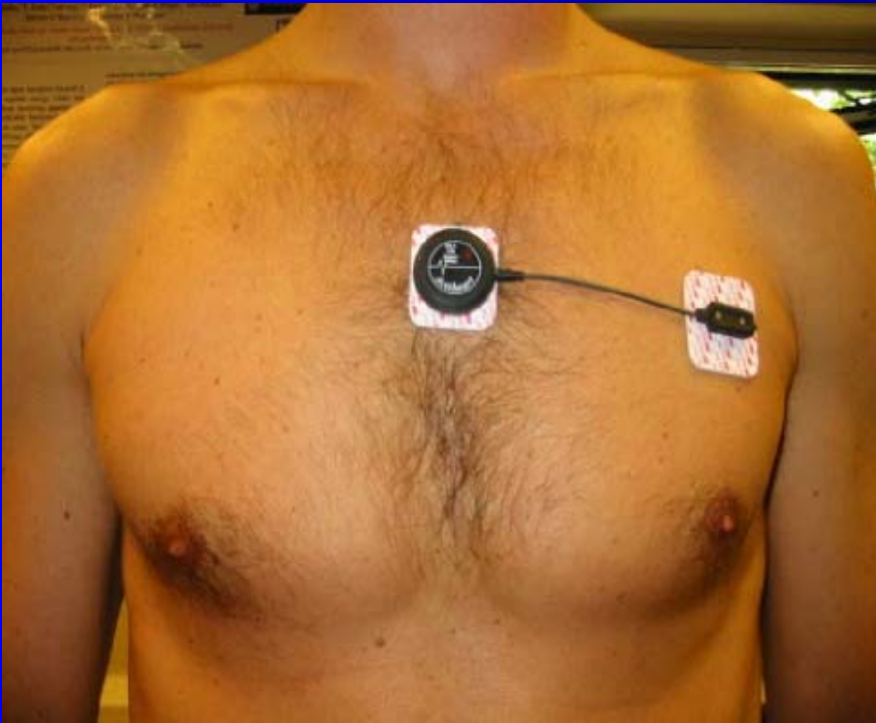


(Brage *et al*, MSSE, 2003)



(Adopted from Åstrand *et al*. 2002)

The next generation of free-living physical activity assessment



Actiheart is a combined HR and movement sensor (8 g, waterproof) currently being validated (submitted).

It will combine the advantages of body movement and HR for prediction of PAEE during free-living conditions using branched PAEE prediction equation modelling.

(Brage *et al*, JAP, 2004)

SUMMARY

- The choice of a method is a trade off between the research question, the available resources and feasibility
- Valid objective methods are now available which can be used in relatively large scale epidemiological studies (n~5000)
- Precise methods are needed in order to quantify dose-response relationships, gene-environment interactions, and longitudinal changes in activity patterns

Supplementary reading

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