Internet-based Measures of Physical Activity: Combining Traditional Approaches with New Technology for Better Exposure Assessment in Large-scale Studies

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Overview

• Focus on large-scale etiologic studies
• Why internet-based measures?
• History/evolution of physical activity questionnaires (PAQs)
• Limitations of PAQs and SBQs (sedentary behavior questionnaires)
• An Internet-based Approach: Activities Completed by Time in 24 Hours (ACT24)
Why internet-based measures?
Temporal trends in access to time-saving and labor-saving technology (% US Households)

**Computer Use and Broadband Access – US Adults 2011***

**Computer users**
- 30-49 yrs  87%
- 50-64 yrs  74%
- 65+ yrs    42%

**Broadband access**
- 30-49 yrs  73%
- 50-64 yrs  57%
- 65+ yrs    29%


*The Pew Internet & American Life Project (www.pewinternet.org)
Strengths/weaknesses of internet-based data collection in epidemiology

**Strengths**

Improved data quality
- Logic/error checking; data entry/processing
- Flexibility, responsiveness of assessment
- Automated data collection/reminders

Reduced costs (economies of scale)

**Limitations**

Selection factors (computer users; internet access)
Non-response bias (generalizability)

**Need More Information**

*Do traditional methods translate to e-environment?*

History and evolution of physical activity questionnaires (PAQs)
Initial assessment methods for free-living physical activity behaviors

Energy, Work and Leisure

Institute of Physiology, University of Glasgow

and R. Passmore, M.D.
Department of Physiology, University of Edinburgh

Early 1950’s → 1970s
The energy expenditure and food intake of middle-aged Glasgow housewives and their adult daughters

By J. V. G. A. Durnin, Elaine C. Blake and J. M. Brockway

Time

Energy expenditure

- Bed
- Personal necessities
- Sitting
- Standing activities
- Walking
- Shopping

Housewives

Daughters
### LEISURE TIME PHYSICAL ACTIVITIES

Listed below are a series of Leisure Time Activities. Related activities are grouped under general headings. Please read the list and check “YES” in column 3 for those activities which you have performed in the last 12 months, and “NO” in column 2 for those you have not. Do not complete any of the other columns.

<table>
<thead>
<tr>
<th>Activity (1)</th>
<th>Did you perform this activity?</th>
<th>Month of Activity</th>
<th>Average number of times per month</th>
<th>Time per occasion</th>
</tr>
</thead>
<tbody>
<tr>
<td>010 Walking for Pleasure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>020 Walking to Work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>030 Using Stairs When Elevator is Available</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>040 Cross Country Hiking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>050 Back Packing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>060 Mountain Climbing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>115 Bicycling to Work and/or for Pleasure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>125 Dancing-Ballroom, Square and/or Disco</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>135 Dancing, Aerobic, Ballet</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140 Horseback Riding</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Montoye AJCN 24:1113, 1971**
Streamlined assessments in current etiologic/prospective studies

Example: Overall sitting in one question

**National Health and Nutrition Examination Survey**

680 The following question is about sitting at work, at home, getting to and from places, or with friends, including time spent sitting at a desk, traveling in a car or bus, reading, playing cards, watching television, or using a computer. Do not include time spent sleeping. How much time do you usually spend sitting on a typical day? (Enter the number of minutes; you may need to use a calculator. If participant refused or doesn't know, see below or indicate minutes below.)
**Examples of domain/behavior-specific questions**

The first set of questions asks about your usual level of activity.

1. During the past 12 months, approximately how much time per week did you participate in each of the following activities? (For each activity, mark only one response.)

<table>
<thead>
<tr>
<th>ACTIVITY</th>
<th>AVERAGE TOTAL TIME PER WEEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Light household chores (for example, cooking, cleaning up, laundry,</td>
<td>None 5 min 15 min 30 min 1 hr 1 hr and 30 min 2-3 hrs 4-6 hrs 7-10 hrs More than 10 hrs</td>
</tr>
<tr>
<td>dusting, etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>b. Moderate to vigorous household chores (for example, vacuuming,</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>sweeping, etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>c. Moderate outdoor chores (for example, weeding, raking, mowing the</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>lawn, etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>d. Vigorous outdoor chores (for example, digging, carrying lumber, snow</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>shoveling, etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>e. Home repairs (for example, painting, plumbing, replacing carpeting,</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>f. Caring for children (for example, pushing a stroller, playing, lifting,</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>g. Caring for another adult (for example, lifting, pushing a wheelchair,</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>h. Walking for exercise</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>i. Walking for other daily (but not leisure time) activities, such as</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>shopping, getting to and from work, etc.</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>j. Jogging or running</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>k. Playing tennis, squash, or racquetball</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>l. Playing golf</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>m. Swimming bats</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>n. Bicycling (including riding a stationary bike)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>o. Other aerobic exercise (for example, aerobic class, exercise machines,</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>p. Weight training or lifting (includes free weights, resistance</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
<tr>
<td>training, etc.)</td>
<td>○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○</td>
</tr>
</tbody>
</table>

2010

Owing

D Day

utes
Limitations of Questionnaires to Estimate Usual Physical Activity (PA) and Sedentary Behavior

- Success in etiologic studies, but measurement errors are large
- Cognitive demands associated with reporting long-term averages are extraordinary
- Scope of questionnaires often limited (e.g., only leisure-time, television, or MVPA)
- Systematic reporting errors typically assumed (i.e., social desirability)
- Assessment of sedentary behavior in its infancy
Options for improving measures of activity-related behaviors and obtaining better estimates of behavior-disease associations

Current status: Large measurement errors and high levels of attenuation

**Option 1.** Use measurement error correction methods to minimize the impact of reporting errors

**Option 2:** Eliminate reporting errors: use objective indicators of behavior (e.g., accelerometers)

**Option 3.** Use short-term recalls to reduce the amount of reporting error in active and sedentary behaviors

= application of measurement error correction models

Matthews et al. ESSR (in press) 2012
Rationale for Short-term Recalls in Large-scale Studies

Short-term PA recalls (diaries, previous-day recalls)

- Often used as a reference instrument (assumed more valid).
- Rarely used as a primary exposure due to expense (to studies) and burden (on participants).

Internet-based implementation

- Automated data collection/scoring
- Economies of scale
- A modest number of recalls may be sufficient (for many “current” behaviors)
Activities Completed by Time in 24 Hours (ACT24) Development Team

Steven Moore
Heather Bowles
Amy Subar
Gordon Willis
Activities Completed by Time in 24 Hours (ACT24) System

Objective

• To assess how adults spend their time in sleep, active, and sedentary behaviors over 24-hrs via an automated email/web-based system

Development

• Review extant PA instruments and time use data
• Feasibility testing (NIH-AARP participants)
• Cognitive testing (card sorting, usability testing)
ACT24 Design Considerations

• 14 Major categories
• 111 individual activities (plus “Other”)
• Exercise/sports search (~110 activities)
• Four 6 hour time-periods
Activities added to timeline

Posture-based estimates of sedentary time

Activities added to timeline
ACT24 Next Steps

Methodological Studies

MEASURE Studies
• ACT24 vs. DLW, PA Monitors (ActiGraph, activPAL)

Quantify error structure in self-report relative to reference instruments
• Active behaviors (hrs/d, PAEE), sedentary behaviors (hrs/d)

Determine optimal sampling strategy to estimate usual amount (long-term average) of active/sedentary behavior
• How many days, how many periods/seasons (per year)?
MEASURE Studies

• Lifestyle Validation Studies (Harvard School of Public Health)
  – Nurse’s Health Study (women); N=750
    • Started Fall 2010, just completed
  – Health Professionals Follow-up Study (men); N=750
    • Starting Spring 2012

• Interactive Diet & Activity Tracking in AARP (iDATA, US National Cancer Institute)
  – AARP (women, men); N=760
  – Started Winter 2012
Development of Researcher Site

- Provide access to external studies
- Fall/winter 2012

If you want to take a look

http://act24demo.westat.com
Summary / Conclusions

Better measures of active and sedentary behavior are needed in large-scale epidemiologic studies.

Internet-based measures may enable implementation of less error prone ("traditional") methods in large-scale epidemiologic studies.
Thanks!
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NCI
Steve Moore, PhD

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NCI Intramural Research Program
Evaluation of a Cell Phone–Based Physical Activity Diary

BARBARA STERNFELD¹, SHENG-FANG JIANG¹, TERESA PICCHI¹, LISA CHASAN-TABER², BARBARA AINSWORTH³, and CHARLES P. QUESENBERY JR.¹

TABLE 2. Comparison of estimates of PA and data quality variables from cell phone and paper diaries (On the Move pilot study).

<table>
<thead>
<tr>
<th>Data quality variables</th>
<th>Cell Phone Diary (n = 39)³</th>
<th>Paper Diary (n = 38)³</th>
<th>Within-person Difference (n = 33)³</th>
<th>Spearman Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Median (Interquartile Range)</td>
<td>Mean ± SD</td>
<td>Median (Interquartile Range)</td>
</tr>
<tr>
<td>Total PA (MET-min⁻¹)</td>
<td>2014 ± 452</td>
<td>1941 (1687–2265)</td>
<td>2074 ± 267</td>
<td>2038 (1904–2165)</td>
</tr>
<tr>
<td>MVPA (min⁻¹)</td>
<td>136 ± 100</td>
<td>103 (70–169)</td>
<td>130 ± 91</td>
<td>102 (76–140)</td>
</tr>
<tr>
<td>Activities recorded (n.d⁻¹)</td>
<td>9.0 ± 1.7</td>
<td>8.6 (7.8–10.6)</td>
<td>10.6 ± 2.2</td>
<td>10.5 (9.1–12.3)</td>
</tr>
<tr>
<td>Time accounted for (min⁻¹)</td>
<td>1278 ± 145</td>
<td>1261 (1159–1397)</td>
<td>1301 ± 117</td>
<td>1328 (1246–1393)</td>
</tr>
<tr>
<td>Valid/expected days</td>
<td>0.71 ± 0.31</td>
<td>0.75 (0.5–1)</td>
<td>0.76 ± 0.37</td>
<td>1 (0.75–1)</td>
</tr>
</tbody>
</table>

23 men, age 45–65 yr, completed cell phone and paper PA diaries 4 d wk⁻¹ for three consecutive weeks and a user satisfaction survey. In the subsequent validation study, 623 middle-age participants (52.5% women) were asked to complete the cell phone diary and wear an accelerometer for two 7-d periods, approximately 6 months apart. They also completed two PA questionnaires. Fitness, body mass index, and percent body fat were obtained as indirect validation criteria. Results: Estimates of PA from the cell phone and paper diaries were similar (mean within person difference = -43.8 MET-min⁻¹ of total PA, SD = 360, P = 0.49, 7.4 min⁻¹ of moderate–vigorous PA, SD = 66, P = 0.53). Users preferred the cell phone diary over the paper diary (59.6% vs 35.4%). In the subsequent study, intraclass correlations for the cell phone diary ranged from 0.55 for light PA to 0.63 for vigorous PA. Although PA estimates from the cell phone diary were generally significantly higher than those from the accelerometer and the questionnaires, correlations for moderate and vigorous PA were moderate (ρ = 0.25–0.59 with the questionnaires and 0.27–0.35 with the accelerometer). The correlations between the cell phone diary and the indirect validation criteria were generally in the expected direction and of moderate magnitude. Conclusions: A cell phone–based PA diary is equivalent to a paper diary, acceptable to users, and a relatively reliable and valid approach to self-reported PA. Key Words: RELIABILITY, VALIDITY, SELF-REPORTED PHYSICAL ACTIVITY, RECALL ERROR, MOBILE TECHNOLOGY, ECOLOGICAL MOMENTARY ASSESSMENT
What kinds of studies do our measures need to serve?

**Association studies** (etiology of active and sedentary behaviors and disease outcomes, determinants studies)
- Long-term average, or usual level of behavior
- Specificity: targeted behaviors & contexts

**Interventions** (assess changes in sedentary time in response to intervention messages)
- Specificity (targeted behaviors) / responsiveness

**Surveillance** (estimate population average, or prevalence during specific period of time).
- Specificity (behaviors tracked by PHS)
Additional Questions for Certain Behaviors

Transportation

• Purpose of trip (e.g., commuting, errands, etc)

Sports/exercise

• Details about selected activities (e.g., walking, running, swimming distance)
• Rating of perceived exertion (relative intensity)
• Contextual information (where?, with whom?)
## Approaches to Self-Reported Physical Activity

<table>
<thead>
<tr>
<th>Category</th>
<th>Level of Detail</th>
<th>Timeframe</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaries</td>
<td><strong>High</strong> (all activities)</td>
<td>Real time</td>
<td>Validation</td>
</tr>
<tr>
<td>Logs</td>
<td><strong>High</strong> (specific activities)</td>
<td>Real time, past day</td>
<td>Intervention adherence</td>
</tr>
<tr>
<td>Recalls</td>
<td><strong>Medium</strong> (selected activities)</td>
<td>Past 1 to 7 days</td>
<td>Changes, current activity</td>
</tr>
<tr>
<td>Questionnaires</td>
<td><strong>Medium</strong> (selected activities)</td>
<td>Past year, usual</td>
<td>Usual activity</td>
</tr>
<tr>
<td>Global surveys</td>
<td><strong>Low</strong> (broad categorization)</td>
<td>Current, unspecified</td>
<td>Ranking usual activity</td>
</tr>
</tbody>
</table>

Adapted from Sternfeld JPAH 9:S19, 2012
Test-retest (9 wk) reliability (ICC) for the Past Year
Total Physical Activity Questionnaire
Friedenreich et al. AJE 163: 959, 2005

Men (n=75)  Women (n=79)
0.0  0.2  0.4  0.6  0.8  1.0
Total PA  Household  Recreation  Occupation

Intra-class Correlation (ICC)
FIGURE 1—Distribution of time in upright/active and sedentary behaviors in healthy controls and cancer survivors (N = 95).
Reliability and prevalence of reporting in the Yale PA Survey, by activity type
Study Types and Objectives

Consider three study types,…

1. Surveillance (public health objectives)
2. Interventions (behavior change)
3. Association studies (etiologic relations)

Population estimates (means, prevalence [%])

Individual estimates (classification)
Characteristics of behavior, cognition, and accuracy of long-term recall

### Higher

**Accuracy: Long-term Recall**

- Common daily activities
  - Sedentary time
  - Light, moderate activity
- Housework
- Occupation (details)

#### Exercise
- Occupation (broad)
- Television
- Commuting

#### Recall specific events / behaviors

### Lower

- Estimation strategies

- High frequency (weekly, within-day)
- Short duration (daily)
- Spontaneous/unstructured

- Lower frequency (within wk or day)
- Long duration (per day, 10+ mins)
- Planned/structured

Characteristics of free-living active/sedentary behaviors