Advances & Challenges in Measuring Physical Activity and Dietary Intake in Adults

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Acknowledgements

- NIH
- Blue Cross Blue Shield of Kansas City
- Healthy Weight Research Network
Dietary Assessment

- Food Frequency Questionnaire
- 24-hour diet recall
- Diet Record
Subjective vs. Objective Assessment of Energy Intake

Donnelly et al., Obesity, 2013
Self-report-based Estimates of Energy Intake Offer an Inadequate basis for Scientific Conclusions

- Schoeller, et al., AJCN, 2013 (16 prominent co-authors)

  “Going forward, we should accept that self-reported EI is fatally flawed and we should stop publishing inaccurate and misleading EI data.”
Weigh and Measure
Comparison of Energy Intake (Weigh & Measure) vs. Energy Expenditure (DLW) : MET 1

\[ \Delta 3\% \text{ for Men and Women} - \text{NS} \]

DK DK49181, Donnelly, PI
Digital photography+diet recall (DP+R)

- Photos taken of all meals
- Dietary recalls were conducted at each cafeteria meal to document any foods or beverages consumed outside the cafeteria
- Types and amounts of food and beverages consumed at the cafeteria, and results from recalls were entered into the Nutrition Data System for Research (NDS-R Versions 2011, University of Minnesota, Minneapolis, MN)
Digital Photography Examples

Before Meal

After Meal
Energy Intake Assessed by DLW, Digital Photography, 3d Food Records

Ptomey et al., JAND 2015

DLW-PPW Δ baseline = 6.8% error,
DLW-3DFR Δ baseline = 15.7 error%
Limitations

- Evaluated only in a cafeteria setting
- Relies on self-reported recall for meals consumed away from cafeteria
Remote Food Photography

- Use of smart phones for portion size estimation and nutrition analysis

Figure 2 When using the Remote Food Photography Method, participants use a smartphone to capture images of their food selection, leftovers and a reference card. These images are then immediately sent to a server for analysis. Reprinted with permission from Martin et al. (2012).

Table 1 Mean energy and macronutrient intake: pilot data comparing the Remote Food Photography Method (RFPM) with weighed food intake

<table>
<thead>
<tr>
<th>RFPM*</th>
<th>Mean (SD)</th>
<th>CV%</th>
<th>Weighed intake</th>
<th>Mean (SD)</th>
<th>CV%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, kJ [kcal]</td>
<td>4085 (1603)</td>
<td>[976.4 (338.3)]</td>
<td>34.7</td>
<td>Energy (kcal)</td>
<td>3516 (1242)</td>
</tr>
<tr>
<td>Protein, kJ [kcal]</td>
<td>677 (271)</td>
<td>[161.9 (64.9)]</td>
<td>40.1</td>
<td>Protein (kcal)</td>
<td>578 (225)</td>
</tr>
<tr>
<td>Carbohydrate, kJ [kcal]</td>
<td>2204 (795)</td>
<td>[526.8 (190.2)]</td>
<td>36.1</td>
<td>Carbohydrate (kcal)</td>
<td>1887 (725)</td>
</tr>
<tr>
<td>Fat, kJ [kcal]</td>
<td>1240 (568)</td>
<td>[296.6 (135.9)]</td>
<td>45.8</td>
<td>Fat (kcal)</td>
<td>1081 (500)</td>
</tr>
</tbody>
</table>

eButton

- Automatically takes pictures of foods consumed
- Can be combined with food recognition software
- 2.8% relative error in portion size compared to seed displacement


Limitations

- Requires recall or self-report for items that can not be captured by camera (condiments used in cooking, low fat vs. regular)
- If not using food analysis software must have staff who can analyzed photos.
- Requires individuals to remember to take photos of all meals, or wear device at all times
- Privacy concerns
Image Assisted Records

- Individuals fill out a standard food record and also capture images of foods
- When reviewing the record the researcher can get additional information/clarification of meals from both the photos and record
- High participant and researcher burden
- While studies show this improves estimates of energy intake by 10-54% it has not been validated to weight/measure or DLW

Automatic Image Analysis

- Measure food type and portion size through image analysis
- Error <6% in food volume for most foods

Limitations

- Individuals need to take the images
  - Adolescents better than adults at capturing images
  - Adults took better quality images
- High volume error for some food groups (condiments)
  - Improving with time
- Can’t determine some details of foods (ie. low-fat vs. regular fat)
- Cost and availability of software

Commercial Apps

Lose it!

My Fitness Pal

Edit

Dairy

Yesterday

1,600 - 1,610 + 600 = 5,980

Dinner

Fajitas - Steak
Homemade, 1 ea

377

Mexican Rice
Rice, 0.1 cup

50

Southwest Tortilla Soup
Burrito, 1 tackle (5 oz)

112

Chocolate Chip Bread Pudding
Burrito: 0.5 cup (7 tsp) / 160

190

Add Food

***

Morning Snack

Add Food

***

Adobe BBQ Restaurants

0.01 mi - 9700 N. Tompkins Rd

Request menu

Tin Tins Cotton Wine Bar & Private Dining

Request menu

Adobe BBQ Restaurants

0.04 mi - 9700 N. Tompkins Rd

Request menu

Cafe Venturas

Request menu

Cafe Fusion 5

Request menu

Cafe

2
Limitations

- Can be a good feedback/self-monitoring tool
- However, still self-report
- Data can be difficult to export for outcome analysis
- Poor long term compliance
  - 37% of days over 6 month study
  - 44% of days within 100 calories of goal EI

Willis et al. Distance Learning Strategies for Weight Management Utilizing Online Social Networks versus Group Phone Conference Call. (In Press)
Monitoring of Hand Gestures

- Bite frequency has been correlated with energy intake.
- Bite-based measure of energy intake showed less error than self-report compared to weigh and measure.

Scisco JL et al. (2014). Examining the utility of a bite-count-based measure of eating activity in free-living human beings
Swallowing Monitor

- Measures passage of food through the larynx during swallowing
- Up to 90.1% accuracy identifying when a person is eating food

Kalantarian H (2015). Monitoring eating habits using a piezoelectric sensor-based necklace
Ingestion Monitor

- Combines a jaw motion and hand gesture sensor, with an accelerometer
- Study in 12 individuals eating in a free living environment

Limitations

- Cost
- Inconvenient and cumbersome
- Device bias
- Not valid for measuring energy intake
- Rely on estimates of energy content in a bite or swallow
Food Spectroscopy

Scan
Near Infra Red (safe)

Food and beverages

Bluetooth

965 kcal eaten
% Carb
% Fat
% Protein
% Alcohol

App

DietSensor Database

Chronometric Database

Internet network
Wi-Fi
3G
4G
Things to Consider

- There have been numerous technological advances in dietary assessment
- Additional validation in free-living settings is needed
  - Needs validation for outcomes of interest (EI, portion size, food intake, macro/micro intake).
- Challenges include
  - Cost, participant burden (wear device or take photos), responder bias
Considerations for Dietary Assessment

- **Outcome** - Energy intake, macro/micronutrient intake, change vs. value?
- Reliability and validity for the outcome of interest
  - Do you need precision or accuracy?
- Participant and investigator burden for data collection
- Investigator burden for data processing and analysis
- Cost
Physical Activity Assessment

- **Subjective**
  - PA Questionnaire or Survey
  - Exercise Diary or Log

- **Objective**
  - Pedometer
  - Heart Rate Monitor
  - Direct Observation
  - Accelerometer
In a Perfect Research World
Next Best Thing?
Pedometers

- Inexpensive
- Activity categories based on step counts
- Some models store data which can be downloaded to a computer database

**Table 1**

<table>
<thead>
<tr>
<th>Physical activity level</th>
<th>Steps per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary or inactive lifestyle</td>
<td>&lt;5000</td>
</tr>
<tr>
<td>Low active</td>
<td>5000–7499</td>
</tr>
<tr>
<td>Somewhat active</td>
<td>7500–9999</td>
</tr>
<tr>
<td>Active</td>
<td>10,000–12,500</td>
</tr>
<tr>
<td>Highly active</td>
<td>&gt;12,500</td>
</tr>
</tbody>
</table>

Limitations

- Most only provide total daily steps
- Manipulate to increase “steps”
- Most require individuals to manually record pedometer steps to obtain data
- Minute-by-minute step data is only available with more expensive models
Heart Rate Monitors

- Convenient, relatively inexpensive, non-invasive, and versatile.
- Ability to quantify the intensity of exercise and estimate EE in continuous or steady state aerobic exercise.
- Used to estimate EE based on the assumption of a linear relationship between HR and oxygen consumption (VO2).

Heart Rate Monitors

- Limitations
  - Have to chest strap all day in order to capture all daily activities.
  - While there is a very close relationship between HR and EE during exercise, this is not the case during rest and light activity
    - Poor association between HR and EE at the lower end of the HR VO2 curve
  - The relationship between HR–VO2 differs between upper-body and lower-body activities, the use of a single regression line derived from an activity such as walking or running will not be accurate for other activities.
Accelerometer

- Small, hip worn device that detects accelerations of the body
- The most used device among research groups

Troiano et al. (2014) Evolution of accelerometer methods for physical activity research. BJSM
Limitations

- Participant compliance
  - 4-7 days for 10 hours a day
- Inability to measure static activity or differentiate level vs. uphill walking
- Inability to detect sitting vs. standing time
- Counts
- No uniform cut-points
- Conversion to energy expenditure
Wrist Worn Accelerometer

- Better compliance
  - 70% compliance and 61.8 Minutes/day of waking wear time then hip worn *
- Correlation between activity counts and EE lower on wrist then hip
- Dominant vs. non-dominant wrist
- No established intensity cut-points

* Measured in children not adults


Troiano et al. (2014) Evolution of accelerometer methods for physical activity research. BJSM
SenseWear Arm Band

- Collects data from multiple sensors: skin temperature, near-body temperature, heat flux, galvanic skin response, and a bi-axial accelerometer
- TEE within 10% of DLW

Limitations

- Cumbersome and uncomfortable to wear on upper arm
- Jawbone acquired Body Media in 2014 and they discontinued production of the Sensewear Arm band
  - Sensors now being used in commercial jawbone devices.
Intelligent Device for Energy Expenditure and Activity

- Estimates EE from 35 postures and activities identified and recorded using multiple sensors.
Limitations

- Much of the published work is laboratory-based, either validation studies of EE or highly controlled, short duration gait and posture analyses
- Difficulty of attaching the sensors
- Inconvenience and discomfort of wearing the sensors
- Limited memory capacity
- Cost
Consumer Physical Activity Trackers

- Many combine accelerometry with heart rate
- Upload data wirelessly
- Popular among individuals
Limitations

- **Accuracy**
  - Devices are redeveloped faster than accuracy/validity research can be conducted.
  - Published accuracy of devices is inconsistent

- **Not designed for research**
  - Access to data from multiple devices provided by manufacturers is difficult and time consuming
  - Data management available from third-party sites can be expensive
  - Manufacturers will not provide their cut-points/algorithms for intensity/EE

- **Provide immediate feedback**
One Device To Rule Them All?

OConnell et al. (2016) PLOS One

Remoortel et al. (2012) PLOS One
Considerations When Deciding on a Physical Activity Assessment Device

- What is the intended use? Physical activity, energy expenditure, sedentary time?
- Evidence for reliability and validity for assessing the outcome of interest
- Participant burden
- Cost
- Convenience – data collection and data management and analysis
Key Takeaways

- Measuring physical activity and dietary intake remains a challenge
- More research is needed to improve and validate technology for assessing physical activity and dietary intake
- When using technology for PA and EI one needs to determine what is most important for the outcome of interest
  - Validity
  - Burden
  - Cost