Methods of Measuring Adherence

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Energy Intake and Adherence

- A reduction in energy intake (EI) from habitual levels, is a key intervention in many clinical weight loss trials.

- Determining a dose-response relationship between calorie restriction (CR) and physiologic changes requires a robust assessment of EI at baseline and throughout the intervention.

- Intervention trials attempting to establish a relationship between diet and chronic disease require careful measurement of adherence to dietary protocols.
Methods of Measuring Adherence

- Traditionally, clinical studies designed to measure dietary adherence have involved weighing and measuring all foods and drinks consumed. Such labor-intensive methods make studies of large numbers of participants impossible.

- Many of the current options for estimating EI and %CR in clinical trials have limited accuracy.

- Self-reported energy intake is recognized to be inaccurate, with a bias towards under-reporting, particularly among obese individuals.

- Weight change is also an imperfect quantitative indicator of EI and %CR, in part because individuals differ in the degree of metabolic adaptation in response to a given level of CR.

- Only objective measure is the doubly-labeled water method, which is the gold standard for quantifying TEE in free-living individuals.
Self-Reported Measures of Dietary Adherence

24-hour recall:
• Participants are asked to recall their food intake during the previous day

• Interviews are conducted by trained interviewers or nutritionists

• Drawback:
  dietary intake is highly variable from day to day,
  multiple days of dietary intake are usually required
  extremely time-consuming

• May be inadequate for characterizing individual adherence but can serve
  the purpose of measuring dietary adherence of a large group
Self-Reported Measures of Dietary Adherence

Food frequency questionnaires (FFQ):

- List of foods with a frequency response section for participants to report how often each food was consumed

- Can be self or interviewer administered

- Method is inexpensive even if repeated assessments of dietary intake are required on large groups of participants because the form processing is computerized

- The drawback:
  May have limited validity for individual nutrient intakes; Generally assumed that individual assessment of nutrient intakes from the FFQ may be useful only in ranking individuals according to categories of nutrient intakes.
Self-Reported Measures of Dietary Adherence

Dietary Records or Food Diaries:
• Detailed records of types and quantities of food and beverages consumed during a specified period, usually 3 –7 days.

The advantages:
• No recall of past dietary intake
• Allows participant to measure their portion sizes
• Multiple days are recorded, so the problem of day-to-day variation is reduced

Drawbacks
• Extensive data entry and management that is required. Additionally, these records may not represent usual intake.
• Considerable burden on the participant, which limits its use to highly motivated participants.
Limitations – Self Report

Because of the potential inaccuracies of self-reported data, ongoing research is evaluating the usefulness of objective biomarkers (blood and urine) that may soon play a role in calibrating and improving the dietary data collection methods used to measure adherence to a dietary intervention.
Intake-Balance Technique for Assessment of Dietary Accuracy

• If total energy expenditure and energy balance are measured accurately, energy intake can be validated because:

Energy Intake = Total Energy Expenditure + Δ Energy Balance/Stores

• TEE can be assessed objectively by the doubly-labeled water method, which is the gold standard for quantifying TEE and EI in free-living individuals

• This approach is based on changes in concentrations of the nonradioactive isotopes deuterium and $^{18}$O in body fluids over 7 to 14 days following administration of DLW
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<tr>
<th>Element</th>
<th>Isotope</th>
<th>Abundance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>$^{1}\text{H}$</td>
<td>99.9844</td>
</tr>
<tr>
<td></td>
<td>$^{2}\text{H}$</td>
<td>0.0156</td>
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<tr>
<td>Oxygen</td>
<td>$^{16}\text{O}$</td>
<td>99.7630</td>
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<tr>
<td></td>
<td>$^{17}\text{O}$</td>
<td>0.0375</td>
</tr>
<tr>
<td></td>
<td>$^{18}\text{O}$</td>
<td>0.1995</td>
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</table>
Daily intake of $^2$H and $^{18}$O

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Intake (mg/kg/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^2$H</td>
<td>6.9</td>
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<tr>
<td>$^{18}$O</td>
<td>133.4</td>
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Theoretical Basis of the Doubly Labeled Water Method

Energy Metabolism

Carbohydrate
Fat + O₂ → CO₂ + H₂O + Heat
Protein

\[ ^2H_2{}^{18}O \]
Determination of Total Energy Expenditure
DLW Technique

Consuming a Weighed Mixed Dose of $^{2}\text{H}_{2}{^{18}}\text{O}$

Urine Samples 14 day period

$^{2}\text{H}$

$^{18}\text{O}$

$\text{H}_{2}\text{O}$ output

$\text{H}_{2}\text{O}$ output + $\text{CO}_{2}$ production

Isotope ratio mass spectrometer

$^{18}\text{O}$ - $^{2}\text{H}$

$\text{CO}_{2}$ production

$\text{CO}_{2}$ production

TEE
Energy Expenditure: Doubly Labeled Water Method

- Water inputs
- Body water $^{2H}_2^{18}O$
- Liquid water losses $^{2H}_2^{18}O$ (l)
- Evaporative water losses $^{2H}_2^{18}O$ (g)
- $C^{18}O_2$ (g)
Energy Expenditure: Doubly Labeled Water Method

Normalized enrichment (%)

Time (d)

Deuterium
Oxygen 18

Isotopic backgrounds
**DLW: Equations**

\[ VCO_2 \ (\text{mol/d}) = 0.4812 \times [(k_O \times N_O) - (k_H \times N_H)] - 0.0246 \times r_g \]

- \( k_O \) = fractional turnover rate of \(^{18}\text{O} \) (d\(^{-1}\))
- \( k_H \) = fractional turnover rate of \(^2\text{H} \) (d\(^{-1}\))
- \( r_g \) = evaporative water loss (mol/d)
  \[ = 1.05 \times (N_O \times k_O - N_H \times k_H) \]

\[ EE \ (\text{kcal/d}) = VCO_2 \ (3.815/RQ + 1.2321) \]

- \( RQ \) = provisional respiratory quotient of 0.86
Using DLW for Assessing Adherence

- \( EI = TEE + \Delta ES \)

  where \( EI \) is true energy intake
  \( TEE \) is total energy expenditure
  \( \Delta BE \) is the change in body energy

- You can compare this estimate of “true” \( EI \) to reported energy intake (ie. provided or prescribed) during CR to assess adherence
EI and Adherence Calculations

\[
CR\% = \frac{\text{Baseline EI} - \text{CR}_{(EI)}}{\text{Baseline EI}} \times 100
\]

\[
CR\% = \frac{\text{TEE}_{(BL)} - [\text{TEE}_{(CR)} + \Delta \text{BES}]}{\text{TEE}_{(BL)}} \times 100
\]

TEE is measured at intervals we calculate a weighted TEE value. For example,

\[
\text{TEE}_{0-6\text{mo}} = \frac{(\text{TEE}_{BL} \times 1 + \text{TEE}_{6\text{mo}} \times 5)}{6}
\]

for the BL to 6 mo period
Calculation of Body Energy Stores

Changes in body weight (g/day) are converted to \( \Delta ES \) (kcal/day) using the energy coefficient 7.4 kcal/g

\[
\Delta ES \ (\text{kcal/d}) = \Delta \text{weight} \ (\text{g/day}) \times 7.4 \ \text{kcal/g}
\]

Changes in body composition are converted to \( \Delta ES \) using 9.3 kcal/g as the energy coefficients of fat mass (FM) and 1.1 kcal/g as the energy coefficients fat free mass (FFM)

\[
\Delta ES \ (\text{kcal/d}) = \Delta FM \ (\text{g/day}) \times 9.3 \ \text{kcal/g} + \Delta FFM \ (\text{g/day}) \times 1.1 \ \text{kcal/g}
\]
Recovery of Excess Energy in Under/Overfeeding Studies

- Changes in body energy and energy expenditure during under/overfeeding must equal the change in intake unless non-compliance has occurred.

- Adherence cannot be assessed if changes in both body energy and energy expenditure, are not conducted at the same time.

- In the studies that did measure both outcomes, recoveries of energy sometimes differ substantially from 100%.
Adherence Calculation Issues:

• Coefficients for RQ. Using group RQ versus subject-specific RQ values. Subject specific RQ determined from dietary FQ (food logs), how to deal with under-reporting of energy in food records

• Uncertainty in estimates of provided or prescribed food

• Uncertainty in estimates of TEE by DLW

• Range of weight loss for a given Energy Restriction

• Further assumptions (e.g., energy content of weight, FM and FFM change)

• Values for ‘long-term’ based on change in body energy by DXA (so the main assumption is that TEE is the same during measurements as between measurements
What we think about

- DLW and ES are measured intermittently but we would like to know adherence routinely and average over various study periods (consider comparing weight change between DLW and non DLW periods?)

- What is the best way to determine body energy change during weight loss in individuals (regressed weight change?, DXA?)

- Is DLW as good as we think it is, and are assumptions of no change in accuracy during -ve energy balance valid?
Thank You!