Modeling, Validating, and Applying Mathematical Models to Determine Dietary Intake During Weight Loss Interventions?

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February 12, 2022
I do not have conflicts of interest or financial disclosures to declare.

The views expressed in this work are those of the authors and do not reflect the official policy or position of the United States Military Academy, Department of the Army, or the Department of Defense.
What did you eat over the last 24 hours? List everything!
Self-report–based estimates of energy intake offer an inadequate basis for scientific conclusions.

Dale A Schoeller, Diana Thomas, Edward Archer, Steven B Heymsfield, Steven N Blair, Michael I Goran, James O Hill, Richard L Atkinson, Barbara E Corkey, John Foreyt ... Show more
### Under-reporting Bias:

Compared to TDEE by Doubly Labeled Water: -10 to -30%

<table>
<thead>
<tr>
<th>Study</th>
<th>Subjects</th>
<th>Dietary Methodology</th>
<th>Energy Intake, MJ/day</th>
<th>Energy Expenditure, MJ/day</th>
<th>Reporting Bias, %</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coran and Poshman (11)</td>
<td>6 F (elderly), 7 M (elderly)</td>
<td>3-day Food record</td>
<td>5.99</td>
<td>8.75</td>
<td>-32</td>
<td>-3.77*</td>
</tr>
<tr>
<td>Reilly et al. (22)</td>
<td>10 F (elderly)</td>
<td>3-day Food record</td>
<td>6.71</td>
<td>9.21</td>
<td>-27</td>
<td>-3.12*</td>
</tr>
<tr>
<td>Taren et al. (28)</td>
<td>37 F</td>
<td>3-day Food record</td>
<td>8.25</td>
<td>9.33</td>
<td>-12</td>
<td>0.187</td>
</tr>
<tr>
<td>Tomoyasu et al. (31)</td>
<td>28 M (African-American)</td>
<td>3-day Food record</td>
<td>9.75</td>
<td>11.32</td>
<td>-14</td>
<td>NA</td>
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<tr>
<td>Tomoyasu et al. (30)</td>
<td>30 F (African-American)</td>
<td>3-day Food record</td>
<td>7.89</td>
<td>8.74</td>
<td>-10</td>
<td>NA</td>
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<tr>
<td>Tomoyasu et al. (30)</td>
<td>39 M (elder)</td>
<td>3-day Food record</td>
<td>8.73</td>
<td>11.30</td>
<td>-23</td>
<td>NA</td>
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<tr>
<td>Kaczkowski et al. (14)</td>
<td>53 F</td>
<td>4-day Food record</td>
<td>6.87</td>
<td>8.35</td>
<td>-18</td>
<td>NA</td>
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<tr>
<td>Clark et al. (7)</td>
<td>6 F (large eaters)</td>
<td>5-day Food record</td>
<td>10.49</td>
<td>8.49</td>
<td>-24</td>
<td>NA</td>
</tr>
<tr>
<td>Coris et al. (12)</td>
<td>30 M (obese)</td>
<td>7-day Food record</td>
<td>8.00</td>
<td>9.93</td>
<td>-19</td>
<td>NA</td>
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<tr>
<td>Livingstone et al. (18)</td>
<td>16 M</td>
<td>5-day Food record</td>
<td>11.21</td>
<td>14.23</td>
<td>-38</td>
<td>NA</td>
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<tr>
<td>Martin et al. (19)</td>
<td>15 F</td>
<td>7-day Food record</td>
<td>8.00</td>
<td>9.93</td>
<td>-22</td>
<td>0.643</td>
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<tr>
<td>Prentice et al. (21)</td>
<td>9 F (obese)</td>
<td>7-day Food record</td>
<td>6.73</td>
<td>10.22</td>
<td>-54</td>
<td>NA</td>
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<tr>
<td>13 F (lean)</td>
<td>5 F</td>
<td>7-day Food record</td>
<td>7.85</td>
<td>7.96</td>
<td>-18</td>
<td>NA</td>
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<tr>
<td>Seale and Rumpler (27)</td>
<td>14 F</td>
<td>7-day Food record</td>
<td>7.88</td>
<td>9.57</td>
<td>-18</td>
<td>NA</td>
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<tr>
<td>Lichtman et al. (16)</td>
<td>10 M</td>
<td>14-day Food record</td>
<td>8.06</td>
<td>12.91</td>
<td>-31</td>
<td>NA</td>
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<tr>
<td>Platte et al. (20)</td>
<td>10 F (control group)</td>
<td>14-day Food record</td>
<td>9.62</td>
<td>15.51</td>
<td>-46</td>
<td>NA</td>
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<tr>
<td>Tusch et al. (33)</td>
<td>11 F (unrestrained eaters)</td>
<td>14-day Food record</td>
<td>9.45</td>
<td>9.62</td>
<td>-2</td>
<td>NA</td>
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<tr>
<td>12 F (restrained eaters)</td>
<td>8.18</td>
<td>14-day Food record</td>
<td>8.18</td>
<td>8.61</td>
<td>-5</td>
<td>NA</td>
</tr>
<tr>
<td>Buhl et al. (5)</td>
<td>10 F (obese, diet resistant)</td>
<td>14-day Food record</td>
<td>8.30</td>
<td>9.50</td>
<td>-14</td>
<td>0.28</td>
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<tr>
<td>Black et al. (3)</td>
<td>18 F</td>
<td>16-day Food record</td>
<td>9.28</td>
<td>11.67</td>
<td>-14</td>
<td>NA</td>
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<tr>
<td>Rothenberg et al. (23)</td>
<td>27 M</td>
<td>24-h Recall (4 days)</td>
<td>10.06</td>
<td>11.06</td>
<td>-16</td>
<td>NA</td>
</tr>
<tr>
<td>Tran et al. (32)</td>
<td>35 F</td>
<td>Diet history</td>
<td>8.62</td>
<td>9.90</td>
<td>-13</td>
<td>0.27</td>
</tr>
</tbody>
</table>

\[
\text{Reporting bias} = \frac{\text{reported energy intake (EI)} - \text{measured total energy expenditure (TEE)}}{\text{measured TEE}} \times 100. \quad \text{A negative value for reporting bias indicates underreporting of EI. F, female; M, male; NA, not available. *Correlation coefficient determined using both genders. \dag P < 0.05; \ddag P < 0.01; \ddag P < 0.001.}
\]

Discrepancy between Self-Reported and Actual Caloric Intake and Exercise in Obese Subjects


CONCLUSIONS.
The failure of some obese subjects to lose weight while eating a diet they report as low in calories is due to an energy intake substantially higher than reported and an overestimation of physical activity, not to an abnormality in thermogenesis. (N Engl J Med 1992; 327:1893–8.)
Can we use a model to estimate Energy Intake?

- **Build a Model to Predict Weights from Energy Intake**
- **Validate the Weight Model**
- **Invert the Model**
- **Input Weights into the Inverted Model**
- **Predict Energy Intake from the Inverted Model**
- **Validate the Prediction of Energy Intake**
The first thermodynamic model: Antonetti


The equations governing weight change in human beings.

Antonetti VW.
Energy Balance Equation

ES = EI - EE

Rate of Energy Stores (ES) = Rate of Energy Intake (EI) – Rate of Energy Expenditure (EE)

kcal/d
“The human body generates more bioelectricity than a 120-volt battery and over 25,000 BTUs of body heat.”

Quote from Morpheus in the movie The Matrix
Energy Stores (ES)

It is the energy balance modeler’s choice on select state variables based on division of ES.
It is the energy balance modeler’s choice on how to divide EE and what factors of EE to incorporate. These dictate some of the model assumptions.
The first dynamic energy balance model

\[ ES = EI - EE \]

\[ ES = 7700 \frac{dW}{dt} \frac{kcal}{d} \]

The equations governing weight change in human beings

Vincent W. Antonetti

Development of the first energy balance model

\[ EE = 0.10 \, EI \]

\[ + \]

\[ mW(t) \]

\[ + \]

Mifflin St. Jeor

\[ RMR = aW(t) + b\text{Age} + c\text{Height} + d\text{Gender} \]

A new predictive equation for resting energy expenditure in healthy individuals\(^1\)\(^\text{-}^3\)

Mark D Mifflin, Sachiko T St Jeor, Lisa A Hill, Barbara J Scott, Sandra A Daugherty, and Young O Koh
\[ ES = EI - EE \]
A thermodynamic model: Antonetti

\[ ES = EI - EE \]

Rate of Energy Stores (kcal/d)
\[ ES = EI - EE \]

Rate of Energy Stores (kcal/d)

\[ 7700 \frac{dW}{dt} \]
\[ ES = EI - EE \]

Rate of Energy Stores (kcal/d) 
\[ 7700 \frac{dW}{dt} \]

Rate of Energy Expenditures (kcal/d)
A thermodynamic model: Antonetti

\[ ES = EI - EE \]

Rate of Energy Stores (kcal/d)

\[ 7700 \frac{dW}{dt} \]

Rate of Energy Expenditures (kcal/d)

\[ 0.10 \times EI + m \times W(t) + Mifflin St. Jeor \]
• Men

\[ 10 W(t) + 6.25 H - 5 A + 5 \]

• Women

\[ 10 W(t) + 6.25 H - 5 A - 161 \]
An equation that involves the state variable and its derivatives

$$7700 \frac{dW}{dt} = EI - (10W(t) + mW(t))$$

+ Everything else
Multi-site Consortium – Weight Loss Intervention – Doubly Labeled Water and Dual Energy X-Ray Absorpiometry
<table>
<thead>
<tr>
<th></th>
<th>Female CALERIE I</th>
<th>Male CALERIE I</th>
<th>Female CALERIE II</th>
<th>Male CALERIE II</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>7</td>
<td>5</td>
<td>95</td>
<td>40</td>
</tr>
<tr>
<td>age (years)</td>
<td>34.42 (3.97)</td>
<td>38.63 (7.14)</td>
<td>37.08 (7.10)</td>
<td>40.90 (6.65)</td>
</tr>
<tr>
<td>TDEE (kcal/d)</td>
<td>2341.00 (310.09)</td>
<td>3098.00 (404.24)</td>
<td>2246.60 (277.10)</td>
<td>2816.08 (342.13)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27.9 (1.9)</td>
<td>27.1 (1.4)</td>
<td>25.00 (1.78)</td>
<td>26.29 (1.57)</td>
</tr>
</tbody>
</table>

\[
EI_{measured} = 9500 \frac{\Delta FM}{\Delta t} + 1020 \frac{\Delta FFM}{\Delta t} + EE_F
\]
y = -0.07x + 5.57
R² = 0.03
Corey Gerving¹, Robert Lasater², James Starling², Danielle M. Ostendorf³, Leanne M. Redman⁴, Chad Estabrooks², Kevin Cummiskey²,
Vincent Antonetti⁵, Diana M. Thomas²

\[
W(t) = -\frac{\beta}{\alpha} + \left[ W_o + \frac{\beta}{\alpha} \right] e^{\alpha t}
\]

\[
EI = \left[ \frac{77000\alpha [W(t) - W_o e^{\alpha t}] - 10\gamma (e^{\alpha t} - 1)}{9 (e^{\alpha t} - 1)} \right]
\]
Validate the Inverted Model

\[ y = 0.8278x + 256.68 \]

\[ R^2 = 0.6916 \]
Validate the Inverted Model

\[ y = -0.005x - 75.209 \]

\[ R^2 = 7 \times 10^{-5} \]
Thank you Collaborators

Pennington Biomedical Research Center
Steven Heymsfield
Leanne Redman
Corby Martin

University of Wisconsin, Madison
Dale Schoeller

LTC James Starling
COL Corey Gerving
MAJ Rob Lasater
COL Michael Scioletti

Manhattan College/Florida
Vincent Antonetti

West Point
Why do individuals not lose more weight from an exercise intervention at a defined dose? An energy balance analysis


First published: 11 June 2012 | https://doi.org/10.1111/j.1467-789X.2012.01012.x | Citations: 157

expenditures. This information combined with available measurements was used to critically evaluate explanations for low exercise-induced weight loss. We conclude that the small magnitude of weight loss observed from the majority of evaluated exercise interventions is primarily due to low doses of prescribed exercise energy expenditures compounded by a concomitant increase in caloric intake.
Assume $\Delta PAEE=0$

Actual EI (kcal/d) vs. Predicted EI (kcal/d)

- $y = 0.9398x - 10.339$
- $R^2 = 0.8379$
$y = 0.9398x - 10.339$

$R^2 = 0.8379$
y = 0.0275x - 219.96
R² = 0.0043