PREDICTING ENERGY REQUIREMENTS

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“…..Estimated energy requirements are only a starting point, and that all clinicians should regularly review their patients to ensure they are meeting their nutritional goals and to evaluate the effectiveness of nutritional support”
Survey
Survey: Use Energy Equations Non Critical Care Adult Patients

Harris Benedict Equation

**Hands at Side**

Schofield .... Assume eg = SF 10% and AF 15%

(a) If Multiply BMR x \[1.0 + (SF + AF)\] (SF + AF = 25%)

(Non Cumulative approach)

(b) If Multiply BMR x (SF or AF), and then multiply other factor (Cumulative approach)

**Hands on Shoulders**

**Hands on Head**

Neither HB or Schofield

Wave Hands
Basil Metabolic Rate (BMR)

- Largest part of an individual’s total energy expenditure (TEE)
- Energy for internal mechanical activities and maintenance of body temperature
- Measure:
  - Post fast
  - At physical and mental rest
  - 22-29°C environment
  - No artificial stimulants (e.g., tea, coffee, nicotine)
  - No physical activity previous day
- Very difficult to control in clinical practice
BMR

Women:
- Highest between ages 23-35
- Increases more slowly > 65 kg
- More rapid drop > 50 years than for Men

Men:
- Highest between ages 18-20
- Increases more slowly > 75 kg

Horgan Eur J Clin Nutr 2003
Resting Metabolic Rate (RMR)

- 65-70% of TEE
- Little day to day variations
- Declines with age
  Loss Fat Free Mass & Gain of Fat Mass
- Subject to less strict conditions than BMR
  - Client Specific (Fasting, Exercise, Resting, Comfort)
  - Machine Specific (Calibration, Steady State, Adequate Test Time)

Rest of TEE

- Thermogenic response to food (10%)
- Expenditure physical activity (15 - 30%)

Energy Expenditure Equations

- Approx 138 Formulae (or more)....
  Published by 40 Authors
  - Many involve critical care patients

- Most common Australian Energy Expenditure Equations (Non Critical Care Pts)
  - Harris Benedict Equation
  - Schofield Equations

- Others:
  - Energy Estimates (per kg)
  - Others............

Energy Equations - Limitations

- **All** equations open to criticism for multiple reasons
- **Equations Based on Predictions for “Groups”**
  - Poor predictive value for “Individuals”
  - Equations do not explain 20% of variations between individuals
    (eg. tissue variations, disease, genetics, trauma including time since trauma)
- Require some clinical judgement

Energy Equations – Limitations (cont)

- Many based on measurements taken over 50 years with some data closer to 100 years
  - Early data was manually “cleaned up”
  - Some population groups “over” or “under” represented
  - Lack of validation studies
  - Gender % variations (eg. more males)

Current population
- More elderly
- Increased height and weight
- More overweight and obese
- Early puberty

- Equations focused on “healthy” – not designed to be applied for disease or injury
Harris – Benedict Equation

**Background**

- Developed between 1909 and 1917 and based on indirect calorimetry. Published in 1919 (J. Arthur Harris & Francis G. Benedict)

- Predominantly “normal” weight healthy white subjects (Boston) (N = 239)
  - 136 men aged 16-63 years (13 underweight)
  - 103 women aged 15-74 years (21 underweight)

- Younger (Mean Age F 27 +/- 9 Years, M 31 +/- 14 Years)
- Leaner (Mean BMI F 21 +/- 3 Years, M 22 +/- 4 Years)

- More active than current population

- Resting Metabolic Rate

Frankenfield JADA 2005, Reeves Nutr Rev 2003
Harris – Benedict Equation

Males:
RMR = 278 + (57.5 x W) + (20.9 x H) – (28.3 x A)

Females:
RMR = 2741 + (40 x W) + (7.7 x H) – (19.6 x A)

Key:
RMR  Resting Metabolic Rate (kJ/day)
W    Weight (kg)
H    Height (cm)
A    Age (years)
Adjustments to the HB Equation

HB Equation x AF X IF (Long et al 1979)

- **Activity factor**
  - Resting 1.1
  - Confined to bed 1.2
  - Out of bed 1.3

- **Injury factor** (N = 20-39 pts)
  - Minor Op 1.2
  - Skeletal Trauma 1.35
  - Cancer Cachexia 1.3-1.5
  - Major Sepsis 1.6
  - Severe Thermal Injury 2.1
  - Febrile 1 +0.09 per 0.5 °C > N

Reeves Nutr Rev 2003, Long JPEN 1979
HB = BEE or REE

Early works report HB = BEE

Later considered conditions = REE

Seale 1995:
Factor of 1 to 1.5 added to the BEE of HB Equation = RMR
Harris – Benedict Equation

Validation

- 1950’s Measured RMR Within 5%
- More recent studies (Indirect Calorimetry)
  - HB overestimates RMR by 6-15%
  - More predictive for Men
  - Large variation between persons

Reeves Nutr Rev 2003, Garrel NCP 1996
Harris – Benedict Equation

Interperson Variation Study

- Published 1996
- RMR (HB Equation vs Indirect Calorimetry)
- Subjects (39 Men and 28 Women)
  - Healthy, Normal Weight, Sedentary
- Results:
  - Mean overestimate 11.7%
  - RMR Quartile Variations
  - Predictive values women less accurate than men

| Lowest | 20.6% | 11.5% | 9.5% | 4% Highest |
Systematic Review HB 2005

- 25 Studies ..... *Focused on individuals not groups*

- HB as a Prediction of RMR
  - Healthy Non Obese Individual Adults
    - 45 - 80% Individuals
    - Overestimates > Underestimates
  - Healthy Obese Individual Adults
    - 38 - 64% Individuals Overestimates > Underestimates
    - Adjusted weight ↓ Risk of overestimating RMR
      ↓↑ Maximum underestimation error
  - Older Adults
    - Men: Maximum underest 19%, overest 9% RMR
    - Women: Maximum underest 27%, overest 12% RMR

Frankenfield JADA 2005
Schofield Equations

- First published in 1985
  - commonly used in Europe and Australia

- Developed from the statistical screening of data in the literature from 1914 to 1980

- Assumed linear relationship between BMR and Weight


- Recommended for use in Australians (1990, 2005)

Schofield Equations

- Meta-analysis 114 studies (7173 data points BMR) inc HB

- 4809 Men and 2364 Women
  - Infants to Adults (0-100 Yrs)
  - Europeans and North American & Developing countries
  - Italians (esp military)
    - 47% of the Schofield database >18 Years

- Higher proportion of Males, esp Italians 57%
- Very active, ↑ BMI's than other caucasians
- Few elderly (Only 1-2% > 60 years)
- Studies used “Closed-Circuit” Methods – ↑BMR’s
- ? Stress/anxiety breathing from closed chamber

Schofield Equations

- **Italians**
  - Young, physically active
    - (inc labourers, miners)
  - Higher BMR/kg than others
  - Most divergent subject group

- **Indians and Chinese**
  - 10% Lower BMR than Europeans + Americans
    - Age, Sex & Weight matched

Hayter Eur J Clin Nutr 1994
## Schofield Equations

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>RMR (Males)</th>
<th>RMR (Females)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>((0.249 \times W) - 0.127)</td>
<td>((0.244 \times W) - 0.130)</td>
</tr>
<tr>
<td>3-10</td>
<td>((0.095 \times W) + 2.110)</td>
<td>((0.085 \times W) + 2.033)</td>
</tr>
<tr>
<td>10-18</td>
<td>((0.074 \times W) + 2.754)</td>
<td>((0.056 \times W) + 2.898)</td>
</tr>
<tr>
<td>18-30</td>
<td>((0.063 \times W) + 2.896)</td>
<td>((0.062 \times W) + 2.036)</td>
</tr>
<tr>
<td>30-60</td>
<td>((0.048 \times W) + 3.653)</td>
<td>((0.034 \times W) + 3.538)</td>
</tr>
<tr>
<td>&gt;60</td>
<td>((0.049 \times W) + 2.459)</td>
<td>((0.038 \times W) + 2.755)</td>
</tr>
</tbody>
</table>

### Key:

- **RMR** = Resting Metabolic Rate (MJ/day)
- **W** = Weight (kg)

\[
TEE = BMR \times (1.0 + \%IF + \%AF) \quad \text{or} \quad BMR \times IF \text{ (Elia)} \times AF
\]

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>RMR (Males)</th>
<th>RMR (Females)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-3</td>
<td>(0.255 x W) – 0.226</td>
<td>(0.255 x W) – 0.214</td>
</tr>
<tr>
<td>3-10</td>
<td>(0.0949 x W) + 2.07</td>
<td>(0.0941 x W) + 2.09</td>
</tr>
<tr>
<td>10-18</td>
<td>(0.0732 x W) + 2.72</td>
<td>(0.051 x W) + 3.12</td>
</tr>
<tr>
<td>18-30</td>
<td>(0.064 x W) + 2.84</td>
<td>(0.0615 x W) + 2.08</td>
</tr>
<tr>
<td>30-60</td>
<td>(0.0485 x W) + 3.67</td>
<td>(0.0364 x W) + 3.47</td>
</tr>
<tr>
<td>&gt;60</td>
<td>(0.0565 x W) + 2.04</td>
<td>(0.0439 x W) + 2.49</td>
</tr>
</tbody>
</table>

**Key:**
- **RMR** = Resting Metabolic Rate (MJ/day)
- **W** = Weight (kg)

FAO/WHO/UNU (1985)
British Use Of Schofield Equations

British Dietetic Association 2007

- Calculate BMR eg. using Schofield Equation
- Adjust for Stress Factors (SF)
  - *Elia Nomogram (1990)* or
  - *Todorovic and Micklewright (2004)*
- Add a combined factor for activity and dietary induced thermogenesis (AF)
  - *Bedbound, immobile* + 10%
  - *Bedbound, mobile or sitting* + 15-20%
  - *Mobile, on ward* + 25%

BDA Note: Adding SF and AF is not cumulative
  Eg If 10% SF and 15% AF = BMR ↑ 25% total
  (not ↑ BMR by 10%, then 15%)

Thomas 2007, Elia Med Int 1990
Elia Nomogram

- Estimate energy requirements in disease
- Used in conjunction with Schofield equations (British Dietetic Assoc)
- ? Expert opinion

No reference to research or studies or how it is derived

Reeves Nutr Rev 2003
<table>
<thead>
<tr>
<th>Condition</th>
<th>BMR Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain Injury</td>
<td>0-50%</td>
</tr>
<tr>
<td>Cerebral Haem</td>
<td>30%</td>
</tr>
<tr>
<td>CVA</td>
<td>5%</td>
</tr>
<tr>
<td>COPD</td>
<td>15-20%</td>
</tr>
<tr>
<td>Infection</td>
<td>25-45%</td>
</tr>
<tr>
<td>IBD</td>
<td>0-10%</td>
</tr>
<tr>
<td>ICU</td>
<td>0-60%</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>25-34%</td>
</tr>
<tr>
<td>Lymphoma</td>
<td>0-25%</td>
</tr>
<tr>
<td>Pancreatitis</td>
<td>3-10%</td>
</tr>
<tr>
<td>Sepsis / Abcess</td>
<td>20%</td>
</tr>
<tr>
<td>Solid Tumours</td>
<td>0-20%</td>
</tr>
<tr>
<td>Transplantation</td>
<td>20%</td>
</tr>
<tr>
<td>Surgery</td>
<td>5-40%</td>
</tr>
<tr>
<td>Activity</td>
<td>Schofield</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Bed Rest</td>
<td>1.2</td>
</tr>
<tr>
<td>Very Sedentary</td>
<td>1.3</td>
</tr>
<tr>
<td>Sedentary</td>
<td>1.4</td>
</tr>
<tr>
<td>Light</td>
<td>1.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>1.8-1.7</td>
</tr>
<tr>
<td>Heavy</td>
<td>2.1-1.8</td>
</tr>
<tr>
<td>Very Heavy</td>
<td>2.3-2</td>
</tr>
</tbody>
</table>

Griffith University 2007
Schofield Equations

- Height not required

Other equations including height were developed, however including height did not improve accuracy.

- Mean BMI (>16 years) is not known.

14.6%  BMI > 25
4.5%  BMI > 30

*Lower % Overweight / Obese than today*

Schofield Equations

General: Predictive value 36-53%

Men:
- Overestimate BMR in men 3.7%
  Especially 18 - 29.9 Years
- Greater overestimate BMR when overweight and obese included

Women:
- Equations not accurate in women

Reeves Nutr Rev 2003, Ramirez-Zea Pub Health Nutr 2005
Schofield Equations

- Poor predictive value for adults ( > 18 years )
- Overestimates BMR current/most populations 7-10% especially if overweight or obese included
- Not accurate for the Elderly
- Not accurate for young Australian Men/Women (18-30 years)

General Estimates of Energy

Sedentary Adults (BW)

25 to 30 kcal (=105 to 126 kJ) / kg body weight

25 = Unstressed pts ranging to 35 = Pyrexia or Extreme Stress

19 to 21 = Obesity

Slightly Hypermetabolic Patients

For Weight Gain

30 to 35 kcal (=126 to 146 kJ) / kg BW

Anabolic Patients

Hypermethabolic patients

Severely Stressed patients

35 kcal (=146 kJ) / kg BW

Patients with Malabsorption

General Estimates of Energy

- Does not take into account Age, Gender or Energy Expenditure
- Use Actual or Ideal Weight?
- Developed for ventilated critically ill patients
- Underestimates true requirements
- In reality, amount of Energy per kg progressively decreases with increase in body size
- Does not take into account body composition
- What determines which value in the range should be used?
Case Studies – Equation Comparisons

- Green and Smith and Whelan Eur J Clin Nutr 2008
  
  How estimate BMR?
  Which stress factor for 37 clinical conditions?
  Given Standard Scale of Stress Factors (Elia 1990)
  
  40 year old male
  No PMH
  BMI 23
  Referred for Oral Nutrition Support

- Reeves and Capra Nutr Rev 2003 ****
  
  TEE:
  50 year old multiple skeletal traumas (Wt 68kg, Ht 175 cms)

- Reeves and Capra Eur J Clin Nutr 2003
  
  Energy Requirement:
  50 year old post laryngectomy (exc Larynx Ca).
  Wt 54kg, Ht 170 cms, RIB, Medically stable
  Weight loss 7 kg over 6 months secondary to Dysphagia
  Weight stable & intake adequate (2 wks prior to surgery)
"New" Equations (eg. Oxford)

- Why better predictive value?
  - Excluded all Italian subjects
  - Included larger number from Tropics
  - Sample Size
    - 11,000 measurements
“...Clinical judgment must be used to determine what level of nutrition care should be based on these estimates”.

Frankenfield JADA 2005

“...For many patient groups, however, there is a general lack of studies from which to make any useful recommendations”

Weekes Proc Nutr Soc 2007
“Nutrition is not an exact science. The most valuable tool in caring for these patients is a clinical team that uses energy expenditure calculations as a starting point but relies on clinical experience and individualization of patient management to enhance outcome”
REFERENCES

REFERENCES (continued)

REPRESENT (continued)

- Todorovic, VE et al. (2004) A pocket guide to clinical nutrition. BDA