Using Energy Expenditure Assessment from Indirect Calorimetry to Enhance Care and Practice

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Objectives
- Review components of energy expenditure
- Evaluate evidence-based methods for estimating energy requirements in adult normal individuals and ill or injured patients.
- Discuss indirect calorimetry for measuring energy requirements in adult normal individuals and ill or injured patients.
- Discuss application of energy expenditure methodology in private practice.

Energy Expenditure

Maintenance of body functions is dependent on a constant amount of voluntary and involuntary energy expenditure. Energy is expended in the human body for microprocesses such as active transport, the synthesis of macromolecules, and for contraction of muscles.
### What Effects Energy Expenditure?

- Age
- Gender
- BSA - Height / Weight
- Activity
- Size/Stature
- Race
- Other: climate, smoking

### Components of energy expenditure

- Basal metabolic rate - 60 - 80%
- Resting metabolic rate - 10% above
  BMR - typically represents 60 to 75% of TEE in free living people
- Thermic Effect of Food - 6 - 10%
- Activity ????
- Disease or illness - ????

### BMR/BEE

- Minimum amount of energy expended that is compatible with life.
- Reflects the amount of energy used over 24 hours while physically and mentally at rest in a thermoneutral environment that prevents the activation of heat-generating processes such as shivering.
RMR/REE

- the energy expended in the activities necessary to sustain normal body functions and homeostasis – includes
  - respiration and circulation
  - the synthesis of organic compounds, the pumping of ions across membranes
  - energy required by the central nervous system and for the maintenance of body temperature
- ~60% of REE can be accounted for by the heat produced by the liver, brain, heart, and kidneys

TEF (DIT, SDA, SEF)

- increase in energy expenditure associated with the consumption, digestion and absorption of food
- ↑'s more after ↑ protein meal compared to a ↑ fat meal
- Spicy foods enhance and prolong the effect of the TEF.
- accounts for approximately 10% of TEE

Other factors

- Caffeine. Intakes of 200 to 350 mg in men and approximately 240 mg in women have been show to ↑ REE by 7% to 11% and 8% to 15%, respectively
- Nicotine. ↑ REE by 3% to 4% among men and by 6% among women
- Alcohol. ↑REE in women by 9%
- Fevers. ↑ REE by ~7% for each degree of increase in body temperature above 98.6°F or 13% for each degree above 37°C (Hardy and DuBois, 1930).
Activity

- energy is expended in activity – (daily work and movement)
  - Activity thermogenesis (AT) - energy expended during sports or fitness exercise
  - Nonexercise activity thermogenesis (NEAT) - energy expended during activities of daily living – during the work day, during leisure-type activities (e.g., shopping, fidgeting, and even gum chewing)
  - most variable component of TEE ranging from 100 kcal/day to 3000 kcal/day in athletes
Energy Equation Evaluation

What is the goal or research question of the study?
What type of patients were studied?
How many patients were studied?
Is the statistical analysis suitable?
Do the results of the researcher coincide with your observations in clinical practice?

Harris - Benedict Equations

Subjects - 239
136 male 103 female
Weights Heights Ages
40 - 100 kg 140-210 cm 20-70 yrs

Measurement Conditions
no skeletal activity for 30 minutes
traveled to the center
indirect calorimetry

Men: RMR = 66 + 13.8 (W) + 5 (H) - 6.8 (A)
Women: RMR = 655 + 9.6 (W) + 1.8 (H) - 4.7 (A)
W – weight (kg), H – height (cm), age = yrs

Harris, JA and Benedict FG. Biometric Studies of Basal Metabolism in M Carnegie Institution of Washington, publication no. 270, 1919.

Indirect Calorimetry to Harris - Benedict Estimates

- It has been well documented that the Harris-Benedict equations, the stress factors and activity factors are frequently inaccurate
  Weissman et al., 1986, Van Lanschot et al., 1986, Daly et al., 1985, Frankenfield, 2003
- Special circumstances:
  - Post polio syndrome – BEE lower than normal
    Bargieri, 2008
  - Alzheimer’s Disease – altered energy metabolism
    Mosconi, 2008
  - Micronutrient deficit? – Li, 2010
Newer Equations

- **Mifflin** - M=251, F=247; BMI>30-42; 1990
  - M: kcal/day = 10(wt) + 6.25(ht) – 5(age) + 5
  - F: kcal/day = 10(wt) + 6.25(ht) – 5(age) – 161
- **Owen** - M=60, F=44; 30% BMI>30 to 59; 1986-7
  - M: kcal/day = 879 + 10.2 (wt)
  - F: kcal/day = 795 + 7.2 (wt)

Validation of several established equations for resting metabolic rate in obese and non-obese patients. Frankenfield, et al JADA, Sept 2003

- 130 normal subjects - 83 not-obese, 47 obese
- Equation % +/- 10% % above % below
  - HB(not obese) 69 27 4
  - HB (obese) 64 30 6
  - Mifflin (not obese) 82 10 8
  - Mifflin (obese) 70 9 21
  - Owen (not obese) 73 6 21
  - Owen (obese) 51 6 43

*Mifflin is more accurate more often than HB or Owen. HB and Owen are similar in accuracy*

Individual Variability Between Estimates and Measures

<table>
<thead>
<tr>
<th>Subjects of Same Height and Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>E</td>
</tr>
<tr>
<td>Actual</td>
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<tr>
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<tr>
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</tr>
<tr>
<td>1523</td>
</tr>
<tr>
<td>1778</td>
</tr>
<tr>
<td>1979</td>
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<td>2152</td>
</tr>
</tbody>
</table>

Adjusted Body Weight

\[ \text{Adj BW} = [(\text{current weight} - \text{IBW}) \times 0.25] + \text{IBW} \]

Wilkens K. Adjustment for obesity
ADA Renal Practice Group
Newsletter, 1984, Winter

Validation of several established equations for resting metabolic rate in obese and non-obese patients. Frankenfield, et al. JADA, Sept 2003

<table>
<thead>
<tr>
<th>Equation</th>
<th>% ± 10%</th>
<th>% above</th>
<th>% below</th>
</tr>
</thead>
<tbody>
<tr>
<td>HB(adj BW)</td>
<td>25</td>
<td>2</td>
<td>72</td>
</tr>
<tr>
<td>BMI 30-40</td>
<td>60</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>BMI &gt;40</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>
Suggested Factors

- Sedentary – RMR x 1.1
- Moderate – RMR x 1.2-1.3
- Active – RMR x 1.4-1.5

Summary – Evidence based data for normals (non-critically ill)
- HBEE – should not be used
Summary:
- Adjusted body weight is not helpful and should not be used.
- Mifflin-St Jeor is better even for the obese

What about critically ill or injured patients?
- Instead of HB, use Mifflin?
- Use an equation for ill or injured patients?
Variations in EE by diagnosis

**Cancer**
- Energy expenditure cannot be accurately estimated in patients with cancer because metabolic rate varies.

**Liver disease**
- Energy expenditure cannot be estimated with accuracy in patients with liver disease.

**COPD**
- Measured RMR, compared to estimated, is significantly higher in malnourished COPD patients.

**Pressure Ulcers**
- “Use of indirect calorimetry helps distinguish that group of patients at greatest risk for development of pressure sores due to poor nutritional status.”

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EE Factors - Critical Care

- Ventilator – dependent vs. spontaneously breathing
- Type of nutrition support
- Factors influencing REE:
  - Faisy, et al/Frankenfield, et al - weight, height, age, minute ventilation, body temperature
  - Uehara – sepsis, LOS
- Applying prediction equations that were developed for normal, healthy subjects to critically ill patients will result in significant errors.

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Energy Expenditure Equations for hospitalized patients

- **Ireton-Jones Equations**
  - Ventilator-Dependent:
    \[ IJEE(v) = 1925 - 10(A) + 5(W) +281 (G) +292 (T) +851 (B) \]
  - Spontaneously Breathing:
    \[ IJEE(s) = 629 - 11 (A) + 25 (W) - 609 (O) \]
- \( IJEE = \text{kcal/day}; A = \text{age (yrs)}; W = \text{actual wt(kg)}; G = \text{gender(male=1, female=0)}; T = \text{trauma}, B = \text{burn}, O=\text{obesity (if present=1, absent=0)}
- No additional factor is added for activity or injury
- Tested prospectively
- Compared to other equations in retrospective studies of obese patients with measured RMR as the gold standard
- Presence of obesity is accounted for by the varying factors in the ventilator-dependent and spontaneously breathing equations.
Energy Expenditure Equations for hospitalized patients

- **Penn State Equations (1984, 2004)**
  
  \[
  \text{Kcal/day} = \text{HBE} (0.85) + \text{Tmax} (175) + \text{VE} (33) - 6433
  \]
  
  or
  
  \[
  \text{Kcal/day} = \text{MSJ} (0.96) + \text{Tmax} (167) + \text{VE} (33) - 6212
  \]

  MSJ = Mifflin St. Jeor or HBE – Harris Benedict Equation; Tmax – max body temp (C) previous 24 hours; VE – L/min from the vent

- **McCowen & colleagues, Crit Care Med 2000**
  
  - 25 kcal/kg using usual or current body weight
  - normal weight and obese patients requiring PN
  - average blood glucose, frequency of hyperglycemia, and infection rates were similar for both groups

Energy Expenditure Equations for obese, hospitalized patients

- 25 kcal/kg using usual or current body weight
- IJEE/Penn State
- 11-14 kcal/kg – ASPEN/SCCM Guidelines
- Hypocaloric/high protein feeding
  - Studies by Dickerson, Choban, Burge
  - Outcomes – • LOS, ▼ LOICUS, ▼ ABX
  - ~50% of RMR provided to patient (~14 - 20 kcal/kg)
  - 1.8-2.5 gm/kg IBW – protein

Measurement of Energy Expenditure

- Direct Calorimetry - Research only
- Indirect Calorimetry - bedside applications
  - Measure O2 consumption and CO2 production
  - Can also calculate RQ (CO2/O2) to determine energy substrates utilized
  - Requires reliable equipment, standardized conditions and experienced personnel to do the study and interpret it.
Measurement of Energy Expenditure from Respiratory Gas Exchange

Equations

- **Weir Equation**: 
  
  \[ \text{REE} = \text{resting energy expenditure (kcal/d)} \]
  
  \[ \text{REE} = [3.941 (\text{VO}_2^2) + 1.106 (\text{VCO}_2^2)] 1.44 - 2.17 \text{ (UN)} \]
  
  \( \text{VO}_2^2 = \text{oxygen consumption (mL/min)} \)
  
  \( \text{VCO}_2^2 = \text{carbon dioxide production (mL/min)} \)
  
  \( \text{UN} = \text{urinary nitrogen (g/d)} \)

- **Abbreviated Weir Equation**: 
  
  \[ \text{REE} = [3.941 (\text{VO}_2^2) + 1.106 (\text{VCO}_2^2)] 1.44 \]

- **RQ**: 
  
  \[ \text{RQ} = \frac{\text{VCO}_2^2}{\text{VO}_2^2} \]

Haugen H. Nutrition in Clinical Practice 22:377–388, August 2007
Respiratory Quotient
VCO2/VO2

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>RQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat</td>
<td>0.70</td>
</tr>
<tr>
<td>Protein</td>
<td>0.80</td>
</tr>
<tr>
<td>Carbohydrate (Glucose)</td>
<td>0.95 - 1.00</td>
</tr>
<tr>
<td>Mixed Diet</td>
<td>0.85</td>
</tr>
<tr>
<td>Net Fat Synthesis</td>
<td>&gt; 1.01</td>
</tr>
<tr>
<td>Hyperventilation</td>
<td>&gt; 1.10</td>
</tr>
<tr>
<td>Ketosis</td>
<td>&lt; 0.60</td>
</tr>
</tbody>
</table>

Metabolic Measurement Carts

- "Indirect calorimeter"
  - Larger versions
    - Measure VO2/VCO2, RQ
    - May measure pulmonary function
    - Priced from $25,000 +
    - Experienced personnel to operate and calibrate
    - Can be used with mouthpiece/canopy and can be connected to ventilator
  - Not easily portable other than internally in institution
- Hand held version
  - Measures VO2 and determines RMR
  - Portable, lightweight, self-calibrating
  - Accurate, clinically validated against Douglas bag and existing metabolic carts
  - Can be used with spontaneously breathing patients only

Indirect calorimeters that measure VO2 and VCO2
Indirect calorimeters that measure VO₂ only

Recommended Pre-measurement Conditions
- The required resting period remains at 10-15 minutes, but we also recommend that the client:
  - abstain from eating for at least 4 hours.
  - abstain from exercise (cardiovascular or resistance-training) for at least 4 hours.
  - abstain from caffeine for at least 3 hours.
  - abstain from nutritional supplements or medications containing ephedra, Ma Huang, or pseudoephedrine for at least 2 hours.
  - abstain from nicotine for at least 1 hour prior to an RMR measurement.
- A simplified version of the test conditions that some of our customers are using is “the rule of 4s” – 4 hr. fast, 4 hrs since exercise, 4 hrs since other factors that may increase RMR.

Measurement Conditions
- Awake but at rest and in a supine position
- Two hours after a meal unless they are on continuous nutritional support
- At least sixty minutes following strenuous activity such as a dressing change, chest physiotherapy, or physical therapy
Case studies

**Limitations of Indirect Calorimetry**
- High frequency mechanical ventilation
- Patients with chest tubes that leak air
- Mechanical ventilation with oxygen concentrations >60%
- Tracheotomy tube has an incompetent or non-existent tracheal cuff
- Inconsistent sources of inspired oxygen (variable levels of inspired oxygen)
- Unskilled personnel conducting the measurement

**What is the evidence to support indirect calorimetry vs. equations to estimate kcal requirements?**
- Can RMR be measured reliably?
  - Yes, under standard conditions to obtain a steady state RMR
- How often in 24 hours?
  - Healthy individuals – once/24 hours
  - Critically ill ventilated patients – once/24 hours if steady state
- How long is the measurement?
  - Single, 10 minute measurement eliminating the first 5 minutes with <10% variation in VO2 and VCO2

ADA Evidence Based Task Force 10-27-03
Measuring Metabolic Rate: Hospital

- Who should be measured?
  - All patients receiving intensive nutritional support (parenteral or enteral nutrition) should have their energy expenditure measured (MRMR) using indirect calorimetry as a part of the initial nutritional assessment.

- Patient prioritization for indirect calorimetry
  - First - all ICU patients receiving PN and potentially enteral; complex patients – e.g., obese
  - Second - patients receiving parenteral nutrition other than those in the ICU
  - Third - All other patients

- How often?
  - Weekly for ICU patients
  - All other patients bi-weekly
  - Reassess when a significant change occurs affecting the condition of the patient

Measuring Metabolic Rate: Home/Private Practice

- Who?
  - Inpatient and outpatient centers dealing with eating disorders as a useful adjunct to therapy.
  - Weight management
  - Segments of the patient population in conjunction with specific diseases or injury
  - Integrated as a component of other programs such as wellness programs.
  - An important part of initial and follow up assessments for people receiving home nutrition support

- How often?
  - Progress to goal
  - Change in condition

So, add IC to your practice?

+ RMR
Marketing

1. Believe in what you are doing.
2. Meet your clients where they are and NOT where you are, think they are (don’t really know) or where you think they need to be.
3. Believe that you bring real value to your clients and that they will be more than willing to pay for success.

When you sell things of value, especially when you are trying to change behavior, your clients will test you to better understand your conviction and knowledge. This is a good thing and those questions are buying signals. Embrace them so that your client can become empowered with added commitment.

Key to Success – Why?

- Increased knowledge?
- Opportunity to target?
- Identify people’s needs
- Meet the clients where they are and what they want. They need you. Believe in what you do and be unabashed about what things cost.

What RDs are doing:

- …just a last resort kind of thing when all else fails - meaning we modify diet and for the folks that insist that they can’t lose weight, despite the plans we have set, then use it to sort of prove the caloric needs.
- …I see it as a way to validate the goals we set based on them as individuals - where equations aren’t accurate and research is slim.
What RDs are doing

- Use indirect calorimetry with my patients who are undernourished (often anorexic or under fueled athletes) and they can see a biomarker that their metabolism is suppressed. When they see their RMR is 680 kcal/day when it should be over 1200 kcal and it opens up a great discussion what is physically happening to their bodies.
- With chronic dieters they may also learn their metabolism is suppressed - we focus on activity and better fueling and they can actually start losing weight by eating more
- Some of my patients just want a better idea what a healthy calorie range is for them, and like reassessment a few months later to see where they are at.
- I have used it for over 10 years and find it a great tool.

What RDs are doing

- I have a package of body comp (BodPod or underwater weighing), RMR(BodyGem) and nutrition counseling. People love this package because then they have all the info they need to start making body composition changes.
- Cost: $75
- Penny L. Wilson, PhD, RDN, CSSD, LD

Challenges

- Reimbursement
- Marketing
- Knowledge base
- Cost of the machine
- Cost of disposables
Why be accurate?

- Negative energy balance is associated with increased complications in the ICU – Dvir D, et al. Clin Nutr, 2006
- High negative energy balance correlates with increased mortality rate – Bartlett RH, et al. Surgery, 1982
- Large negative energy balance is associated with increased ventilator and ICU days – Mault J, et al. JPEN, 2000.

Thank you!