Indirect Calorimetry & Nutrition Evaluation
Objectives

• Explain Energy Balance
• Understand basic physiology and factors that affect metabolism
• Determine Calorie Needs
• Indirect Calorimetry Integration
• Case Studies
• RMR implementation into practice
• Practical instruction
Losing weight
It’s All About Calories

Maintain weight by eating what you burn
Gain weight by eating more than you burn
Lose weight by eating less than you burn

<table>
<thead>
<tr>
<th>Diet</th>
<th>Carbohydrates</th>
<th>Protein</th>
<th>Fat</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adkins:</td>
<td>300 calories</td>
<td>700 calories</td>
<td>500 calories</td>
<td>1500 calories</td>
</tr>
<tr>
<td>Zone:</td>
<td>600 calories</td>
<td>450 calories</td>
<td>450 calories</td>
<td>1500 calories</td>
</tr>
<tr>
<td>Low Fat (WW):</td>
<td>800 calories</td>
<td>500 calories</td>
<td>300 calories</td>
<td>1500 calories</td>
</tr>
</tbody>
</table>

• “Weight loss with any popular diets are similar…..” (Dansinger, et al. 2005; JAMA).
• Americans are consuming more food than they think. Most overweight individuals under-report food consumed vs. activity energy expenditure.\textsuperscript{1-3}

• According to the 2000 U.S. food consumption report, adults an estimated 2,700 calories per day. This is 700 calories more than recommended.

• When asked how many calories is recommended per day approximately 65\% of adults guessed correctly.\textsuperscript{4}

• According to Weight Management Guidelines one of the top education topics is understanding food labels and portion sizes.\textsuperscript{5}

5. NIH. (2000). *Practical guide to the identification, evaluation, and treatment of overweight and obesity in adults*. 

Definition of Metabolism

- Metabolism = the biochemical process of breaking down food to release the energy needed for the body to function

- The amount of energy is commonly expressed in Kcals.

- Kcal = approximates the energy needed to increase the temperature of 1 kilogram of water by 1 °C
Metabolic pathways

- Two metabolic pathways exist to produce energy (ATP) and heat.
  - 1. Aerobic Metabolism (Oxidative): With oxygen (O2)
    - predominant source of energy production. At rest and during activity
  - 2. Anaerobic Metabolism (Non-oxidative): Without O2
    - Short durations for intense activities, a very small part of the total energy production (very inefficient)

**Aerobic Metabolism**

Foodstuff → Respiration → ATP + Heat

O2, N → O2, N, Co2
• Total Energy Expenditure (TEE): anaerobic & aerobic metabolism.

• Comprised of:
  1. Resting Metabolic Rate (est. 75%)
  2. Thermic Effect of Food (est. 5%)
  2. Lifestyle (est. 20%)
  3. Purposeful Activity (est. 5-10%)
Resting Metabolic Rate

• Resting metabolic rate (RMR): calories your body burns with no activity. Approx. 60-75% of TEE for most individuals and up to 100% in critically ill patients.

• RMR is unique to each person and is affected by a number of factors including:
  - Age
  - Body weight
  - Body composition
  - Medications
  - Fever and/or Infection
  - Weight loss
  - Exercise
  - Gender
  - Genetics (UCP1 & 2 gene)
  - Hormones (testosterone, leptin)
  - Nutritional Supplements
    (Caffeine, Ephedra, Synephrine)
  - Caloric restriction

Danforth, E. *Life Sci* 1981.28; 1821-1827
Fung, E. *AACN Clinical Issues* 2000. 11(4); 480-497
Compher, C. *JADA* 2006. 106(6); 881-903
you burn during purposeful exercise (walks around the block, gym class, riding your bike, etc.).

**ACTIVITY GOAL:**

3 hours and 15 minutes of Very Strenuous exercise per week 357 kcals/day (more per day)

**Is My RMR Good or Bad?**

Unlike other health assessments (i.e., blood pressure or cholesterol), there is no such thing as a good or bad RMR. However, your RMR is unique to you. Although there is no specific standard for individual metabolism, your RMR can vary based on your muscle weight, age, gender, genetics, and if you are taking medications. Based on these factors, your RMR may be higher or lower than other individuals. This is why it is important to monitor your RMR throughout your weight management program. A standardized RMR range is provided below as a comparison.

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1260 kcals/day 1680 kcals/day

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“Metabolic Evaluation”
How to Determine Calorie Needs in Clinical Practice?

- Option 1: Use Standard Recommendations
- Option 2: Estimate Calorie Needs
- Option 3: Use Indirect Calorimetry
1. Standard Recommendations

- Recommendations: 1200 Kcal/day women & 1600 Kcal/day men. ¹
- Weight loss is usually 50% less than predicted. ²⁻³
- Low adherence rates (50-80% attrition). ⁴
- Patients want individualized treatment. ⁵⁻⁶

⁵ Bearn, et al. (2008) Am J Life Med. 2(1) 75..
2. Estimate Calorie Needs

Foster et al (1988) evaluated the metabolic differences of like individuals.

(Figure 2).
Subjects of Similar Height and Weight

| RMR   | 1263 | 1523 | 1778 | 1979 | 2152 |

RMR can vary significantly between similar individuals – up to 900 Kcals/day

Foster et al. *Metabolism* 1988. 37(5); 467-472.
Equations

- **Mifflin-St Jeor, 1990**
  - Men: $RMR = 9.99 \times \text{weight} + 6.25 \times \text{height} - 4.92 \times \text{age} + 5$
  - Women: $RMR = 9.99 \times \text{weight} + 6.25 \times \text{height} - 161 - 4.92 \times \text{age}$

- **Harris Benedict, 1919**
  - Men: $RMR = 66.47 + 13.75 \times \text{weight} + 5.0 \times \text{height} - 6.75 \times \text{age}$
  - Women: $RMR = 665.09 + 9.56 \times \text{weight} + 1.84 \times \text{height} - 4.67 \times \text{age}$

- **Owen, 1986-87**
  - Men: $RMR = 879 \times 10.2 \times \text{weight}$.
  - Women: $RMR = 795 + 7.18 \times \text{weight}$.

$RMR = \text{resting metabolic rate in kcal/day, Weight in kg, Height in cm}$
### Equations

#### WHO/FAO/UNU\(^b\), 1985 (13)

- **Weight only:**
  - **Age (y)**
  - **Men**
    - 18-30: \(15.3 \times \text{weight} + 679\)
    - 31-60: \(11.6 \times \text{weight} + 879\)
    - >60: \(13.5 \times \text{weight} + 487\)
  - **Women**
    - 18-30: \(14.7 \times \text{weight} + 496\)
    - 31-60: \(8.7 \times \text{weight} + 829\)
    - >60: \(10.5 \times \text{weight} + 596\)

- **Weight and height (m):**
  - **Age (y)**
  - **Men**
    - 18-30: \(15.4 \times \text{weight} - 27 \times \text{height} + 717\)
    - 31-60: \(11.3 \times \text{weight} + 16 \times \text{height} + 901\)
    - >60: \(8.8 \times \text{weight} + 1,128 \times \text{height} - 1,071\)
  - **Women**
    - 18-30: \(13.3 \times \text{weight} + 334 \times \text{height} + 35\)
    - 31-60: \(8.7 \times \text{weight} - 25 \times \text{height} + 865\)
    - >60: \(9.2 \times \text{weight} + 637 \times \text{height} - 302\)

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RMR = resting metabolic rate in kcal/day, Weight in kg, Height in M
180 cm (5Ft 11 Inches)
220 lbs

1lb muscle burns 3 to 4 times as much kcal/day as 1lb fat
Race/Ethnicity

Equations are based on averages not precise for individuals.
3. (In)direct Calorimetry

- The body uses oxygen for the sole purpose of oxidizing food.

- oxygen consumed = oxygen used to burn calories. (the body does not store oxygen)

- There is a mathematical relationship between oxygen consumption and calories burned.

Direct calorimetry

Specialized chamber

- Gold standard
- Measurement takes an hour
- Very expensive
- Logistically impractical (time, space etc)
Metabolic cart

- Requires dedicated space
- Routine calibration needed
- Accurate and well-accepted in clinical settings
- Cost: $30-50,000
Indirect calorimetry

Douglas bag method

- Easier
- Measurement 5-15 min
- High costs for equipment used for analysis
- $15-30,000
Handheld Indirect calorimetry

MedGem

- Portable
- Easy to analyze
- Very cost-effectiveness
- Costs $4,000

Indirect Calorimetry: A Practical Guide for Clinicians

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*University of Colorado Health Sciences Center, School of Medicine, Denver, Colorado; and the †University of Washington, School of Pharmacy, and ‡Graduate Program in Nutritional Sciences, Seattle, Washington

ABSTRACT: This review provides clinicians with a comprehensive overview of indirect calorimetry including the

Determining Energy Expenditure
FIG 3. Mean±SD resting metabolic rate values for the Douglas bag and BodyGem methods for three body mass index categories.

Clinical evidence

Available online at www.sciencedirect.com

Journal of Science and Medicine in Sport

Original research

Accuracy of four resting metabolic rate prediction equations: Effects of sex, body mass index, age, and race/ethnicity

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3 Received 5 September 2010; received in revised form 5 January 2011; accepted 26 February 2011

Abstract

Objective: This study compared the accuracy of four commonly used RMR prediction equations to measured RMR obtained from the MedGem metabolic analyzer. Accuracy of the Harris–Benedict, Mifflin–St Jeor, Owen, and WHO/FAO/UNU equations was determined by calculating the percentage of predicted RMR values that were within ±10% of measured RMR values. Results: Four of the regression equations overestimated RMR values by 18–29 years of age. The Harris–Benedict equation overestimated RMR values by 18–29 years of age. When the data were stratified by sex, BMI, age, and race/ethnicity, the accuracy of each regression equation varied slightly. The Harris–Benedict equation overestimated RMR values by 18–29 years of age. The Owen et al. equation underpredicted RMR values in all groups, while the Owen et al. equation underpredicted RMR values in both sexes.

Keywords: energy metabolism; basal metabolic rate; obesity

1. Introduction

Resting metabolic rate (RMR) represents the energy requirement for the maintenance of body functions (1) and the resting state (2) of individuals. Because of its importance in the regulation of body weight and composition, it is necessary to use prediction equations to estimate RMR in the setting of hospital inpatient and outpatient populations. The American Dietetic Association (ADA) recently updated the accuracy of RMR prediction equations applied to the general public, with the recognition that these equations were not used in obese, elderly, or non-white populations. This analysis was needed because of the commonly used prediction equations were developed using participants who

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E-mail address: psf@umass.edu (P.S. Freedson).

The Harris–Benedict equation overestimated RMR values by 18–29 years of age. The Owen et al. equation underpredicted RMR values in both sexes.

Keywords: energy metabolism; basal metabolic rate; obesity

Total energy expenditure (TEE) consists of 3 major components: basal metabolic rate (BMR), thermogenic effect of food, and the effect of physical activity or exercise. BMR is defined as the measurement of RMR under the following conditions: a state of complete rest and ambient temperature between 68°F and 77°F, the subject is tested immediately upon waking after a minimum 4-hour sleep and in a postabsorptive state (12 hours after a meal). Thermogenic effect of food refers to the heat that the body generates as food is digested. Physical activity is any activity in which work is performed that results in an increase in metabolic rate. Resting metabolic rate (RMR), which is synonymous with resting energy expenditure (REE), is not measured under basal conditions. It is a measurement taken during a fast (2–4 hours after a meal) and allows for some movement with a rest period prior to testing. The BMR is normally higher than the RMR due to less restrictive conditions for measuring RMR. Therefore, the BMR accounts for 60%–75% of TEE, whereas RMR accounts for 50%–75% of the difference between the BMR and RMR is only about 10%, it is more practical to measure RMR in a clinical setting. In clinical settings, RMR is used to determine accurate energy expenditure of a patient’s caloric needs. Resting metabolic rate can be measured either directly or indirectly. Direct calorimetry is the measurement of whole body heat released from an individual in a specialized chamber (Figure 1). A direct calorimeter is a large insulated, air-tight chamber in which oxygen is introduced while a subject is at rest. Oxygen used is replaced by the addition of a weighed amount of oxygen as required. Expired carbon dioxide and water vapor that is expired by the subject are measured. The temperature within the chamber is maintained with a cooling circuit. Thermal equilibrium within the chamber must be obtained for accurate readings this unstable condition is not normally possible.

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Conclusions Medgem

- Provides valid and reliable measurements of RMR
- Shows high reproducibility
- Suitable for children (>8 years)
- Less suitable for patients with cancer and anorexia nervosa
- MedGem guided diet leads to more weight loss as compared to usual care
- More accurate than predictive equations based on gender, age, and ethnicity for determining resting metabolic rate
- A viable alternative for clinical evaluation of the hospitalized patient
Medgem: How does it work?

**MedGem Components:**

A) Power Supply  
B) Nose clip  
C) MedGem Device  
D) Single-use Mouthpiece  
E) User CD
Indirect calorimeters convert gas exchange (VO$_2$ & VCO$_2$) measurements into metabolic rate (calories).

Calories = (VO$_2$*Fixed Factor) + (VCO$_2$*Fixed Factor) – Nitrogen

Foodstuff $\rightarrow$ Respiration $\rightarrow$ ATP + Heat

O$_2$, N $\rightarrow$ O$_2$, N, Co$_2$
Respiratory Quotient

- Resting Metabolic Rate $= [ (3.941)(VO2) + (1.106)(VCO2)]$

- The Medgem only measures VO2 not VCO2

- Therefore the formula needs to be modified

- Respiratory Quotient (RQ) $= \frac{VCO2 \text{ eliminated}}{VO2 \text{ consumed}}$

- Thus $VCO2 = VO2 \times RQ$

- Resting Metabolic Rate $= [ (3.941)(VO2) + (1.106)(VO2)(RQ)]$
Respiratory Quotient

- RQ’s differ for energy substrates, but on average $\approx 0.85$

$$\frac{(1.00 + 0.82 + 0.71)}{3} \approx 0.85$$

<table>
<thead>
<tr>
<th>Energy Substrate</th>
<th>Respiratory Quotient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>1.00</td>
</tr>
<tr>
<td>Protein</td>
<td>0.82</td>
</tr>
<tr>
<td>Lipid (fats)</td>
<td>0.71</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VO$_2$ ml/min</th>
<th>VCO$_2$ ml/min</th>
<th>RQ</th>
<th>kcal/day using measured VCO$_2$</th>
<th>Constant RQ</th>
<th>kcal/day using $\Delta$ constant RQ</th>
<th>kcal/day</th>
<th>% error from constant RQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>250</td>
<td>187.5</td>
<td>0.75</td>
<td>1,693</td>
<td>0.85</td>
<td>1,732</td>
<td>39</td>
<td>2.3</td>
</tr>
<tr>
<td>250</td>
<td>200</td>
<td>0.8</td>
<td>1,713</td>
<td>0.85</td>
<td>1,732</td>
<td>19</td>
<td>1.1</td>
</tr>
<tr>
<td>250</td>
<td>212.5</td>
<td>0.85</td>
<td>1,732</td>
<td>0.85</td>
<td>1,732</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>225</td>
<td>0.9</td>
<td>1,752</td>
<td>0.85</td>
<td>1,732</td>
<td>-20</td>
<td>-1.1</td>
</tr>
<tr>
<td>250</td>
<td>237.5</td>
<td>0.95</td>
<td>1,772</td>
<td>0.85</td>
<td>1,732</td>
<td>-40</td>
<td>-2.3</td>
</tr>
</tbody>
</table>
Respiratory Quotient

EE = Energy Expenditure
Why Use Indirect Calorimetry?

- It gives you and the patient accurate data for energy expenditure.
- Studies show patients who know their RMR have better weight loss success. \(^1\)
- Patient’s believe RMR assessment is an important part to their weight management program. \(^2\)
- Evidence-based & Guideline Solution for determining calorie needs. \(^3-4\)
- No more excuse, “I can’t lose weight because it’s my metabolism”.

3. Adult Obesity Taskforce Guideline 2011: HealthTeamWorks
MedGem in practice, does it work?
The Biggest Loser Uses Medgem

“The MedGem provides our medical staff an accurate and easy-to-use method for assessing RMR changes in these contestants”

Dr. Robert Huizenga
Medical Advisor to The Biggest Loser
Fifty-four (N=54) overweight (mean BMI: 29.8 ± 2.4 kg/m2), thirty-six males (N=36) and eighteen (N=18) females, active duty AF personnel (mean age: 28.0 ± 7.3 years) participated in the study.

Twenty-five (N=25) usual care individuals and nineteen (N=19) experimental individuals completed the 90 day weight control program (18% attrition).

<table>
<thead>
<tr>
<th>Study Group</th>
<th>Experimental (N=25)</th>
<th>Usual Care (N=29)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITT: LOCF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline WT (kg)</td>
<td>91.5 ± 14.5</td>
<td>89.7 ± 14.5</td>
</tr>
<tr>
<td>Post Weight (kg)*</td>
<td>88.3 ± 13.4 *, ^</td>
<td>88.1 ± 14.8 *</td>
</tr>
<tr>
<td></td>
<td>(-3.3 ± 3.4 kg)</td>
<td>(-1.5 ± 3.0 kg)</td>
</tr>
<tr>
<td>Baseline Body fat (%)</td>
<td>29.7 ± 4.7</td>
<td>29.0 ± 5.0</td>
</tr>
<tr>
<td>Post Body fat (%)*</td>
<td>28.5 ± 5.0 *</td>
<td>28.2 ± 5.8 *</td>
</tr>
<tr>
<td>REE (kcal/day)</td>
<td>1582 ± 196</td>
<td>....</td>
</tr>
<tr>
<td>TEE (kcal/day)</td>
<td>1976 ± 245 ^</td>
<td>2230 ± 360</td>
</tr>
</tbody>
</table>

*significantly different from baseline (p ≤ 0.05)  ^ significantly different between groups (p ≤ .05).
IC vs. Usual Care (25 kcal x BW)

“These data suggest a tailored nutritional message using measured RMR along with a 4-session behavioral treatment program generates significant weight reduction that would have improved health benefits compared to using a generic nutritional message from a population-based estimation equation.”

75% of the intervention participants (n=14) achieved a level of weight loss (≥ 3%) that would generate health benefits compared to 36% (n=9) of the control participants (p=.03).

Obesity is likely to be denied by payers unless the patient has an underlying medical condition related to obesity. Obesity should be listed as the secondary disease.

Sample criteria for determining medical necessity for indirect calorimetry (ICD-9-CM codes). Similar coding as spirometry. Average payer reimbursement is $50-70.00.

- 414 Chronic Pulmonary HT disease*
- 428 Heart Failure*
- 493 Asthma*
- 496 COPD*
- 517.8 Lung involvement in other disease*
- 780. 5 Obstructive Sleep Apnea*
- 786.5 Dyspnea*
- 786.9 Hypoventilation Syndrome*
- 244.9 Hypothyroidism
- 250 Diabetes Mellitus
- 272.1 Hypercholesterolemia
- 272.4 Hyperlipidemia
- 277.7 Metabolic Syndrome
- 278 Obesity
- 401 Hypertension
- 414 Cardiovascular Disease
- 783.1 Abnormal weight gain

* CMS indicates medical necessity.
Medical costs obesity

Cowly et al. obesity reviews 2011
Medgem in practice

**MedGem Components:**

A) Power Supply  
B) Nose clip  
C) MedGem Device  
D) Single-use Mouthpiece  
E) User CD
• Be fasting (> 5 hrs)

• Not exercised (> 2-5 hrs)

• Not consumed stimulants

• Not used nicotine

• Rest for 10-20 min before measurement
It’s all about calories

- 500 Kcal/day ≈ 1lb / week (general assumption)
- ♂ 350 Kcal/day ≈ 1lb / week \(^1\)\(^2\)
- ♀ 490 kcal/day ≈ 1lb / week \(^1\)\(^2\)

Hal et al. In J Obes (lond) 2008
Jane’s Personalized Program

6 Month Weight Goal: 200 lbs

VO2: 319 ml/min 2.6 ml/kg (Normal: 2.4-3.2)

RMR: 2100 Kcal

For Tracie to lose 35 lbs over the next 24 weeks she will need to have an energy deficit of 750 Kcals/ day

TEE: 2730 Kcals/day

Weight Loss (1.5 lb/week) - 750 Kcals/day

Daily calorie needs w/o exercise: 1980 Kcals/day

Energy Plan is 6% below her basic physiologic needs
Case Study: RA

68 year old male with a BMI of 41.4 (kg/m2). He has OSAS (AHI 89.1) and metabolic syndrome (HTN 145/97, LDL 124 mg/dl, CHOL 267 mg/dl). RA indicates that he desires to lose weight and has tried self-help diets and WW in the past. He has lost weight at WW but regained all the weight.

- Current Weight: 309 lbs
- Dx: OSAS, Metabolic Syndrome, & Obesity
- Patient desires to lose weight.
- IC procedure is warranted
- Pharmacotherapy is warranted
- Discuss bariatric surgery.
RA’s Personalized Program

6 Month Weight Goal: 225 lbs

V02: 386 ml/min   2.7 ml/kg   (Normal: 2.4-3.2)

RMR: 2400 Kcal

For RA to lose 50 lbs over the next 24 weeks he will need to have an energy deficit of 1000 Kcals/ day

TEE 3120 Kcals/day

Weight Loss (2 lb/week) - 1000 Kcals/day

Daily calorie needs w/o exercise: 2120 Kcals/day

Energy Plan is 12% below his basic physiologic needs
• At the beginning of a weight loss program to improve energy balance literacy.
• If a patient plateaus &/or if a patient loses 10% of their body weight
• When the patient reaches their goal weight
• Annually
Reimbursement or Cash?

- No guarantee for insurance reimbursement
- You may bill for your time (E/M 99211-99214) to do the procedure
- You may bill for the procedure (CPT 94690)
- Average reimbursement varies per payer ($50-70)
- Cash Pay: $75 - $125
• Add RMR measurement to a package program
  • hCG + appointments + RMR + ???
• Individual RMR measurements
• May consider having patient pay for RMR in advance – pay for now so you can have them come back for their annual visit.
  • Gives you a reason to get the patient back in your office!