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Energy Balance and Obesity: The Role of Physical Activity for Weight Management & Morbidity/Mortality

Mark D. Peterson, Ph.D., CSCS*D, USAW

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Physical Activity & Exercise Intervention
University of Michigan, Medicine
Class Objectives:

- Operationalizing the Problem: A few simple definitions
- Prevalence of Chronic Disease and Potential Link to Lifestyle
- Obesity: A side-effect or the fundamental issue?
- Defining the link between energy balance and alterations in weight
- The Role of Physical Activity: Form or Function?
- Important questions to consider
Evolution of the Human Physique

Drawing of human evolution ending in obesity removed

Defining Obesity: Simple, right...?

- Many definitions –
  - WHO defines obesity for adults as a BMI of > 30.
  - Wikipedia: a condition in which the natural energy reserve, stored in fat exceeds healthy limits.
What to Shoot For??

“Ideal Weight”...?

- Miller Formula
  - Men: Ideal Body Weight (in kilograms) = 56.2 kg + 1.41 kg for each inch over 5 feet
  - Women: Ideal Body Weight (in kilograms) = 53.1 kg + 1.36 kg for each inch over 5 feet.
Ideal Weight: An Example

- Hmmm
- Male Research Fellow...
- Height: 6’2”
- Calculating Ideal Weight
  - Ideal Weight = 56.2 kg + (1.41 kg x 14 inches)
  - Ideal Weight = 56.2 kg + 19.74 kg
  - = 75.94 kg
  - = 167.44 lbs
BMI (Body Mass Index): A Good Proxy for Obesity

- Body Mass Index = \( \frac{wt}{ht^2} \) (kg/ M\(^2\))

- Utility of BMI is particularly relevant to Cross-sectional research, i.e. RISK of disease increases when BMI increases

- Be aware that BMI is NOT based on fat mass. Athletic individuals who are very muscular will have a high BMI.
## BMI Standard Classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>BMI</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 18.5</td>
<td>High Risk</td>
</tr>
<tr>
<td>Normal Range</td>
<td>18.5–24.9</td>
<td>Average</td>
</tr>
<tr>
<td>Overweight</td>
<td>≥ 25</td>
<td>Increased</td>
</tr>
<tr>
<td>Pre-obese</td>
<td>25–29.9</td>
<td>Slight</td>
</tr>
<tr>
<td>Obese class 1</td>
<td>30–34.9</td>
<td>Moderate</td>
</tr>
<tr>
<td>Obese class 2</td>
<td>35–39.9</td>
<td>Severe</td>
</tr>
<tr>
<td>Obese class 3</td>
<td>≥ 40</td>
<td>Very Severe</td>
</tr>
</tbody>
</table>
BMI Standard Classification

Body Mass Index (BMI)

- Classification:

- Example 5’9”, 175 lb Male
  - BMI = 26, Classified “Overweight”
  - Who is Maurice Green
Maurice Green

- Former “World’s Fastest Man”
- Overweight
You’re special.

- Bodies are not created equally...

- It is inappropriate to assign a single geometrical calculation of body dimensions

- Two Component Model...
  - Fat Component
  - Fat-free body component (FFB)

Standards of Body Fat Percentages

Obese

35+ %  *  25% +**

* Must consider Waist Circumference > 85 cm
**Must consider Waist Circumference > 100 cm
Numerous Ways to Measure/Estimate Body Composition

- Anthropometrics
  - Skinfold Measurements
  - Girth Measurements
- Hydrostatic Weight (Former “Gold Standard”)
- Whole Body Plethysmography
- Bioelectrical Impedance Analysis (BIA)
- Dual-energy X-ray absorptiometry (DXA)
  - New Gold Standard

Image of Bod Pod removed

For the purpose of this talk

- **Weight loss** = decrease in excess body fat

- Not
  - Loss of body water (dehydration)
  - Loss of lean muscle mass (atrophy during sarcopenia, cachexia, or space travel...)
  - Limb amputations
Regardless of the Operationalization of Obesity!

- Excess body fat or too little lean (muscle) tissue

- Associated with increased risk for cardiovascular disease, pulmonary dysfunction, orthopedic difficulties, type 2 diabetes mellitus and certain cancers
Prevalence of Diabetes Among U.S. Adults, BRFSS, 1990


4%  4-6%  6%  n/a  Blue


Prevalence of Diabetes Among U.S. Adults, BRFSS, 1997-2000

Obesity Trends* Among U.S. Adults 
(*BMI ≥30, or about 30 lbs. overweight for 5’4” person)
Age-Adjusted Standardized Prevalence of Overweight (BMI 25–29.9) and Obesity (BMI ≥30)

CDC/NCHS, United States, 1960-94, ages 20-74 years
Relative Risks of Obesity-Related Diseases by BMI for Men

Oster et al, Am. J. Managed Care, 2000
Childhood Obesity: Gut Check Time for Parents

Drawing of Childhood Obesity Epidemic removed

Original Images: Tab, The Calgary Sun, caglecartoons.com
Childhood Overweight & Obesity

- The Centers of Disease Control (CDC) has operationally defined “Overweight” among children as a body mass index greater than, or equal to the 75th percentile for age and gender.

- What about “Obesity”?
# Childhood Overweight & Obesity

## Table 6.2  Obesity Risk—BMI

<table>
<thead>
<tr>
<th>Age</th>
<th>Boys BMI (85%) (at risk for obesity)</th>
<th>Boys BMI (95%) (obese)</th>
<th>Girls BMI (85%) (at risk for obesity)</th>
<th>Girls BMI (95%) (obese)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>19.5</td>
<td>22.5</td>
<td>20.0</td>
<td>23.0</td>
</tr>
<tr>
<td>11</td>
<td>20.2</td>
<td>23.2</td>
<td>20.5</td>
<td>23.5</td>
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<tr>
<td>12</td>
<td>20.2</td>
<td>23.2</td>
<td>21.5</td>
<td>25.5</td>
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<td>13</td>
<td>23.0</td>
<td>25.2</td>
<td>22.5</td>
<td>26.2</td>
</tr>
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<td>14</td>
<td>22.5</td>
<td>26.0</td>
<td>26.2</td>
<td>27.0</td>
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<tr>
<td>15</td>
<td>23.5</td>
<td>26.5</td>
<td>24.0</td>
<td>28.0</td>
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<tr>
<td>16</td>
<td>24.0</td>
<td>27.5</td>
<td>24.5</td>
<td>29.0</td>
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<td>17</td>
<td>25.0</td>
<td>28.0</td>
<td>25.0</td>
<td>29.5</td>
</tr>
<tr>
<td>18</td>
<td>25.5</td>
<td>29.0</td>
<td>25.5</td>
<td>30.5</td>
</tr>
</tbody>
</table>

*Note. >85th percentile is considered at risk for overfat; >95th percentile is overfat. BMI = body mass index.*

Data from National Center for Health Statistics, *Prevalence of overweight among children and adolescents.*
Changes in the Prevalence of Obesity (BMI > 95th Percentile) Among U.S. White and Black Female Children Ages 6-11 years

- NHES I (1963-65 and 1966-70)
- NHANES I (1971-74)
- NHANES II (1976-80)
- NHANES III (1988-91)

M. Peterson
Tracking BMI-for-Age from Birth to 18 Years with Percent of Overweight Children who Are Obese at Age 25

Whitaker et al. *NEJM*: 1997;337:869-873
CVD Risks in Youth

% of children, aged 5-10, with 1 or more adverse CVD risk factor levels:

27.1%

% of children, aged 5-10, with 2 or more adverse CVD risk factor levels:

6.9%

CVD Risks in Youth

% of OVERWEIGHT children, aged 5-10, with 1 or more adverse CVD risk factor levels: 60.6%

% of OVERWEIGHT children, aged 5-10, with 2 or more adverse CVD risk factor levels: 26.5%

Explaining the Epidemic:

- Genetic
  - Heritability of obesity-related phenotypes is high (60-90%)

- Poor Diet/ Lack of Physical Activity
  - Cannot be explained by genetics

- Environmental Conditions
  - Physical and social environment influence our choices

- “Genes are the gun BUT the environment is the trigger” Bray 2001
  - Genetic susceptibility (i.e., diet and physical activity may not influence us the same)
“The human body is the only machine that breaks down when it is not used.”

(DiNubile 1993)
OBESITY IS A NORMAL ADAPTATION TO A STATE OF ENERGY IMBALANCE
Simple Energy Balance

In Energy Balance
Energy Intake = Energy Expenditure

In Energy Excess
Increase in Stored Energy
Energy Intake > Energy Expenditure

Energy Deficit
Decrease in Stored Energy
Energy Intake < Energy Expenditure
Calorie Restriction and Weight Loss

- Small controlled / physiologic trials.
- Large Randomized Controlled Trials.
- Very large historical events / disasters.
  - Somalia
  - Holocaust
  - Irish Potato Famine
Why isn’t calorie restriction the answer?

Most people cannot do it when:
- Tasty, cheap high calorie density foods are readily available
- Friends and family eat without restriction
- Lots of competing demands distract you or cause stress leading to emotional eating
- Limited financial resources
Self-Imposed Calorie Restrictions

- Being hungry is unpleasant.
- People eat to relieve non-hunger stimuli
- Unconscious eating
- Calories are hard to track
- Most people have other high priority tasks
- Calorie dense food is cheap and satisfying
- Diet fatigue and rebound weigh gain
However...

Is it easier to create a calorie deficit by
- A. Calorie Restriction (i.e. less intake)
- B. Increased Calorie Expenditure
- C. A combination of both

- What is the calorie deficit required to lose one (1) lb of weight?
- Implications for Diet and Physical Activity?
Energy Expenditure

EE = Basal Metabolic Rate + Thermic Effect of Food + Physical Activity
Basal Metabolic Rate (BMR)

- AKA Resting Metabolic Rate (RMR)
- The energy your body expends at rest
  - Keep your brain functioning
  - Breathing
  - Circulating and cleaning blood
Basal Metabolic Rate (BMR)

- Gender inequality
- For the same body mass, age, and height, **MEN** have greater BMR

- Why?
- Lean Body Mass (LBM) or muscle is a metabolic tissue
- Implications for Aging...?
  - Sarcopenia?
Aging and Sarcopenia...

21 year old woman

63 year old woman

Image of Arnold Schwarzenegger removed

Original Image: http://z.about.com/d/politicalhumor/1/0/N/9/arnold_then_now.jpg
Important Question:

Is Obesity caused by low BMR?

Interestingly, although BMR comprises a large percentage of the total kcal expended during the course of a day, cross sectional data demonstrate that mean BMR between obese and non-obese adults are not necessarily lower... more in a minute
Thermic Effect of Food (TEF)

- Energy required to digest, absorb and assimilate food.
- Averages 10 to 30% of BMR
- Protein digestion requires more energy than carbohydrates or fats.
Physical Activity

Includes all voluntary muscle activity that expends energy beyond rest.

- Physical Exercise
- Walking
- Sitting or Standing
- Fidgeting
  - NEAT: Non-exercise activity thermogenesis)
Total Energy Expenditure

- Physical Activity: 20%
- TEF: 10%
- BMR: 70%
Fitness vs Fatness

- Sumo wrestlers lose 10 to 20 life years
  - Due to fat or ETOH or Puffer Fish?
  - Those who lose weight after retiring live longer

- Steve Blair – Fat and fit live longer than thin and unfit.

- Predict mortality independently.
Total Daily Energy Expenditure and Voluntary Physical Activity

- Estimate total daily calorie needs as a function of BMR and Physical Activity Level:

  - Confined to bed: $1.2 \times BMR$
  - Ambulatory, low activity: $1.3 \times BMR$
  - Average activity: $1.5 \times BMR$
  - Highly active: $2.0 \times BMR$
Energy Expenditure Examples

- Tour de France: 6000 calories / day
- Triathlons: 4500 calories / day
- Distance Runners: 3500 calories / day

- Energy expenditure from physical activity = ___ (intensity, duration, frequency)
METs - Metabolic Equivalents

- A measure of physical activity intensity
- Expressed as multiple of BMR
- Relative to BMR vs Absolute
Walking

- The number one choice of people who exercise regularly
- Highly variable in intensity
- Moderate activity = 3 to 6 METs = walking at 3 to 4.5 miles per hour.
- Increased if you are carrying or pushing something, walking up a hill
- 2000 steps = 1 mile
Leptin

- A peptide hormone
- Generated by Adipose Tissue
- High Levels $\rightarrow$ Energy Excess
  (Increase Activity, Decrease Appetite)
- Low Levels $\rightarrow$ Energy shortage
  (Decrease Activity, Increase Appetite)

Do Obese People Have High or Low Leptin Levels?
Metabolic Characteristics in Obesity
(compared to non-obese controls)

- Leptin: High
- RMR: High
- Fat Oxidation: High
- Sympathetic NS activity: High
- Insulin Sensitivity: Low
Metabolic Characteristics in Obesity and Pre-Obesity (compared to non-obese controls)

<table>
<thead>
<tr>
<th></th>
<th>Obese</th>
<th>Pre-obese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leptin</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>RMR</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Fat Oxidation</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Sympathetic NS</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Insulin Sensitivity</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Physical Activity and Obesity – Editor Claude Bouchard, p72.
Hypothetical Sedentary Person

- Intake / day = 2000 calories
- Energy Burned / day
  = 1200 calories for BMR
  + 120 calories for Thermogenesis
  + 180 calories for Physical Activity

1500 calories burned

⇒ 500 calorie energy excess / day
Theoretical Result of Energy Excess

- 500 calories / day
- X 7 days = 3500 calorie excess

→ 1 pound weight gain per week.
Actual Results

- However, there is large inter-individual variation in actual weight gain/loss.

- Weight regulation is a complex system with multiple metabolic and hormonal pathways, lots of feedback loops, redundancy, and a strong tendency to dampen the effect of changes in energy supply.
Contrary to Popular Belief

- As you gain weight, your basal metabolic rate increases.

- So after day one, if you gained $\frac{1}{7}$ of a pound, you also increased your BMR → day 2 energy excess is less than 500 cal.
Health Benefits of Exercise

- Decreased CVD risk
- Decreased Cancer risk
- Decreased obesity
- Improved blood lipids/ lipoproteins
- Improved glucose tolerance
- Improved fibrinolytic activity
- Reduced blood pressure
- Prevention of osteoporosis
- Improved mental health
Energy Expenditure and All-Cause Mortality
Harvard Alumni Study

Relative Risk

Kcal per week
Age-Adjusted Death Rates per 10,000 Person Years of Follow-Up: Cooper Clinic Men and Women

Fitness Level

Age-adjusted Death Rate/10,000 PY

Low
Moderate
High

Men
Women

JAMA 282:2397, 1980
Mortality Rates from Five Population-based Studies on Physical Activity or Physical Fitness

Comparative Mortality Rates, %

Level of activity or fitness

M. Peterson
CDC: Adults participating in NO leisure-time physical activity
Current average = 40%
Mortality Risk per 10,000 person years among individuals with a BMI > 25

Lifestyle Changes that Promote Sedentary Behavior

- Increased use of electronic media
- Labor saving devices
- Increased use of cars / reductions in walking
- Reductions in school physical activity programs
Percent of Trips Made From Home by Auto 1977 - 1995

- 1977: 83.9%
- 1983: 85%
- 1990: 87.1%
- 1995: 89.3%

National Personal Transportation Survey, 1995
Percentage of Students Enrolled in Physical Education Class, by Grade

NCYFS (1984, 1986)
YRBS 1997

NCYFS = National Child and Youth Fitness Study
YRBS = National Youth Risk Behavior Survey
Ok... So How Much Exercise or Physical Activity is Recommended?!
General Exercise Guidelines for Health: Still Frequently Sited

“All individuals should accumulate a minimum of 30 minutes of moderate exercise on most, preferably all days per week”

CDC/ACSM 1995
IV. ACSM/AHA Guidelines for Physical Activity in Healthy Adults

A. Rationale for Update

- Clarify recommended frequency for moderate intensity physical activity
- Explicitly incorporate vigorous physical activity
- Specify that moderate and vigorous physical activity are complementary in the production of health benefits
A. Rationale for Update (Continued)

- Clearly state that recommended physical activity is in addition to activities of daily living
- Emphasize that physical activity above the minimum results in > health benefits
- Minimum length of short bouts clarified
- Specific muscle-strengthening activities added
### B. Aerobic Activity (Chronic Disease Protection)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Frequency</td>
<td>&gt; 5 d/wk for moderate intensity, or &gt; 3 d/wk for vigorous intensity</td>
</tr>
<tr>
<td>- Intensity</td>
<td>Moderate intensity between 3.0 and 6.0 METS; vigorous intensity above 6.0 METS</td>
</tr>
<tr>
<td>- Duration</td>
<td>&gt; 30 min/d of moderate-intensity activity, in bouts of at least 10 min each; continuous vigorous activity &gt; 20 min/d</td>
</tr>
</tbody>
</table>
## C. Weight Gain & Weight Loss

<table>
<thead>
<tr>
<th>Category</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevent unhealthy weight gain</td>
<td>60 minutes of moderate to vigorous intensity on most days of the week</td>
</tr>
<tr>
<td>Sustain weight loss</td>
<td>60-90 minutes of moderate intensity activity daily</td>
</tr>
</tbody>
</table>
## D. Muscle Strengthening Activity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Frequency</td>
<td>&gt; 2 d/wk</td>
</tr>
<tr>
<td>- Exercises</td>
<td>8-10 involving the major muscle groups</td>
</tr>
<tr>
<td>- Sets &amp; Repetitions</td>
<td>&gt; 1 set of 8-12 repetitions</td>
</tr>
</tbody>
</table>
A Packaging Problem

- Automobile
- Television
- Computers
- Convenience Engineering
- Built Environment
- Human Nature

Image of a gym entrance with escalators removed

Original image: http://www.goodexperience.com/broken/i/04/02/americafitness-s.jpg
A New Public Health Paradigm: Using Planning and Transportation Strategies to Promote Active Living Behaviors

What is active living?

“Active living” is a way of life that integrates physical activity into daily routines. The goal is to accumulate at least 30 minutes of activity each day. You may do this in a variety of ways, such as walking or bicycling for transportation, exercise or pleasure; playing in the park; working in the yard; taking the stairs; and using recreation facilities.
Healthy People 2010 Objectives

“Physicians and other health care providers should counsel their patients to be physically active as part of routine health care visits“

U.S. Preventive Services Task Force 2000
2007-Present: ACSM Physical Activity Promotion Campaign

Exercise is Medicine
Calling on physicians to assess and review every patient’s physical activity program at every visit.
CONCLUSIONS / RECOMMENDATIONS

- Overweight and obesity has become THE epidemic in the U.S.
- Obesity is associated with increased morbidity and mortality
- Physical activity reduces the risk of all-cause mortality, CVD, Diabetes, Cancer
- Reduce Sedentary Behaviors and Eliminate Physical and Social Barriers
- Exercise is Most Critical for Primary Prevention
Additional Source Information

for more information see: http://open.umich.edu/wiki/CitationPolicy

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Slide 24: CDC/NCHS, United States, 1960-94, ages 20-74 years
Slide 25: Oster et al, Am. J. Managed Care, 2000
Slide 26: Original Image: [Link to Image]
Slide 28: Human Kinetics 2009
Slide 29: M. Peterson
Slide 33: Ian Falconer, The New Yorker, [Link to Image]
Slide 34: CDC
Slide 37: US Federal Government
Slide 48: Source Undetermined
Slide 62: Harvard Alumni Study
Slide 63: JAMA 282:2397, 1980
Slide 64: M. Peterson
Slide 65: CDC
Slide 66: Blair, SN et al. Physical Fitness and all-cause mortality, JAMA 1989; 262:2395-2401,
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