Lesson 2: Energy Expenditure

Introduction

In this lesson students explore the energy expenditure of various levels of physical activity (from resting metabolism to vigorous activity) and the potential impact of physical activity on energy balance and healthy weight.

The human body is meant to move. The muscles, bones, heart, and brain improve through regular activities of daily living and exercise. Lack of regular physical activity puts our health at risk.

Decreased physical activity, coupled with an over-consumption of calories, allows the efficient human body to store surplus energy as fat. Any food intake that results in an excess of calories relative to how much the body burns off during the day through physical activity is stored as fat, whether it comes from carbohydrates, fats, or proteins.

Canada is facing an obesity epidemic. Overweight and obese populations in Canada are at increased risk for a variety of chronic health problems, and we are now beginning to see diseases that are found in adults appearing in children as well. Canadians can expect to see increasingly younger people suffering from heart disease, stroke, type 2 diabetes, and joint damage. A 2007 report by Canada's Standing Committee on Health states that "today's children will be the first generation for some time to have poorer health outcomes and a shorter life expectancy than their parents" (*Healthy Weights for Healthy Kids* 1).

REFERENCE

For additional information, refer to the following report:

Canada. House of Commons. Standing Committee on Health. *Healthy Weights for Healthy Kids: Report of the Standing Committee on Health.* Ottawa, ON: Standing Committee on Health, 2007. Available online at <http://cmte.parl.gc.ca/Content/HOC/committee/391/hesa/reports/rp2795145/hesarp07/05_Report-e.htm#part1> and on the National Library of Canada Electronic Collection website at <http://epe.lac-bac.gc.ca/100/200/301/hoc_cttee_reports-ef/health/healthy_weights-ef/hesarp07-e.pdf>.

For website updates, please visit Websites to Support the Grades 11 and 12 Curriculum at <www.edu.gov.mb.ca/k12/cur/physhlth/>.

Specific Learning Outcomes

12.NU.3 Demonstrate understanding of the relationship between the energy spent in physical activity and healthy weight.

12.NU.4 Demonstrate the ability to estimate daily energy expenditure by analyzing personal physical activity participation.

Key Understandings

- The body requires energy for various life-sustaining functions and activities of daily living.
- Regular physical activity increases the amount of energy spent each day.
- More energy is expended with vigorous activity than with low- and moderate-intensity activity.

Essential Questions

1. In what ways are calories spent?
2. What impact does the intensity of physical activity have on energy expenditure?
3. What role does physical activity play in energy balance and healthy weight?

Background Information

Energy

When we consume plant and animal products, the carbohydrates, fats, and protein (energy-containing macronutrients) are broken down during digestion, releasing energy and nutrients. Some of the energy from these foods is used immediately for various body functions, and some is stored as energy to be used at a later time.

The chemical energy provided by food is ultimately transformed into mechanical energy. *Mechanical energy* is the capacity to do work (e.g., muscle contraction). As the intensity of work increases, energy requirements also increase. For example, if we exercise at low intensity for 10 minutes, the amount of energy expended will be far less than if we exercise at high intensity for 10 minutes. The use of energy during work is referred to as *energy expenditure* (EE).

No energy is lost during the conversion of chemical energy into mechanical energy. For example, the chemical energy of carbohydrates and fats is converted into mechanical energy and heat energy. This process of converting food energy into mechanical work goes on continuously, maintaining the body's life-sustaining processes and keeping body temperature at 37°C. When we exercise, we use the energy in food to make the muscles contract, including the heart, and this requires energy. But since we are not perfectly efficient in converting energy into work, we also create heat. Muscle contraction during exercise increases our body temperature, which often makes us sweat to keep from overheating. During exercise, the energy demands of the body increase dramatically, often resulting in significant increases in body temperature.

Energy (Calories)

While it is important to be familiar with calories, it is essential that students understand the concept of energy consumed in food, energy spent being active, and the balance between the two.

Energy is measured in units called *calories*. Most of the food we eat contains energy, and everything we do (even sleeping) requires energy, resulting in caloric expenditure.

The eating patterns described for males and females of various ages in *Canada's Food Guide* are designed to meet the energy requirements, as well as nutrient needs, of most consumers. This means that individuals who follow the recommended eating patterns will consume an amount of energy that supports healthy weight, even if they are relatively inactive. Maintaining healthy body weight means, in general, that the energy consumed through food is approximately equal to the amount of energy expended. More active individuals should consume more Food Guide Servings to meet increased energy needs.

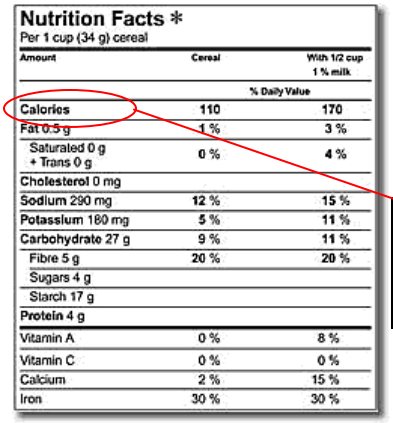
NOTE TO TEACHER

The measure of the energy value in food and physical activity is expressed in several forms: kilocalorie (kcal) or Calorie (equal to 1000 calories).

1 kcal = 1 Calorie = 1000 calories

In discussing energy value in food, it is uncommon to use calories (with a lower case *c*); most references to a specific number of calories actually refer to Calories.

The measure of the energy value contained on the Nutrition Facts panel on food labels is expressed in Calories. In fact, Calories must be listed on the Nutrition Facts panel, as shown in the following example.



Nutrition Facts *

Per 1 cup (34 g) cereal

Amount	Cereal	With 1/2 cup 1% milk
	% Daily Value	
Calories	110	170
Fat 0.5 g	1 %	3 %
Saturated 0 g + Trans 0 g	0 %	4 %
Cholesterol 0 mg		
Sodium 290 mg	12 %	15 %
Potassium 180 mg	5 %	11 %
Carbohydrate 27 g	9 %	11 %
Fibre 5 g	20 %	20 %
Sugars 4 g		
Starch 17 g		
Protein 4 g		
Vitamin A	0 %	8 %
Vitamin C	0 %	0 %
Calcium	2 %	15 %
Iron	30 %	30 %

This food item contains 110 Calories in 1 cup or 34 g serving.

Caution

Avoid focusing on calorie counting. Ensure that students understand that the eating patterns outlined in *Canada's Food Guide* and the "foods to limit" are designed to support healthy weight.

* Source: Health Canada. "Interactive Nutrition Label and Quiz." *Food and Nutrition*. 29 Mar. 2006. <www.hc-sc.gc.ca/fn-an/label-etiquet/nutrition/cons/quiz1-eng.php>.

Energy balance refers to the relationship between energy in (food consumption) and energy out (physical activity).

- *Positive balance* refers to a situation where energy intake from food exceeds energy expenditure from activity (fat gain).
- *Negative balance* refers to a situation where energy expenditure from physical activity exceeds food intake (fat loss).

In the best scenario, we are able to expend lots of energy from physical activity, and then have to eat sufficient food to balance the energy output. Restricting our food intake when we have low physical activity levels is not a healthy lifestyle.

Storing Fat as Energy

Historically, the body's ability to store energy as fat was extremely useful. Our cave-dwelling ancestors may have spent several days stalking a meal before actually eating it. The energy they stored from consuming the catch of the last hunt was important to sustain them until their next meal.

Fat stores are still important today, as they help us to

- maintain body temperature
- build and maintain body tissue and cells
- protect internal organs
- fuel muscle movement

In our society, however, it is easy to over-consume food and store an excess of energy. In addition, we have systematically reduced physical activity in our daily lives through all the conveniences available to us (e.g., remote controls, elevators and escalators, cars to travel even short distances). This remarkable decrease in daily physical activity is a key factor in the obesity epidemic. An excess of stored energy (body fat), particularly around the abdomen, is associated with increased risk of many diseases.

Energy Expenditure

The human body spends energy for many different purposes, such as life-sustaining metabolic functions, digestion, and physical activity. Regardless of the purpose for which the body spends energy, the energy expenditure will fall within one of the following three categories:

- basal or resting metabolic rate (BMR or RMR)
- thermic effect of food (TEF)
- energy expenditure of activity (EEA)

Overall Energy Expenditure = RMR + TEF + EEA

A detailed description of each of these categories follows.

Basal or Resting Metabolic Rate

Basal or *resting metabolic rate* (BMR or RMR) is the amount of energy per minute the body uses to maintain a quiet resting state. This is approximately 1 Cal per minute. Over the course of the day (and night), a person will expend a substantial amount of calories just to maintain the body (1440 minutes in a day x 1 Cal / min = 1440 Cal per day). Approximately 60% to 75% of the energy used every day is needed to maintain the essential body functions that sustain life. These functions include nervous system activity, breathing, heart function, maintenance of body temperature (thermoregulation), and hormone activity.

BMR and RMR measurements are taken under different conditions:

- **BMR measurements** are typically taken in a darkened room upon waking after 8 hours of sleep and 12 hours of fasting (to ensure that the digestive system is inactive), with the subject resting in a reclining position.
- **RMR measurements** are typically taken under less restricted conditions than BMR measurements, and do not require the subject to spend the night sleeping in the test facility prior to measurement. As a result, RMR has become the more popular measure, and BMR is not often measured anymore.

Factors Affecting BMR/RMR

BMR/RMR, primarily related to lean tissue/fat-free mass, is influenced by a number of factors working in combination, including the following:

- **Age:** Metabolism slows with age (2% to 3% per decade after 30 years of age), primarily due to a loss in muscle tissue due to inactivity, but also due to hormonal and neurological changes.
- **Gender:** Generally, men have a faster metabolism than women because they tend to be larger and have more muscle tissue.
- **Body size:** Larger adult bodies have more metabolically active tissue, which leads to a higher BMR/RMR.
- **Body composition:** Muscle tissue uses more calories than fat, even at rest.
- **Genetic predisposition:** Metabolic rate may be partly determined by genes.
- **Growth:** Infants and children have a higher BMR/RMR related to the energy needs of growth and maintenance of body temperature.
- **Hormonal and nervous controls:** Hormonal imbalances can influence how quickly or how slowly the body burns calories.
- **Environmental temperature:** If temperature is very low or very high, the body has to work harder to maintain a normal temperature; this increases the BMR/RMR.
- **Infection or illness:** BMR/RMR increases if the body has to build new tissue or create an immune response to fight infection.
- **Crash dieting, starving, or fasting:** Eating too few calories encourages the body to conserve through a potentially significant decrease in BMR/RMR. There can also be a loss of lean muscle tissue, which further contributes to reducing BMR/RMR.
- **Physical activity:** Hard-working muscles require extra energy during activity. Regular exercise increases muscle mass, which increases energy consumption, even at rest.
- **Stimulants:** Use of stimulants (e.g., caffeine) increases energy expenditure at rest. However, this is not a healthy way to lose weight.

Thermic Effect of Food

Thermic effect of food (TEF) is the energy required to process the food we eat. Approximately 10% of the calories in a meal are used to digest, metabolize, and store the food just eaten. The energy expenditure is directly related to the size of the meal and the food composition (i.e., the amount of protein, fat, and carbohydrate). Energy is also used for storing carbohydrates and fat as energy in body tissue.

Energy Expenditure of Activity

Energy expenditure of activity (EEA) is the amount of energy needed to fuel body movement as it occurs in activities of daily living, including exercise. Muscle tissue consumes approximately 20% of this energy at rest, but during vigorous exercise, the rate of energy consumption by muscle tissue may go up 50 times or more. Physical activity can have a dramatic impact on a person's daily energy expenditure. During heavy physical exertion (vigorous activity), the muscles may burn as many as 1200 Cal per hour in a very fit individual. An unfit person may only be able to expend 200 Cal per hour. Involuntary movements such as fidgeting and posture control (called NEAT: non-exercise activity of thermogenesis) also contribute to EEA.

Exercise is an extremely important variable in the daily energy expenditure equation and the maintenance of energy balance. Not only is exercise the most changeable component during a 24-hour period, but it is also the one component that is completely under voluntary control (for most people).

In addition to increasing caloric expenditure, exercise has many other benefits, including building more muscle, better bones, and a better heart.

REFERENCES

For additional information, refer to the following resources:

American College of Sports Medicine (ACSM). *ACSM's Advanced Exercise Physiology.* Ed. Charles M. Tipton. Philadelphia, PA: Lippincott Williams & Wilkins, 2006.

---. *ACSM's Metabolic Calculations Handbook.* Ed. Stephen Glass and Gregory B. Dwyer. Philadelphia, PA: Lippincott Williams & Wilkins, 2007.

---. *ACSM's Resource Manual for Guidelines for Exercise Testing and Prescription.* Ed. Leonard A. Kaminsky, et al. 5th ed. Baltimore, MD: Lippincott Williams & Wilkins, 2006.

The Cost of Being Sedentary

The rising rates of obesity are due as much to reduced energy expenditure (associated with the Canadian population's decreasing levels of physical activity) as to over-consumption of calories. Canadian adolescents are spending more time on computers, playing video games, and watching television than ever before. The 2007 report of the Standing Committee on Health states: "On average, adolescents in Canada spend almost 35 hours a week in front of a screen, representing more time than in the classroom over the course of the year" (*Healthy Weights for Healthy Kids* 4). Combining classroom and screen time does not leave much time for active living. In fact, in 8- to 18-year-olds, the average amount of time per day spent using media is at least 6 hours and 21 minutes a day (Rideout, Roberts, and Foehr 36). This amount of time does not include time spent sitting in class.

Another report indicates that more than half the young people ages 5 to 17 are not active enough for optimal growth and development (Canadian Fitness and Lifestyle Research Institute). The term *active enough* is equivalent to an energy expenditure of at least 8 kilocalories per kilogram of body mass per day.

Canada's Physical Activity Guide for Youth (Public Health Agency of Canada) recommends that young people participate in at least 90 minutes a day of moderate to vigorous physical activity.

It is generally accepted that moderate physical activity expends between 3.5 Cal / min and 7 Cal / min and vigorous physical activity expends over 7 Cal / min. It is important to understand that these are approximations only. An accurate calculation of the energy expended is dependent on the body weight of the individual. If two people completed the same physical activity for the same duration at the same heart rate, the individual with a higher body weight would expend more Cal / min.

Below is an example of approximately how much energy would be expended if an individual were to meet the minimum physical activity guidelines:

- **Moderate physical activity:** 60 min at 6 Cal / min = 360 Cal
- **Vigorous physical activity:** 30 min at 9 Cal / min = 270 Cal

With the addition of 90 minutes a day of physical activity, the total daily energy expenditure can be increased by 630 Cal.

> NOTE TO TEACHER
>
> By following the eating patterns described in *Canada's Food Guide*, individuals will meet the daily energy (caloric) requirement for the average sedentary person. As students become more active, they should choose (consume) the extra energy required from more Food Guide Servings.

REFERENCES

For additional information, refer to the following reports:

Canada. House of Commons. Standing Committee on Health. *Healthy Weights for Healthy Kids: Report of the Standing Committee on Health.* Ottawa, ON: Standing Committee on Health, 2007. Available online at <http://cmte.parl.gc.ca/Content/HOC/committee/391/hesa/reports/rp2795145/hesarp07/05_Report-e.htm#part1>.

Canadian Fitness and Lifestyle Research Institute. "Kids Fatter, Not Active Enough." *Tips for Being Active.* 6 June 2006. <www.cflri.ca/eng/lifestyle/1997/kids_fatter.php>.

Public Health Agency of Canada. *Canada's Physical Activity Guide for Youth.* Ottawa, ON: Public Health Agency of Canada, 2002. Available online at <www.phac-aspc.gc.ca/pau-uap/fitness/downloads.html>.

Rideout, Victoria, Donald F. Roberts, and Ulla G. Foehr. *Generation M: Media in the Lives of 8–18 Year-Olds.* Menlo Park, CA: The Henry J. Kaiser Family Foundation, March 2005. The full report is available online at <www.kff.org/entmedia/upload/Generation-M-Media-in-the-Lives-of-8-18-Year-olds-Report.pdf>. The executive summary is available at <www.kff.org/entmedia/upload/Executive-Summary-Generation-M-Media-in-the-Lives-of-8-18-Year-olds.pdf>.

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Suggestions for Instruction / Assessment

Energy Expenditure of Physical Activities

Determining Resting Metabolic Rate (RMR)

This learning activity is designed to help students understand the large energy expenditure associated with life-sustaining metabolic processes as a part of daily energy expenditure. Health Canada suggests males ages 17 to 18 need between 2450 and 2900 Cal each day. Females of the same age need between 1750 and 2100 Cal each day. These are estimates of the combined effects of resting metabolic rate and daily living activities, including moving around at home or school, as well as moderate exercise (Health Canada, "Estimated Energy Requirements").

BMR / RMR can be estimated by adding a "zero" to body weight in pounds (e.g., for an individual weighing 140 lbs. [63.5 kg], BMR / RMR is *approximately* 1400 Cal).

BMR / RMR can also be calculated by using the following equations (Livingston and Kohlstadt):

RMR (Female) = $248 \times m^{(0.4356)} - (5.09 \times a)$

RMR (Male) = $293 \times m^{(0.4330)} - (5.92 \times a)$

- Where: m = body mass in kg; a = age in years.
- This equation will yield the number of Calories required for a 24-hour period.

NOTE TO TEACHER

- Remember to use the order of operations where exponents are dealt with before multiplication.
- In performing the calculations, **m** is to the power of 0.4356 for women, or 0.4330 for men, and NOT multiplied by.

Have students calculate female and male RMRs using RM 4–NU.

Refer to RM 4–NU: Resting Metabolic Rate (RMR) Calculator (Excel spreadsheet).

The Excel spreadsheet is available on the CD-ROM version of this document, as well as online at <www.edu.gov.mb.ca/k12/cur/physhlth/>.

Simple Example (17-Year-Old Female at 56 kg)

Energy Expenditure

The body spends energy on various types of activity. "Activity" includes the movement we choose to do, as well as energy required to stay alive (e.g., metabolic activity such as heart beat, breathing, and maintaining body temperature). Estimated energy requirements are based on age, gender, and body weight.

Resting Metabolic Rate (17-Year-Old Female)

Energy Required to Sustain Life

Energy is required for breathing, nervous system activity, maintaining body temperature, heart function, and hormone activity.

$248 \times m^{(0.4356)} - (5.09 \times a)$, 56 kg, 17 years old
Energy Required to Sustain Life (per day) = **1350 Cal**

+

Energy Required for Activities of Daily Living

Energy is required for daily activities, such as brushing teeth and hair, eating, sitting in class, sitting at a computer, texting, and so on.

Activities of Daily Living = Approximately **400 Cal**

+

Active Living

Walking Time

5 min walk to school
5 min walk back from school
3 min of walking (4 classroom changes with walk between classes)
15 min walk at lunch
Walking Time = 28 min x 3 Cal/min = **86 Cal**

Running Time

20 min run on treadmill at home
Running Time = 20 min x 11.5 Cal/min = **230 Cal**

Total 316 Cal

Total Energy Expenditure =

1350 Cal + 400 Cal + 316 Cal = 2066 Cal for the day as described

Energy Intake

The food we eat is important to supply nutrients and energy for health and to fuel activity. The more active we are, the more energy we spend each day. For example, the number of Calories needed to maintain energy balance for a 17-year-old female is between **1750 Cal** (sedentary individual) and **2400 Cal** (with 60 minutes of moderate daily activity).

Energy Intake to Meet Energy Expenditure

Breakfast

½ plain bagel with	
1 tbsp peanut butter	195 Cal
1 large banana	105 Cal
1 cup milk (1%)	100 Cal
	400 Cal

Lunch

1 slice pepperoni pizza	290 Cal
1 cup chocolate milk (1%)	160 Cal
1 granola bar (26 g)	110 Cal
1 small apple	47 Cal
	607 Cal

Dinner

2 cups spaghetti with meatballs and tomato sauce	520 Cal
200 g garden salad with	
1 tbsp oil and vinegar dressing	109 Cal
1 cup milk (1%)	100 Cal
¼ cantaloupe	48 Cal
	777 Cal
Total	**1784 Cal**

Snacks

175 g cherry yogurt (175 g = some small containers)	100 Cal
1 chocolate chip cookie	138 Cal
16.8 g (3 cups) microwave popcorn	78 Cal
	316 Cal
Total	**2100 Cal**

Total Energy Intake =

Approximately 2100 Cal per day

Food Guide Servings

Vegetables and Fruit = 6	
banana (large)	2
apple (small)	1
tomato sauce	1
salad	1
cantaloupe	1
Grain Products = 6	
bagel	1
pizza crust	1
granola bar	1
spaghetti	3
Milk and Alternatives = 4	
milk (3 cups)	3
yogurt	1
Meat and Alternatives = 2	
peanut butter	½
pepperoni	½
meatballs	1

Foods to Limit = 3

popcorn
chocolate chip cookie
granola bar

Determining the Energy Expenditure of Various Physical Activities

This learning activity is designed to help students understand the relationship between the intensity of a physical activity and the corresponding energy required to perform that activity. Each student will need to know his or her body weight.

Directions/Description

- Students identify several activities from their physical activity plan (or other comparable activities) and locate them in RM 5–NU, which lists physical activities in alphabetical order, as well as by intensity.
- Where a physical activity is listed more than once, students note the different levels of intensity and select the level that best reflects their participation.
- Students then write a journal entry comparing and contrasting energy expenditure associated with activities at different levels of intensity.

Refer to RM 5–NU: Energy Expenditure of Physical Activities (Excel spreadsheet).

The Excel spreadsheet is available on the CD-ROM version of this document, as well as online at <www.edu.gov.mb.ca/k12/cur/physhlth/>.

Determining Relative Energy Expenditure through Daily Physical Activity Intensities

In this learning activity, students gain a greater understanding of their personal daily energy expenditure by examining their daily physical activities and categorizing them by intensity level.

Directions/Description

- Students first determine the amount of time they spend engaged in physical activities in various intensity categories over a three-day period using RM 6–NU. Daily estimates will be more accurate if students first identify the number of hours spent sleeping (resting), and then the time spent in vigorous or moderate activity, and finally the time spent in very light or light activity. Activity descriptions are provided in RM 6–NU. The total time must equal 24 hours.
- Students will use the 24-hour account of activities for the culminating Final Tally activity in Module C, Lesson 3, where they will analyze physical activity by intensity and food consumption habits and use the information to create a daily energy balance plan.

Refer to RM 6–NU: Determining Daily Physical Activity Intensities.

REFERENCES

For additional information, refer to the following websites:

CyberSoft, Inc. "Exercise Calorie Expenditures." *NutriBase*. <www.nutribase.com/exercala.htm>.

Health Canada. "Estimated Energy Requirements." *Food and Nutrition.* 5 Feb. 2007. <www.hc-sc.gc.ca/fn-an/food-guide-aliment/basics-base/1_1_1-eng.php>.

Livingston, Edward H., and Ingrid Kohlstadt. "Simplified Resting Metabolic Rate-Predicting Formulas for Normal-Sized and Obese Individuals." *Obesity Research* 13.7 (July 2005): 1255-62. The BMR equation is cited online at <http://cat.inist.fr/?aModele=afficheN&cpsidt=17018417> (27 Oct. 2008).

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