CARBOHYDRATE NEWS

Providing the most current and practical scientific information on carbohydrate and its role in nutrition and health.

Carbohydrate for Healthy Active Living

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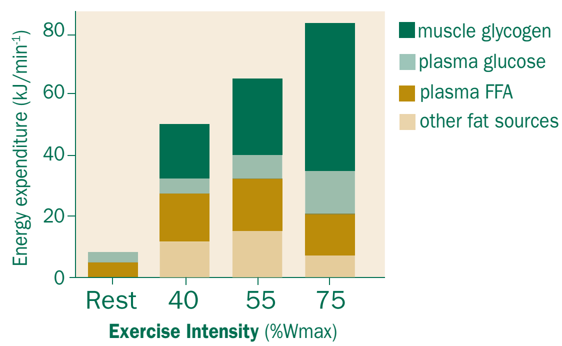
The human body is engineered for movement and the average body has ~25-30 kg of skeletal muscle that allows us to perform a wide variety of actions. We often categorize movements that are structured and measurable as physical activity or exercise. To perform movement of any type, the body requires energy. The heart and skeletal muscles increase energy production during exercise and the energy demand can increase 100-fold compared to resting energy requirements (1).

The cells of the human body contain mitochondria, which are capable of providing biochemical energy for all types of functions. The mitochondria produce energy through oxidative (aerobic) metabolism that requires a constant supply of oxygen and nutrients from our diet. The primary nutrients for this process are fat and carbohydrate, while protein is not a significant fuel in a well fed individual. During aerobic exercise, mitochondrial energy production is dramatically increased (2) and much higher rates of fuel provision are needed compared to rest.

The intensity of aerobic exercise largely determines the proportion of energy that comes from carbohydrate or fat sources. Intensity is measured by determining how much oxygen an individual's body is consuming (taking up) and using in the muscles. This measure directly relates to *the rate* at which they are doing work (power, Watts) or *the total amount* of work that was done (kilojoules). The maximum rate that you can take up and use oxygen to produce energy is referred to as your maximal oxygen uptake (VO_2max). At rest, the demand for fuel is low and carbohydrate provides ~30-40% of what is needed (3). When exercise is initiated, carbohydrate provides almost all of the energy required. As the exercise session continues at low intensities, fat becomes a more important energy source and carbohydrate contributes only ~40% of the needed fuel (4). At moderate or heavy exercise intensities (greater than 50% of VO_2max), carbohydrate becomes the dominant fuel throughout the exercise session.

Figure 1 indicates the source of energy depending on the intensity of exercise. For example, at 75% VO_2max, carbohydrate is the primary energy source, coming from carbohydrate stored as muscle glycogen and from glucose in the blood (3). A common misconception is that lower intensity exercise (e.g., 40% VO_2max) is favoured for weight loss because more fat is used at this intensity (often referred to as the "fat burning zone"). Figure 1 demonstrates that while a greater percentage of fat may be utilized at 40% of VO_2max, the absolute amount of fat used is highest at 60% VO_2max because more total calories are needed. At higher intensities (~75% VO_2max), however, fat use is reduced somewhat, but even more calories are used (per minute), which is important for weight management.

Figure 1. **Fuel selection during exercise of varying exercise intensities (van Loon et al, 2001 (3)).**



FFA = free fatty acids; Wmax = percent of maximal power output attained in Watts; Other fat sources represents predominately intramuscular fat.

Carbohydrate is also used for energy during "anaerobic" (without oxygen) exercise, which is needed to complement the oxygen-dependent energy production in exercise that requires bursts of activity like sprinting, jumping and changing directions (5, 6). Sports like hockey, basketball, soccer, field hockey and football require large amounts of aerobic energy and anaerobic energy. Carbohydrate is the predominant fuel source for these types of activity, because it provides fuel for both "aerobic" and "anaerobic" energy production. While we may only use approximately 0.1-0.2 g of carbohydrate per min at rest, it is common for athletes to use 2-4 g of carbohydrate/min in anaerobic activities (6). Games played by children also involve these bursts of activity, and carbohydrate is needed in these situations.

Carbohydrate stores in the body are quite small. Some carbohydrate is stored in muscles and the liver as glycogen – a large molecule made up of many glucose units. On average, a 70 kg male has approximately 350 g of stored carbohydrate in skeletal muscle, which represents 1400 kcal of stored energy (7). The other form of carbohydrate in the body is glucose in the blood and fluids surrounding cells. Glucose is the only source of energy for the brain and red blood cells and is required by other tissues, including skeletal muscle. The primary goal of carbohydrate metabolism in the body is to maintain a constant blood glucose level (~5 mmol/L) and ensure an ample supply for these tissues. Because glucose is always needed and not much is available, carbohydrate metabolism is carefully controlled.

Most of the body's glucose comes from dietary carbohydrate (starch and sugars). All dietary carbohydrate, regardless of source, is broken down into monosaccharides (glucose, fructose, and galactose). While glucose is used directly by cells for energy, galactose and fructose must first be converted in the liver to glucose. An eating pattern consistent with *Eating Well with Canada's Food Guide* (8) can meet the carbohydrate requirements of sedentary and active individuals by supplying the recommended 45-65% of energy as carbohydrate (9). Because the Guide was based on the energy requirements of sedentary individuals, additional energy for physical activity, particularly for athletes, should be supplied by foods high in carbohydrate (10, 11).

Since the body has a very limited ability to store carbohydrate, athletes and others engaged in high intensity physical activity should take steps to a) maximize the amount of carbohydrate they have in their bodies before a demanding exercise event, b) supplement the body with carbohydrate during an athletic event, and c) consume carbohydrate immediately after exercise to replenish the body store of carbohydrate in preparation for the next exercise session (10, 11). Individual needs should be considered (e.g., eating preferences, timing of food ingestion) and experimented with during training. Specific recommendations related to nutrient timing for athletes are described in Table 1 (as reviewed in references 10-12 and cited in 13-17).

Carbohydrate has a variety of roles in the body, but the most important is provision of energy to cells, particularly the brain and working muscles. All people who are active or are contemplating increasing their level of activity should consume regular meals and snacks that are high in carbohydrate given its important role in enabling exercise. Carbohydrates are not just essential for athletes. Dietary advice provided to athletes before, during, and after exercise, should focus on the timely provision of carbohydrate. Strategies for exercise nutrition will be specific to the individual to avoid gastrointestinal distress and to maximize performance.

Table 1.	General nutrition recommendations: before, during and after exercise.
Pre-exercise	• The timing of a pre-exercise meal or snack depends on individual's preferences. • Foods should be low in fat and fibre to reduce gastric distress and promote gastric emptying, high in carbohydrate to maximize glycogen stores and prevent an exercise-induced decline in blood glucose levels, and moderate in protein.
During Exercise	• Carbohydrate ingestion during exercise is recommended, particularly for events lasting longer than 1 hour. • Extensive research supports the ingestion of fluid containing 6-8% carbohydrate based on volume, which is the amount typically found in most sport drinks. • Carbohydrate should consist primarily of glucose or mixtures of sucrose, glucose, fructose, and maltodextrin, as found in most sports drinks. Large amounts of fructose are not recommended due to the greater likelihood of gastrointestinal problems.
Post-exercise	• The sooner carbohydrate is ingested post-exercise, the faster and higher the glycogen levels will be after exercise. • The type of carbohydrate consumed is also important for optimizing glycogen restoration – glucose and sucrose are equally effective, whereas fructose is less effective. Foods that cause a larger rise in insulin, such as rice, potatoes, etc. appear to lead to higher muscle glycogen levels 1 day after exhaustive exercise. • Recovery snacks right after exercise, in addition to being high in carbohydrate, should also include protein to stimulate protein synthesis and muscle repair and a small amount of fat – mini-meals, essentially. For example, a liquid recovery snack typically contains ~54 g of carbohydrate, 20 g of protein and 8 g of fat (~365 total kilocalories). • It is recommended that a full meal follows 2-4 hours after intense exercise.

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BEYOND THE WEIGHT SCALE: ROLE OF PHYSICAL ACTIVITY IN OBESITY REDUCTION

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Weight loss remains a primary treatment strategy for the reduction of obesity and its co-morbidities. The success of obesity-reduction strategies that focus on increased physical activity in combination with a balanced diet is often determined by the degree of weight loss or reduction in body mass index (BMI). However, obesity prevalence continues to increase (1,2) and individuals who engage in weight-loss behaviours rarely experience long-term success (3). Recent evidence indicates that weight loss is not absolutely required to reduce metabolic risk, mortality, and morbidity with lifestyle changes that include physical activity combined with a healthy diet (4,5). A focus on small changes in lifestyle-related behaviour, rather than weight loss, may be critical to the success of obesity-reduction programs. In addition, primary targets of lifestyle-based strategies must be redefined by leading health authorities to include waist circumference, body composition and measures of cardiometabolic health in addition to BMI or weight loss.

OBESITY REDUCTION WITHOUT WEIGHT LOSS

Increased physical activity in combination with a healthy eating pattern can result in weight loss or a reduction in BMI. A number of studies have also observed improvements in body composition and abdominal obesity with minimal changes in body weight (reviewed by Ross and Janiszewski (5)). Several investigations have examined the effects of increased physical activity while providing subjects with additional food calories to prevent weight loss. For example, Ross et al (6) found that after 14 weeks of exercise with caloric compensation and no weight loss, total (7%), abdominal (10%), and visceral (18%) fat decreased in obese women. These reductions in fat mass were similar to the calorie-restricted weight loss group that lost 6% of their original body weight (6). It is possible that in this study and others that do not result in weight loss that the reductions in body fat are offset by gains in lean muscle mass (7).

EXERCISE AND REDUCTION OF CARDIOMETABOLIC RISK FACTORS WITHOUT WEIGHT LOSS

The benefits of physical activity extend beyond weight loss and body composition. Even a single bout of aerobic exercise can generate temporary cardiovascular and metabolic improvements. For example, hypertensive individuals have demonstrated a reduction in resting systolic and diastolic blood pressure of up to 18-20mm Hg and 7-9mm Hg. This "post exercise hypotension" may last for a number of hours after exercise (8). One session of exercise also reduces triglyceride (TG) levels by 10-25% and increases HDL cholesterol by 7-15% (9,10). The reduction in TGs can be detected 24-48 hours after exercise and is most pronounced in those with highest pre-exercise TG levels (9). A single bout of exercise also increases muscle glucose uptake (11) and improves insulin sensitivity by approximately 20% in healthy and insulin resistant individuals (12). The metabolic effect of exercise may vary depending on the fitness level of the individual, their pre-exercise metabolic profile, and the intensity and duration of the session (10).

Chronic exercise, or the cumulative total of single bouts of exercise, results in improved cardiorespiratory fitness (CRF), which is also related to reduced mortality and morbidity, independent of BMI (13,14). In addition, further improvement in blood lipids, insulin sensitivity, fasting blood glucose, and blood pressure are observed beyond those seen with a single exercise session. These enhancements have also been observed in physical activity interventions where minimal weight loss was documented. For example, three months of exercise training resulted in a 30% increase in insulin sensitivity in obese men who experienced no change in body weight (15). These changes can be accounted for in large part by alterations in body composition (15) and changes in the expression of metabolic genes (11). Alterations in these genes may lower free fatty acids, enhance glucose uptake, and decrease the risk of insulin resistance and type 2 diabetes.

BEYOND THE WEIGHT SCALE AS AN INDICATOR FOR SUCCESS

Figure 2 demonstrates the positive effects of physical activity and a balanced diet on morbidity and mortality. The greatest benefit is observed in Scenario 1 by decreasing BMI and waist circumference and increasing cardiorespiratory fitness (CRF). Scenarios 2 and 3 also demonstrate improvements in health due to increased CRF, with no change in body mass index (BMI) and/or waist circumference (WC). Scenario 3, in particular, illustrates the importance of lifestyle-related behaviour change. Regular self-monitoring or evaluation by a healthcare professional of physical activity and dietary habits will encourage long-lasting behaviour change. Some commonly used tools for physical activity measurement include pedometers for determining how many steps have been taken each day, a daily physical activity diary or record, or a simple physical activity questionnaire (see page 4).

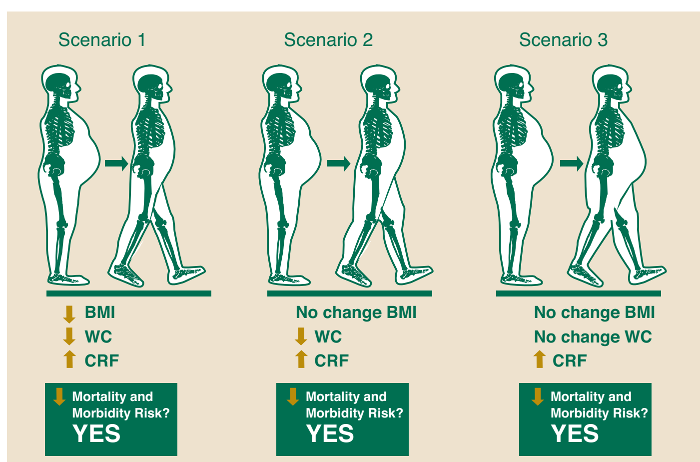

Figure 2. Three possible outcomes when increasing physical activity with a balanced diet for the purpose of reducing obesity and related co-morbidities (Ross and Janiszewski (5)). BMI = Body mass index; CRF = Cardiorespiratory fitness; WC = waist circumference.

Physical Activity Questionnaire
(Marshall et al (16))

Q1 How many times a week do you usually do 20 minutes or more of vigorous physical activity that makes you sweat or puff and pant? (e.g., jogging, heavy lifting, digging, aerobics, or fast bicycling).

Response	Score
a. 3 or more times a week	4
b. 1 to 2 times a week	2
c. none	0

Q2 How many times a week do you usually do 30 minutes or more of moderate physical activity or walking that increases your heart rate or makes you breathe harder than normal? (e.g., carrying light loads, bicycling at a regular pace, or playing doubles tennis).

Response	Score
a. 5 or more times a week	4
b. 3 to 4 times a week	2
c. 1 to 2 times a week	1
d. none	0

Scoring:
Add Q 1 + Q 2.
Score 4 or more = "Sufficiently" active
(encourage patient to KEEP IT UP)
Score 0 to 3 = "Insufficiently" active
(encourage patient to do MORE)

Leading health authorities often suggest that weight loss of 5-10% is associated with a wide range of health benefits (reviewed by Ross and Bradshaw (4)). While weight loss improves obesity-related health risk, regular exercise combined with a healthy diet results in reduced waist circumference and improved cardiometabolic risk factors and cardiorespiratory fitness, even with minimal weight loss. This presents an opportunity for health professionals to guide patients or clients on the benefits of exercise in combination with healthy eating, focusing on behaviour change while reducing the emphasis on the weight scale. This strategy may encourage patients to develop and maintain lifestyle changes, particularly if they have difficulty losing weight.

MEASURING WAIST CIRCUMFERENCE

While there is no consensus on the best method to measure waist circumference, a recommended protocol is detailed below (17). Regardless of the methodology used, consistency is critical for repeat measurements (18).

To measure waist circumference, locate the top of the right hip bone (iliac crest) and place a measuring tape in a horizontal plane around the abdomen at the level of the iliac crest (Figure 3). Before reading the tape measure, ensure that the tape is snug, does not compress the skin and is parallel to the floor. The measurement is made after the patient exhales (19).

If it is not possible to locate the hip bone due to excess adipose tissue in that region, measure at the level of the belly button to allow for consistent repeat measurement.

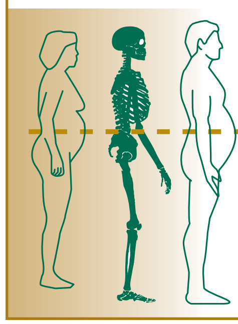

Figure 3. Measuring tape position for waist circumference in adults.

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