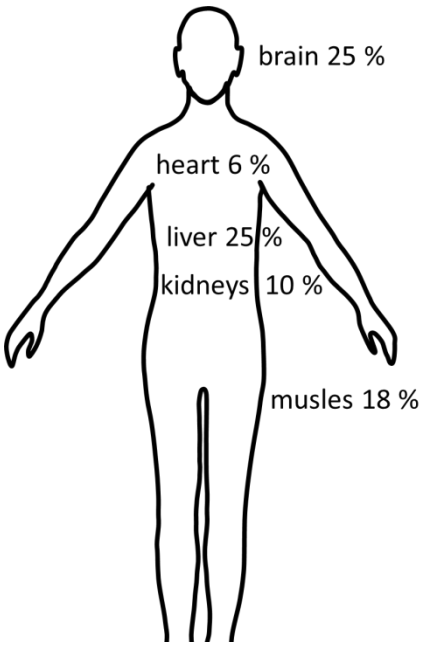
Name: Numer: Study group:

Theoretical part

Assessment of energy expenditure using indirect calorimetry and Harris-Benedict formula

All events connected with life are bound to energy. In one day, the amount of ATP in kilograms used up by our bodies approximately equals our body weight. Measurement of energy expenditure is an important tool in clinical practice, enabling us to determine the optimal nutritional support of a patient. The energy expenditure of an organism and consequently the need for energy intake are increased during disease, post-surgical recovery, and in a state of malnutrition. On the other hand, we need to decrease the energy intake in patients suffering from obesity. It is particularly urgent in patients who already have hypertension or diabetes to prevent them from suffering other, more serious consequences like heart attack, renal failure, or loss of vision. Moreover, diabetes is one of the leading causes of vision loss in developed countries. Therefore, we cannot underestimate the value of proper therapy of obesity. Also, the area of nutritional care for athletes is very important. Athletes need to be placed on an adequate diet that suits their personal needs and the type of activity that they perform. Finally, it is crucial for each one of us to know our energy expenditure so that we keep our energy balance (food intake and expenditure) in equilibrium and thus promote good health. In order to understand how to measure the energy balance of an organism in one day or during the day, we need to get familiar with some terms like basal, resting and actual energy expenditure.

Basal energy expenditure (BEE) is the amount of energy that our bodies spend on basic processes that are crucial for life, such as the beating of the heart, basic metabolism of nutrients and regulation of them, breathing, maintaining body temperature, resting tone of muscles and the functioning of the central nervous system that oversees the regulation of homeostasis. Naturally, there are many more processes involved in the basal metabolic energy expenditure. When we look at the microenvironment of every cell, the greatest amount of energy is spent on the mere maintenance of the resting membrane potential of a cell. Basal metabolism represents about 50–70% of the whole energy spent by the body and forms the basis of the energy demand that we need to cover with our diet every day. The basal metabolic rate is defined as the energy used up in a unit of time in a person in a lying position, at physical and mental rest, in a thermoneutral environment (22–26 °C), at least 10–12 hours fasting, and without the effect of stimulating drugs (e.g. tea, coffee, etc.). It is therefore not very suitable for measuring hospitalized patients. However, we can approximately estimate BEE by



Participation of different organs on basal metabolic rate

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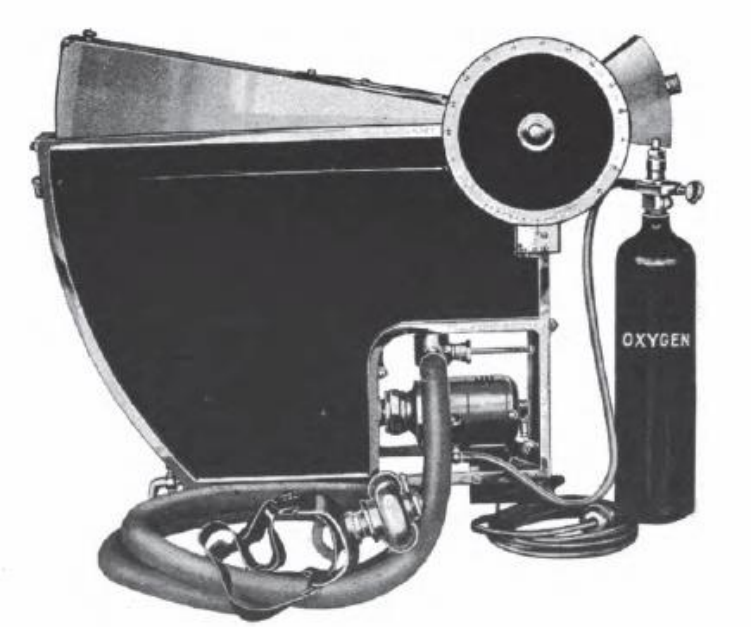
measuring resting energy expenditure either using indirect calorimetry or assessing it by calculation, for example using the Harrison and Benedict formula.

Resting energy expenditure is therefore an approximate value of BEE measured in clinical conditions in a hospital whereby all the following restrictions must be maintained:

- e measure in the morning in a lying position in the bed from which the person hasn't stood up yet (to prevent energy from being burnt due to muscle work)
- The examined person must be relaxed and comfortable, but awake
- In a thermoneutral environment (so that we prevent energy expenditure being spent on thermoregulation)
- Before a morning meal (to prevent energy being spent on digestion and peristaltic movements) and making sure that there were no proteins in the last meal (proteins have the highest specific dynamic effect, which is the energy that is spent on digestion, absorption and metabolism of a nutrient after absorption).
- In addition, we can measure the **actual energy expenditure (AEE),** which accounts for the energy that is spent to cover the actual energy requirements, i.e. in standing position, it is the energy necessary for maintaining the upright position by antigravity muscles. After physical exertion, the actual energy expenditure basically covers the increased energy requirements of the heart and lungs that are still at work trying to bring the deviated homeostasis of the organism caused by the exertion to equilibrium. Moreover, the body tries to get rid of excessive heat by sweating, and this requires energy as well. The value of AEE can likewise be calculated by an equation which you can find in the protocol for this practical. Another option for calculating the energy output is to sum up all the components of energy expenditure during one day, and this can be found in the practical on compiling a daily diet.

Indirect calorimetry is based on the presumption that oxygen spent by an organism stands in some relationship to the energy spent for metabolic processes of cells. The cells respire and thus use up oxygen while creating energy in the form of ATP. This energy is then expended on various functions.



Krogh's respirometer - reservoir filled with oxygen

To calculate the energy expenditure of a person, we need to know the **energy equivalent of the oxygen (EE).** For simplification, we will use the EE for mixed nutrition (every nutrient has its own EE, but we assume that the examined person eats mixed nutrition during the day). Its value is 20.19 kJ/liter of O_2. This means that when the organism consumes 1 liter of oxygen, it gains 20.19 kJ of energy which is then continually used (since ATP is an unstable compound, and cannot be stored) for different processes in the body. Consequently, if we measure the amount of O_2 that was consumed, we can calculate the energy expended by the body. For the measurement of the consumption of O_2, we will use **Krogh's respirometer**. This is a device with closed circulation of air, i.e. the subject

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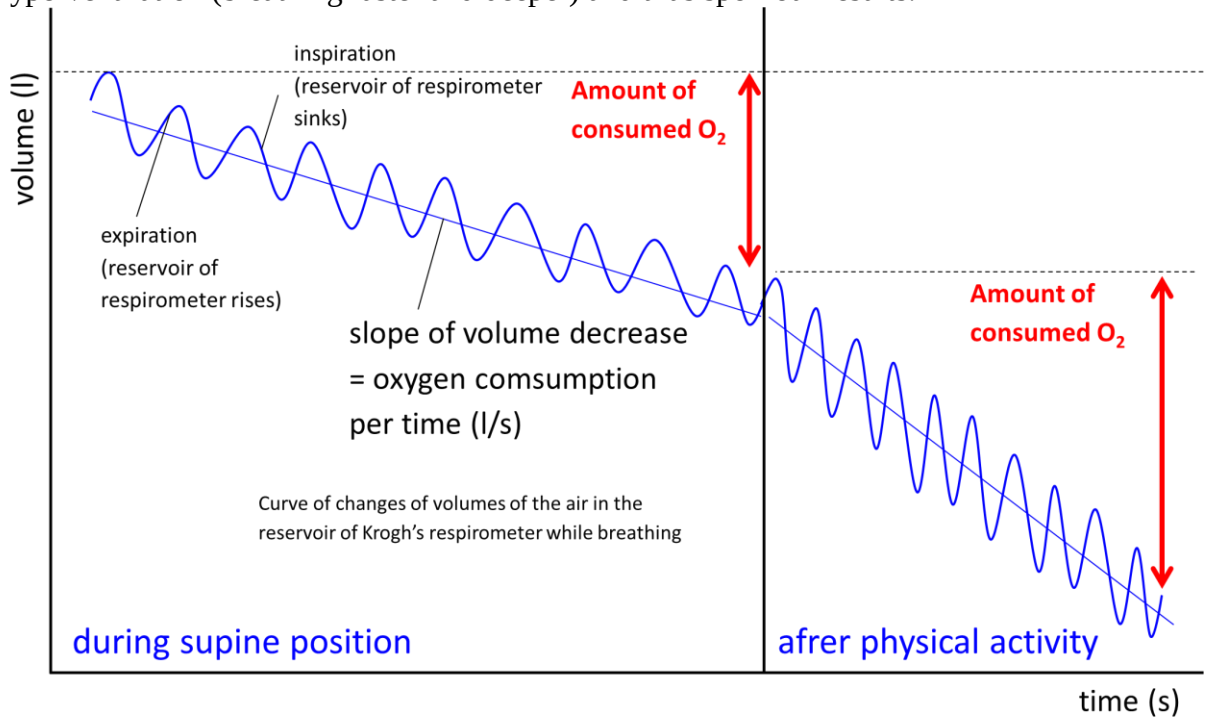
breathes both air from and into it. The reservoir is filled with oxygen, and surrounded with water. The level of the oxygen continually diminishes as the examined person is breathing. Consequently, the reservoir sinks further and further into the water, and the curve of changes of volumes in inspiration and expiration sinks as well while the person is consuming the oxygen, and its slope tells us about the amount of oxygen consumed.

CO_2 from the expired air is removed by an CO_2 absorber (so-called soda lime consisting of sodium and calcium hydroxide). Otherwise, CO_2 would accumulate in the air (since it is a closed system) and cause hypercapnia (increased CO_2 in the bloodstream). Hypercapnia would then, through the stimulation of the respiration center in our brain stem, cause hyperventilation (breathing faster and deeper) and thus spoil our results.



The energy expenditure can be measured also via **direct calorimetry**, which is based on the fact that all metabolic processes in the body are connected with the production of heat. Thus, if we measure the heat produced over some time, we will be able to calculate how much energy was actually burnt in the body. This method is, however, very complicated and is no longer used in clinical practice today.

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Theoretical part
Compiling a daily diet: principles of proper nutrition

It is important for everybody to know the basic principles of a healthy lifestyle and nutrition since it contributes to the prevention of various diseases. There are many diets and recommendations for a healthy lifestyle available today. Moreover, this field is becoming more and more commercialized, and money has become more important than the health of an individual. It is therefore very important to be familiar with this field. Optimal nutrition is an important part of a healthy lifestyle, which in turn determines almost 60% of our health. The problem of proper nutrition is particularly important for certain groups in the population that vary in some aspects pertaining to the way their bodies function. In children, proper nutrition (both how many calories they eat and what composition their meals have) is essential for their growth and proper development and functioning of the organs as well as their bodies as a whole. Pregnant women, whose tastes and needs markedly change during pregnancy, must also pay special attention to nutrition. Athletes, likewise, depend on an adequate and individual type of diet, as their bodies are often strained in an extreme way.

Nutrition and disease

In the therapy of certain diseases there are some nutritional restrictions and dietary adjustments that need to be respected. These restrictions and changes are based on a knowledge of the pathogenesis of a disease (i.e. the mechanisms resulting in the development of a disease). As an example could serve a low-protein diet and restriction of fluid intake in patients with liver failure (for example, in cirrhosis caused by excessive alcohol intake or chronic hepatitis). The explanation for this is that bacteria of the gut digest proteins and produce ammonia (NH_3), but the ammonia cannot be sufficiently processed by the liver and it can cause toxic damage to the central nervous system. At the same time, low production of proteins by the liver and increased pressure in portal venous circulation due to scarring of the liver (the portal vein brings blood from the gastrointestinal tract and spleen to the liver) can cause significant swelling, particularly in the abdominal region. This explains the restriction of the water intake. A nice example of a nutritional recommendation based on a disease and its therapy could also be the fact that diabetics who are dependent on insulin therapy should have a snack before they go to bed. This is due to the fact that they are at risk of low sugar levels (so-called hypoglycemia) during the night because of the effect of insulin. On the other hand, for patients with type-2 diabetes (those who are not at first dependent on insulin injections) it is recommended to lose weight and increase physical activity since the resistance of tissues to insulin, which is the cause of this type of diabetes, can be frequently tackled by losing weight. All recommendations naturally need to be approved by the physician that treats the patient.

Food allergy

However, we must mention one disease that might be connected with food and is nowadays very common. The occurrence of it also shows an increasing trend and we all know it: allergies. An allergic reaction is an “overreaction” of the immune system to some substances that are called **allergens**.

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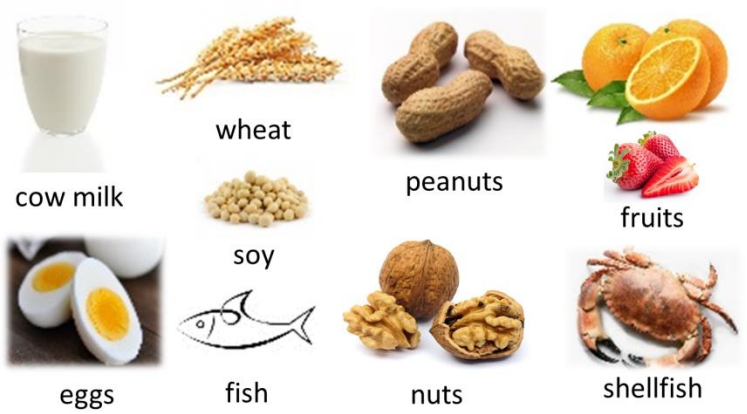
Foodstuffs are a significant source of allergens. Food allergies can be manifested by all sorts of symptoms such as intestinal problems (diarrhoea, bloating, pain), but also frequently skin (different types of rash) or even respiratory problems. If the causes are unclear, it is recommended to start writing down as precisely as possible the content of one's daily diet (for 1–2 weeks). The correlation between the occurrence of symptoms and the type of food can lead to finding out what the specific allergen is. We can then attempt to remove it from our diet, and see if the problems improve or even disappear.

The most common allergens:



other: seeds like sesame seeds, spices (e.g. mustard, garlic, coriander), vegetables (celery), meat – essentially anything can be an allergen.

Nutritional advice

If we look at the recommendations below, we might say that we have not learnt anything new. However, once we reconstruct our daily diet from yesterday and compare the reality with the recommended doses of nutrients, we might be very easily surprised by the "nutritional mistakes" that we make, much more than we would have admitted before this practical. To be able to do this, we need to examine in detail all of the components of our diet, including vitamins and minerals.

It is important to observe not only intake of proper amounts of the food components, but it is also important that the component come in a suitable and soluble form. For example, we should eat more polysaccharides (e.g. bread, fruits, vegetables, etc.) than monosaccharides (e.g. sugar or sweets), and regarding fats, the diet should contain unsaturated fatty acids like omega 3 or 6 (so-called n-3 or n-6 PUFA) in an optimal amount. They are essential to us since our body cannot synthesize them. Also, **fibre** is an essential part of our daily diet. It consists of polysaccharides (like cellulose) and cannot be digested by our bodies' enzymes. Since it draws water, it makes the faeces softer and bigger, and thus promotes peristaltic movements of the gut. In this way it prevents constipation. It also helps to prevent diverticles (small pouches on the wall of the colon) and hemorroids (dilated veins in the lower rectum or anus) that are caused by the increased pressure in the colon due to the difficulty of moving the faeces forward if they are hard. Moreover, hard faeces can damage the mucosa of the anus during defecation, causing small but painful fissures.

Nutrition for a healthy lifestyle

- varied and balanced diet
- adequate intake of food rich in fibre, vitamins and minerals like fresh vegetables, fruits (optimally 5 times per day) and pulses
- drink mineral water (without sugar) and diluted fruit juice

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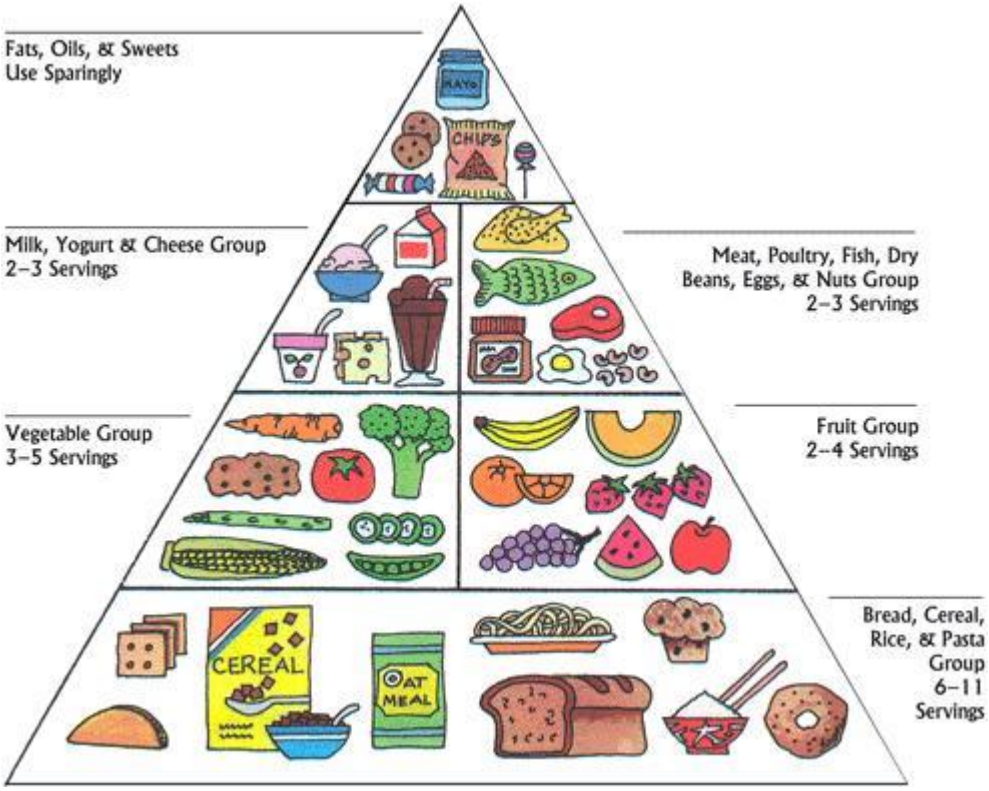
- prefer dark bread and whole-grain pastries (which contain more of some important minerals and vitamins and particularly fibre)
- restrict consumption of:
- fatty meals and sweets like chocolate, cakes and fatty meat (prevention of caries and being overweight)
- fried foods, canned foods and smoked foods (these contain carcinogens)
- meat (mainly red – pork, beef) – recommended consumption of meat 150–200 g/week
- exchange red meat for poultry instead (red meat is associated with an increased risk for certain types of cancer)
- increase consumption of fish (at least twice a week), as these contain unsaturated fatty acids like omega-3 and vitamin D
- restrict salt intake and avoid salty food like salted peanuts or chips (for prevention of hypertension)
- alcohol intake only occasionally and moderately (prevention of various diseases like cancer, or injuries and car accidents)
- increase number of daily meals (the more calories it is necessary to eat the more meals per day)
- keep an adequate body weight and do regular exercise (at least an hour daily) (gain and expenditure of energy should be in balance)

You can find the recommended doses for adults for one day in your protocol.



Food pyramid
(http://mariasols.com/wp-content/uploads/2008/05/food_pyramid.JPG)

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Theoretical part
Evaluation of nutritional state

Even today, in our developed society, we encounter disorders connected with eating and a person's nutritional state. We can find the two extremes, both undernourishment (called inanition and, in its extreme variant, cachexia) and being overweight (and its extreme variant obesity). The occurrence of these disorders shows an increasing trend. Both of the extremes can take their toll, with consequences both somatic (endocrine, e.g. decreased fertility, cardiovascular, immune disorders, problems with motor apparatus, etc.) and mental (inferiority complex, depression). If these problems are neglected, they may lead to severe complications and early death.

For the evaluation of a subject's nutritional state, the most common parameter is body weight. However, body weight can be interpreted in many ways, because it informs us neither about height or fat distribution (amount of subcutaneous fat, e.g. fat in breasts, buttocks or thighs, as opposed to visceral or abdominal fat which increases the risk of cardiovascular diseases) nor about muscle mass. Therefore, we use other parameters to sort out these deficiencies, e.g. the body weight/body height ratio, hip and waist circumference and other indices derived from them.

Using multiple values to describe the nutritional state helps us to distinguish some physiological deviations (caused, for example, by the influence of hormones) from already pathological conditions. Moreover, they can distinguish between men and women pertaining to their different body constitution. There are many other parameters determining the nutritional state of an individual that are used in clinical practice, primarily calculation of active muscle mass and skinfold thickness. These values can be determined very precisely in many different ways (dilution methods, spectrometry or computed tomography – CT). However, they are complex in terms of equipment and can be substituted by more simple ones that are accurate enough for clinical practice, such as measuring the skinfold thickness by a caliper, measuring active muscle mass by a simple measuring tape and few calculations, or measuring the fat percentage in the body by the bioimpedance method.

Measurement of skinfold thickness by a caliper

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Principle of the bioimpedance method

All devices in this practical class use a method called BIA, i.e. bioelectrical analysis of impedance. During the measurement, these devices produce an extremely low alternating electrical current (5V, 25kHz) which passes through the body. Tissues rich in water (e.g. skeletal muscles) have better conductivity, while fat tissue is highly resistant to electrical current and has almost no electrical conductivity. Consequently, the more fat the examined person has, the more resistance needs be overcome by the current. This enables us to determine the ratio of the amount of fatty tissue to other tissues. However, it is important to realize that the results of this measurement are affected by the amount of water in non-fatty tissues, i.e. by the person's hydration status. The more water the examined person has, the lower the fat percentage will be than in reality and vice versa. That is the reason why measured values may fluctuate over time and also when the measurement is performed under non-standard conditions, such as immediately after a meal, after a bath or after consumption of alcohol. Values are different also in patients suffering from diseases accompanied by water loss (diarrhea, vomiting, profuse sweating during exercise or fever), or even in women during menses. For this practical we will use two types of devices: a hand to hand device which measures impedance predominantly of the upper part of the body and bioimpedance scales (so-called foot to foot measurement) which measure body fat percentage in the lower part of the body. The results can thus vary due to the different distribution of body fat.

Hand to hand bioimpedance measuring device

Bioimpedance scales

From the clinical terms, it is necessary to mention **metabolic** (Reaven´s) **syndrome** here. The definition of the word syndrome is multiple symptoms (subjective problems), signs (objective findings), or biochemical markers that occur together, and are characteristic of a certain disease. Metabolic syndrome comprises:

- Hyperglycemia after fasting (increased level of blood glucose), which may or may not be a sign of diabetes
- Arterial hypertension (increased blood pressure)
- Dyslipidemia (increased levels of serum cholesterol and/or triglycerides – TGs) and
- Abdominal obesity (determined by measurement of waist circumference)

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hypertension

abdominal obesity

hypercholesterolemia, dyslipidaemia

METABOLIC SYNDROME

hyperglycaemia after fasting

The combination of these four findings increases the risk of occurrence and development of atherosclerosis (fatty and sclerotic plaques) in blood vessels and its complications, such as a heart attack or stroke. The crucial step in therapy of metabolic syndrome is the therapy of obesity since obesity plays an important role in the development of the resistance of tissues to insulin (and thus hyperglycemia), and also arterial hypertension (mostly through the activation of the sympathetic nervous system). Our aim is, therefore, to reduce weight, and motivate the patient to exercise and move around more.

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