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Effects of physical activity on the cardiovascular system

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ABSTRACT

Introduction:

It has been known for years that physical activity has a significant impact on human health and function. It is also inextricably linked to the cardiovascular system. It induces a number of positive changes in the cardiovascular system, both in the short term and in the long term. However, cardiovascular disease is the leading cause of death in Poland and patients affected by it constitute a very large group. In addition to appropriate pharmacotherapy, appropriately selected training and physical activity, the load and intensity of which will be planned individually for each patient, is also important.

Aim of the study:

The aim was to show how cardiovascular function changes during physical activity and what type of physical activity would be most appropriate in patients with cardiovascular disease.

Materials and methods:

The review is based on an analysis of scientific papers and materials collected from Pumbed, Google Scholar and other scientific articles using the keywords: physical activity, physical exertion, cardiovascular disease, training, cardiovascular primary and secondary prevention

Conclusions:

A number of changes in cardiovascular function occur during physical activity. Changes include heart rate, blood pressure, stroke volume, cardiac output, arterio-venous difference and blood flow redistribution. By knowing how the above parameters change, we are able to offer patients with cardiovascular disease training at an appropriate frequency, intensity or load. With such tailored training, patients will be able to improve their physical parameters safely and without any concerns.

Key words: cardiovascular disease, physical activity, training, physical exertion, cardiovascular primary and secondary prevention

INTRODUCTION

PRIMARY AND SECONDARY PREVENTION OF CARDIOVASCULAR DISEASE

Physical activity plays a major role in the prevention and treatment of cardiovascular diseases. It significantly prevents their occurrence and reduces the risk of death. Primary prevention applies to healthy people, in whom a change to a more active lifestyle reduces mortality by around 30%. We should aim to reduce sedentary lifestyles at the expense of increasing daily physical activity. In addition, physical activity is beneficial in improving physiological parameters, blood pressure and reducing other risk factors such as obesity. A fundamental element of secondary prevention in patients with cardiovascular disease is cardiac rehabilitation, which has several effects resulting in an increase in the body's loading capacity. The main element of cardiac rehabilitation is physical training, resulting in an increase in the capacity of the body.

FUNCTIONAL CHANGES IN THE CARDIOVASCULAR SYSTEM DURING PHYSICAL ACTIVITY

During physical activity, a number of functional changes occur in the cardiovascular system to deliver sufficient oxygen to the tissues. Adaptation of the cardiovascular system to physical activity includes changes in, among other things: blood pressure and heart rate, stroke volume, minute volume, blood flow distribution, arteriovenous oxygen saturation difference [1].

Blood pressure

During physical activity, there are significant changes in both systolic and diastolic blood pressure. Systolic blood pressure values are above 200 mmHg in proportion to the increase in physical intensity, while the increase in diastolic blood pressure - under normal conditions - is a maximum of 12% compared to values at rest [2].

Heart rate

The normal heart rate is between 60 and 100 beats per minute. During dynamic submaximal exertion (running, walking, cycling) a reaction takes place, which in English literature is referred to as a steady state. During this reaction, the heart rate accelerates with the duration of the physical effort, until after a few minutes an equilibrium is established with a constant HR value, which changes with further increase in the intensity of the effort, to stabilise at a given level again after 2-4 minutes. When exercise is performed at high temperatures, the increase in heart rate increases continuously, which is one of the thermoregulatory mechanisms. Both of the above-mentioned mechanisms can lead to a maximum HR value, approximated by a simple formula: 220 - age.

Stroke volume

Another parameter that increases during exercise is stroke volume [3]. The stroke volume in an adult is on average 80 ml in the standing or sitting position and 110 ml in the supine position. The stroke volume value is influenced by the interaction of the cardiac pump (which determines blood flow through working muscles) and the peripheral pump (which supports venous return and ensures diastolic filling of the heart), which is particularly important during exercise in the upright position. The peripheral pump plays a key role in the adaptation of the cardiovascular system to exercise [4].

As the intensity of exercise increases, there is a gradual increase in stroke volume initially, which then settles at a constant level.

Cardiac output

Cardiac output of the heart is the product of the heart rate (HR) and stroke volume (SV). During exercise, there is an increase in both heart rate and stroke volume, and consequently the cardiac output of the heart also increases [19][28]. This process continues until an exercise intensity level corresponding to 40-60% of maximal oxygen uptake (VO2max) is reached. From this point on, the build-up of cardiac output is mainly dependent on the acceleration of cardiac activity [25].

Arterio-venous difference

Physical exertion also significantly affects the arteriovenous oxygen saturation difference in blood. During exercise, it increases on average from 5 ml O2/100 ml at rest to 15 ml O2//100 ml in maximal exercise, which is the result of a gradual decrease in the oxygen content of venous blood due to an increase in oxygen extraction from the blood flowing through the working muscles [30].

Redistribution of blood flow

The change to adequately adapt the body to exercise is the redistribution of blood flow through different vascular areas, as a result of, among other things: vasodilation in working skeletal muscles and constriction of the vascular bed in internal organs. Physical exertion causes 80-85% of the heart's minute volume to go to skeletal muscles, coronary flow increases by 4-5 times, while cerebral flow increases by 30% [27].

CARDIOVASCULAR ADAPTATION TO PHYSICAL ACTIVITY\

Regulatory mechanisms are responsible for the proper adaptation of the cardiovascular system to physical activity, which we can divide into two main groups: internal and external. Internal regulatory mechanisms include only the cardiac pacemaker system, while there are many more external regulatory mechanisms. In this group we can include, among others: all the neural and hormonal influences that result from the activity of the sympathetic and parasympathetic nervous system, the vasomotor centre of the medulla oblongata, which is responsible for modifying the actions of the autonomic system in response to stimuli from peripheral receptors located in blood vessels, muscles and joints, and impulses originating from the cerebral cortex.

PHYSICAL ACTIVITY IN PATIENTS WITH CARDIOVASCULAR DISEASE

The main element of physical activity in patients with cardiovascular disease should be aerobic endurance training, which can be supplemented with resistance training to improve muscular endurance. Each patient should have an individualised exercise plan and load to achieve the most beneficial results.

Elements of physical training

Physical training consists of the following components: a warm-up (5-10 minutes), core exercises (20-30 minutes) and a recovery period (5-10 minutes). The total time of the entire training session should be approximately 30-45 minutes. The first component, the warm-up, involves exercises to prepare the body for exercise with gradually increasing intensity. The main part of training, the core exercises, take on an endurance or resistance character depending on the training used [18][23]. The final phase of training, the quieting period, uses stretching, breathing and lower intensity exercises. This is to prevent a sudden drop in blood pressure. The frequency and intensity of physical training is determined individually for each patient. Optimally, patient training sessions should take place 3 - 5 times a week. Patients with low physical capacity should have training sessions of shorter duration, but higher intensity [22]. In the following phases, the duration of the training session is gradually extended and the intensity increased. In the following phase, the aim is for patients to maintain the gains made [5][6].

Endurance training

It is the most commonly used type of exercise applicable to the rehabilitation of patients with cardiovascular diseases, including chronic heart failure. This training aims to use dynamic exercises that engage large muscle groups with a dominance of aerobic transformations. It can be carried out in the form of walking training, cycling exercises or systemic exercises. Training in the form of walking is the most popular option, which is easily accessible and simple to perform. It is characterised by low loads that can be dosed and controlled by the patient himself. He or she can regulate the intensity of the training by increasing the distance or changing the pace. An additional advantage of this type of training is the possibility of monitoring basic haemodynamic parameters. A major advantage of walking is that it can be carried out both in the gym - on a treadmill - and outdoors - in the field. It can also be used with a variety of patient groups, especially those with reduced exercise tolerance or the elderly. By controlling and adjusting the loads, this type of training is safe and beneficial in improving patients exercise tolerance [6][24]. Cycloergometer, like walking uses light loads and allows the intensity of the exercise to be adjusted to the patient's current condition. This type of training consists of three stages of endurance training starting with low-intensity exercise and gradually increasing in intensity. After a period of several months of this type of training, there is a maintenance phase, which can last up to the end of life. Exercises on the cycloergometer can be performed

continuously with a constant load or in an interval manner [7]. Systemic exercises also have a beneficial effect on the whole body. They involve parts of the body and lead to an improvement in the muscular strength of the whole body. This type of exercise is carried out on a cycloergometer, using rehabilitation balls or gymnastic ladders. A major advantage is that they can be performed at home without the need for equipment. Depending on which model is chosen, the frequency and intensity of training is adjusted [7]. Endurance training on a treadmill or cycloergometer can be carried out in both continuous and interval forms. During continuous training, the load is constant, and the intensity of the exercise does not change. During interval training, more intensive but short duration efforts are used, which are alternated with periods of rest. An appropriate intensity is set and the patient undertakes this type of exercise over a short period of time, from 30 seconds to 4 minutes, followed by a 1-3 minute break. Interval training is preferable to continuous training. It improves muscular strength and endurance to a much greater extent without putting undue stress on the cardiovascular system. It works particularly well for people with low physical capacity [8].

Resistance training

More recently, resistance exercises have been recommended for cardiac patients. Their purpose is to improve specific muscle groups in the upper and lower limbs, while also having a beneficial effect on cardiac muscle function. They also improve the endurance and strength of skeletal muscles, which are often weakened in this group of patients. Resistance exercises should be introduced approximately four weeks after the start of endurance training. They can be carried out in conjunction with aerobic (aerobic) training or be dynamic resistance exercises on their own. The loading period lasts approximately 1 minute, during which 10-12 repetitions are performed with a load of up to 50% of maximum muscle strength. This is followed by a break of 2 minutes. After the rest period, the next series is started. Over the course of the training, 1-3 series are carried out, depending on the individual condition and needs of the patient. This type of training is recommended 2-3 times a week [9].

Resistance training uses isometric, isotonic and isokinetic exercises. Isometric exercises are exercises in which the muscles are flexed without changing their length. They are designed to increase muscle strength without putting stress on the joints. However, they should not be used in excessive amounts, as they cause an increase in vascular resistance. Isotonic exercises use a constant resistance of the body's own weight or a constant external resistance causing a change in the length of the muscle [20]. The muscle is loaded at each moment of movement.

Compared to isometric exercises, the risk of injury is higher. This type of training needs to be used with caution in people with osteoarticular problems and in the elderly. Isokinetic exercises require the application of appropriate resistance at a constant angular velocity of the movement being performed. The loads in isokinetic training are adjusted according to the patient's exercise capacity during the movement.

Breathing exercises

They complement training or are used by patients with low exercise tolerance. By performing correct breaths, they teach the correct rate and track of breathing. By improving the respiratory system, they lead to an improvement in overall fitness. They also serve to strengthen and improve muscles such as the abdominal muscles, chest muscles or diaphragm. They influence the patient's general wellbeing and reduce shortness of breath. This type of exercise can be performed as passive, free active or assisted active exercises, depending on the patient's capabilities [10].

PHYSICAL ACTIVITY AS A FORM OF REHABILITATION

The World Health Organisation defines cardiac rehabilitation as the comprehensive and coordinated application of medical, social, educational, occupational and economic measures to adapt and prepare the patient for a new life and enable him or her to become as fit as possible. A comprehensive form of cardiac rehabilitation encompasses a range of measures that are taken to achieve full physical, psychological and psychosocial fitness. It increases the chance of recovery as well as better functioning in professional and social life. The aim of the activities carried out is to reduce the risk of recurrence of the disease and its complications and to maintain fitness and independence in everyday life for as long as possible [11].

The overriding principle of cardiac rehabilitation is comprehensiveness. Comprehensiveness of rehabilitation involves the implementation of measures in several directions. Among other things, it includes measures aimed at regaining the patient's full mobility and mental condition. Cardiac rehabilitation should begin as soon as possible and continue until the patient's normal function is restored [21]. This form of rehabilitation requires the involvement of specialists in various fields of medicine. The main premise of this type of rehabilitation should be an individual approach to the patient and their needs [12].

Cardiac rehabilitation according to the standards of the Polish Cardiac Society should be implemented as soon as possible after stabilisation of the patient's general condition. The correct course of the cardiac rehabilitation programme should be carried out in several stages. It should start in the hospital setting and continue all the way to the end of the patient's life. We can distinguish between an early period of rehabilitation comprising stage I and stage II and a late period of rehabilitation, which is referred to as stage III [12,13]. Cardiac rehabilitation is carried out in three stages. The first as the in-hospital phase, stage two as the early post-hospital phase and stage three as the late post-hospital phase lasting until the end of life. According to the recommendations, low-risk patients should be included in a rehabilitation programme like the recommendations for healthy people with moderate intensity. Patients at higher risk should have an individualised activity plan. Aerobic (aerobic) training is the most appropriate form of activity. Mainly rehabilitation programmes consist of continuous or interval endurance efforts. These can be supplemented with resistance exercises [14].

Stage I is early in-hospital rehabilitation. It takes place during the patient's stay in hospital. The basic and most important aspect is to adapt the patient as quickly as possible to perform daily activities independently, i.e. preparing food, washing, cleaning and minimising the negative effects of immobilisation. Stage I lasts from 7 to 14 days, depending on the patient's condition. During this period, patients perform breathing exercises, relaxation exercises and simple exercises that engage small and larger muscle groups. Walking is also slowly and gradually incorporated. Stage I ends when the patient has reached a clinical state that allows them to leave the hospital or other treatment facility. Depending on the outcome of the exercise test, the patient is qualified for further stages of rehabilitation and their treatment and diagnosis is determined [13].

The next stage, namely stage 2 of cardiac rehabilitation, can be carried out at home, in hospital or outpatient. The duration of stage 2 is 4-12 weeks. Patients qualified for the inpatient form are those with a high risk of cardiovascular disease, who are residents of small towns with poor social conditions or who have difficulties and problems getting to an inpatient facility [23]. Young people with an uncomplicated course of the previous disease and rehabilitation are qualified for rehabilitation in the form of outpatient or home-based rehabilitation. During this period, general physical exercise, relaxation, stretching and improvement of overall fitness, e.g. water, walking, ergometer or stationary bicycle training, are recommended [29]. The most important goal is to achieve the most beneficial state of health for the patient. Improving physical capacity and achieving the best possible physical fitness are the main focus of this stage of rehabilitation. Often neglected by patients, it is also very important to receive help with

psychological and psychological aspects. Physical training is carried out according to the rehabilitation model adapted to the patient. There are 4 main models: A, B, C and D. Depending on the level of physical performance, the patient is qualified for one of them, depending on the level of physical performance achieved [15].

Stage III is late rehabilitation in the outpatient setting. It lasts for the rest of the patient's life and aims to achieve and maintain the effects of rehabilitation. It involves maintaining a healthy lifestyle and sustaining the results of treatment to prevent recurrence of ailments and disease. It encompasses a wide range of physical activities, including walking, general fitness exercises, cycling and team games. The most important thing is to increase physical activity on a daily basis, so it is necessary to find a sport that the patient enjoys undertaking. In both Stage II and Stage III rehabilitation, physical activity should start with a warm-up of 5 minutes to allow the body to adapt to the core training, while the end of exercise must include calming exercises lasting 5 minutes [16]. At the beginning of rehabilitation, activity 3 times a week is recommended, which will take place under close medical supervision. After this, the patient is given a set of exercises to take home, which should be performed by the patient 5-6 days a week [17].

Disclosure

Author's contribution

Conceptualization: Tomasz Gańko and Dominika Poborowska; methodology: Weronika Kahan; software: Weronika Szafrańska; check: Katarzyna Polańska and Weronika Szafrańska; formal analysis: Emilia Bąk and Oliwia Najjar; investigation: Jacek Fordymacki and Emilia Bąk; resources: Marta Wojaczek; data curation: Marta Wojaczek; writing - rough preparation: Weronika Kahan; writing - review and editing, Katarzyna Polańska; visualization: Jacek Fordymacki; supervision: Tomasz Gańko and Dominika Poborowska; project administration, Emilia Bąk and Oliwia Najjar; receiving funding - no specific funding.

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The data presented in this study is available upon request from the corresponding author.

Conflict of interest

The authors deny any conflict of interest

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