THE INFLUENCE OF DOSED PHYSICAL EXERCISE ON INDICATORS OF THE CARDIOVASCULAR SYSTEM OF PERSONS WHO HAVE LOST LIMBS

ВПЛИВ ДОЗОВАНОГО ФІЗИЧНОГО НАВАНТАЖЕННЯ НА ПОКАЗНИКИ СЕРЦЕВО-СУДИННОЇ СИСТЕМИ ОСІБ, ЯКІ ВТРАТИЛИ КІНЦІВКИ

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Abstract
The study of the reaction of the cardiovascular system of persons with amputation of the lower limbs at different levels at the initial stage of the application of physical rehabilitation and dosed veloergometric load with the execution of pedal rotation with the upper limbs. **Material.** In the course of the study, theoretical analysis and generalization of data from the scientific and methodological literature on issues related to the use of physical therapy in people after amputation of the lower limbs, variation pulsometry, determination of maximum oxygen absorption, measurement of blood pressure, dosed veloergometric load with the execution of pedal rotation of the upper limbs were used. **Results.** The analysis of modern scientific and methodological literature made it possible to consider the actual problem of scientifically based selection of rehabilitation measures to determine the amount of physical exertion for persons at the initial stage (post-hospital period) of the use of physical therapy means, depending on the level of amputation of the lower limbs and the reaction of the cardiovascular system to the performance of dosed cycle ergometric exercise load and control of their influence on hemodynamic indicators. The level of physical working capacity, the reaction of the cardiovascular system and the level of physical working capacity of persons with amputation of the lower limbs at different levels by means of dosed veloergometric load with the use of the upper limbs at the initial stage (post-hospital period) were studied, which are decisive in the individual appointment of the movement regime, the formation of the volume and intensity of physical exertion, selection of appropriate forms, methods and means of physical therapy. **Conclusions.** The applied adequate research methods made it possible to reveal the dependence of the reaction of the indicators of heart rate, blood pressure and maximum oxygen absorption on the amount of dosed veloergometric load depending on the localization, volume and level of amputation of the lower limbs, which will allow the application of a motor mode adequate to the functional state, the intensity of physical exercises, forms, methods and means of physical therapy for persons with different levels of amputation of the lower limbs.
Key words: physical therapy, dosed physical activity, cardiovascular system, physical capacity.

Мета. Вивчення реакції серцево-судинної системи осіб з ампутацією нижніх кінцівок на різних рівнях на початковому етапі застосування засобів фізичної терапії та дозованого велоергометричного навантаження з виконанням обертання педалей верхніми кінцівками. **Матеріал.** У ході дослідження використано теоретичний аналіз й узагальнення даних науково-методичної літератури з питань, присвячених застосуванню засобів фізичної терапії у осіб після ампутації нижніх кінцівок, варіаційна пульсометрія, визначення максимального поглинання кисню, вимірювання артеріального тиску, дозоване велоергометричне навантаження з виконанням обертання педалей верхніми кінцівками. **Результати.** Аналіз сучасної науково-методичної літератури дозволив розглянути актуальну проблему науково обґрунтованого вибору реабілітаційних заходів з визначенням обсягу фізичних навантажень особам на початковому етапі (післялікарняний період) застосування засобів фізичної терапії, в залежності від рівня ампутації нижніх кінцівок та реакції серцево-судинної системи на виконання дозованого велоергометричного навантаження й контролю за їх впливом на показники гемодинаміки. Вивчено рівень фізичної працездатності, реакцію серцево-судинної системи і рівень фізичної працездатності осіб з ампутацією нижніх кінцівок на різних рівнях шляхом

дозованого велоергометричного навантаження із застосуванням верхніх кінцівок на початковому етапі (післялікарняному періоді), які є визначальними при індивідуальному призначенні рухового режиму, формуванні обсягу та інтенсивності фізичних навантажень, підбору відповідних форм, методик та засобів фізичної терапії. **Висновки.** Застосовані адекватні методи дослідження дозволили виявити залежність реакції показників частоти серцевих скорочень, артеріального тиску та максимального поглинання кисню від величини дозованого велоергометричного навантаження в залежності від локалізації, обсягу і рівня ампутації нижніх кінцівок, які дозволять застосовувати, адекватні функціональному стану, руховий режим, інтенсивність фізичних вправ, форми, методи та засоби фізичної терапії особам з різним рівнем ампутації нижніх кінцівок.

Ключові слова: фізична терапія, дозоване фізичне навантаження, серцево-судинна система, фізична працездатність.

Introduction. One of the most significant consequences that occurs after the loss (amputation) of the lower limbs is a sharp limitation of motor activity (hypodynamia) [5; 8; 10; 12]. To the greatest extent, this is observed in the postoperative period and during preparation for prosthetics, when the person is forced to be in a lying or sitting position and move with the help of crutches or a wheelchair [1; 4; 8; 10; 13]. Limitation of motor activity causes changes in the activity of the cardiovascular, respiratory and other systems and the body as a whole, increases the manifestations of concomitant diseases. Locally insufficient motor activity and other amputation factors cause stagnation in tissues, inhibit exchange and regenerative processes, the formation of a benign mobile postoperative scar, the formation of a stump, contribute to the occurrence of flexion contractures and atrophy of the muscles of the amputated limb, pelvic distortion and postural defects [2; 3; 6-8; 11; 14].

In order to reduce the negative impact of surgical intervention and the forced reduction of motor activity at the stages of the complex recovery process, physical rehabilitation tools are used [8; 10; 13; 15; 16]. They increase the activity, tone and functional state of the body, mobilize its protective and adaptive-compensatory reactions. Physical exercises applied in accordance with the state of the body prevent complications, strengthen the muscle segments of the limb remaining after amputation, reduce muscle imbalance, and accelerate the occurrence of permanent compensations [1; 8; 11; 17; 18]. In people who use physical rehabilitation means, the probability of contracture formation and the occurrence of disability decreases, the level of training of body systems and the level of physical exertion of a domestic and professional nature increases, and the quality of life improves [1; 8; 10; 11; 23].

The analysis of the scientific and methodical literature on the use of physical rehabilitation tools for amputation of the lower limbs showed that in the vast majority of works, from a practical point of view, the need for the use of physical rehabilitation tools and massage in order to prevent postoperative complications, correct defects in the formation of the stump, prepare it for prosthetics and learning to use a prosthesis [9; 14; 18; 20–22]. The need to strengthen the muscles of the trunk, upper limbs, the amputated limb and the one left after unilateral amputation for walking on a prosthesis, performing physical activities of a domestic nature and manual labour is indicated [8; 10; 14; 20; 21; 23]. However, there is practically no information in scientific works on determining the volume of physical loads and the ability of amputees to bear them at the initial stages of using physical rehabilitation tools, depending on the volume and amputation of the lower limbs at different levels. Therefore, the study of the reaction of the cardiovascular system during aerobic exercise in such persons is an objective need for a scientifically based selection of rehabilitation measures and control over their implementation, which is the basis of an objective expansion of the motor regime, determination of means, forms and methods of physical rehabilitation at the stages of the complex restoration process.

Studies of the functional state of the cardiovascular system are carried out using dynamic tests, such as squatting, running, jumping, walking and running on stairs and a treadmill, pedalling on a bicycle ergometer, and others that

involve the lower limbs. In cases of structural and functional incapacity or the absence of one or two limbs, functional dynamic tests using hands are used [1; 8; 10–12].

The purpose of the research is to study the reaction of the cardiovascular system of people with amputation of the lower limbs at different levels at the initial stage of the application of physical therapy tools and dosed cycle ergometric load with pedalling of the upper limbs.

Material and methods. In order to achieve the goal and solve the tasks of the research, theoretical analysis and generalization of data from the scientific and methodological literature on issues related to the use of physical therapy in people after amputation of the lower limbs, variation pulsometry, determination of maximum oxygen absorption, measurement of blood pressure, dosed veloergometric load with pedal rotation were used upper limbs.

Results. It took in research 15 men, beginners, aged from 22 to 37 years old, who lost their limbs due to severe injuries during household or professional activities, underwent surgical interventions for amputation of the lower limbs at various levels, and passed the stage of primary care, took part in the research. prosthetics and were divided by us into two groups: 8 – with unilateral amputations at the level of the middle third of the leg, 7 – with unilateral amputations at the level of the middle third of the thigh.

The study participants agreed to undergo the initial stage (post-hospital period) of physical therapy using complexes of physical exercises and basic strength exercises of bodybuilding and powerlifting with free weights. The initial stage (post-hospital period) included two sub-stages: the first is a short-term gentle regime of performing complexes of exercises of the maximum submaximal power zone with external resistance, which is created due to the weight of objects (dumbbells, weights, barbells), the resistance of a partner, the resistance of elastic objects (spring expanders, rubber); the second – exercises in the zone of submaximal and high power on medium and large muscle groups of the limbs and trunk at a slow and medium pace in a gentle training regime with the use of physical exercises to cover as many muscle groups of the trunk and limbs as possible, ensuring the harmony of the impact with the performance them at a medium and fast pace and strength basic exercise of bodybuilding and powerlifting, horizontal bench press and horizontal bench press from the chest. The stated principle of physical exercises with the involvement of certain muscle groups in certain movement modes is applied to individuals of both groups.

The study of the level of physical capacity was carried out by the method of applying a continuous dosed veloergometric load until failure with the execution of rotation of the pedals by the upper limbs (hereinafter – continuous physical load). The power of the initial continuous exercise was equal to 25 W and gradually increased by 25 W every three minutes, during which the subject maintained a constant speed of pedalling with the upper limbs, 60 revolutions per minute. Subjective feelings, the appearance of external signs of fatigue, such as an excessive increase in heart rate, redness of the face and skin, accelerated breathing rate, which indicated that the threshold of performance was reached dosed physical activity and was the reason for stopping the study. Such careful monitoring of reactions to continuous physical exertion made it possible to objectively determine the permissible level of muscle work in each subject and to prevent possible negative reactions of the cardiovascular system.

The reaction of the cardiovascular system of the body to pedalling with the upper limbs was determined by analyzing the changes that occurred during continuous physical exertion, the main hemodynamic indicators – heart rate (HR) and systolic and diastolic blood pressure (SBP and DBP) and the speed of their recovery on the 1st, 5th, 10th minutes after giving up continuous physical activity. Evaluation of the research results was carried out by comparison with the data of bicycle ergometric testing indicators of practically healthy untrained persons [1; 19; 24].

The results of the study of the level of physical performance of people with different levels of localization and volume of lower limb amputation by the method of continuous dosed veloergometric load to failure with the performance of pedal rotation with the upper limbs showed that

they had a different level of response of heart rate and blood pressure indicators to continuous physical load and recovery after its implementation (Table 1).

In the group of people who underwent unilateral amputation at the level of the middle third of the lower leg (8 people), a level of continuous physical exertion of 125 W was achieved at a heart rate of 140.3±2.4 bpm, which was 89.0% higher than the initial heart rate in at rest. In parallel with the increase in heart rate, systolic and diastolic blood pressure changed with an increase in pulse pressure.

At the maximum load of 125 W, the systolic blood pressure values were equal to 154.7±2.5 mm. Hg, diastolic blood pressure – 65.3±1.4 mm. Hg, and the pulse pressure was 89.4 mm. Hg, which significantly ($p<0.05$) exceeded the initial level at rest (Table 2).

Recovery of heart rate and blood pressure before the weekend occurred mainly at the 5th minute of rest according to the normotonic type

Table 1

Reaction of heart rate indicators to continuous physical activity and during the recovery period (x±m)

No	Stages of continuous physical activity (further – load)	Heart rate (bpm)		
		Leg amputation (*n*=8) x±m	Hip amputation (*n*=7) x±m	Practically healthy untrained individuals
1	At rest	73,7±2,3	74,7±2,6	68,4±2,1
2	Load 25 W	83,1±2,4	84,5±2,2	79,2±2,5
3	Load 50 W	88,6±1,4	90,7±1,8	86,2±2,3
4	Load 75 W	104,6±2,1	113,4±2,4	101,8±2,1
5	Load 100 W	130,5±1,8	139,2±2,7	128,2±2,4
6	Load 125 W	140,3±2,4	147,9±1,7	136,3±1,9
7	1 minute of recovery	105,3±2,1	114,8±2,4	102,5±2,1
8	5 minute of recovery	89,2±1,4	91,1±1,6	84,9±2,6
9	10 minute of recovery	75,3±1,8	81,1±1,4	72,9±2,4

Table 2

The reaction of blood pressure indicators to continuous physical activity and during the recovery period (x±m)

No	Stages of continuous physical activity (further – load)	Blood pressure indicators (mm Hg)			
		BP	Leg amputation (*n*=8) x±m	Hip amputation (*n*=7) x±m	Practically healthy untrained individuals
1	At rest	DBP	75,5±1,6	79,4±2,1	70,1±2,7
		SBP	120,4±2,7	127,3±2,4	119,6±2,9
3	Load 25 W	DBP	71,3±2,2	78,2±1,8	72,8±3,4
		SBP	131,2±1,8	135,2±1,6	126,9±2,3
5	Load 50 W	DBP	68,2±1,8	77,1±2,4	68,7±2,2
		SBP	142,5±1,4	149,4±2,2	135,4±2,6
7	Load 75 W	DBP	65,5±2,4	75,2±2,1	73,1±2,7
		SBP	146,8±2,2	159,6±1,6	141,6±2,5
9	Load 100 W	DBP	64,1±1,4	72,1±1,4	69,3±2,1
		SBP	149,6±1,6	169,3±1,8	147,5±2,4
2	Load 125 W	DBP	65,3±1,4	66,1±2,1	68,5±2,3
		SBP	154,7±2,5	177,3±2,8	149,2±2,7
4	1 minute of recovery	DBP	66,3±1,2	73,1±1,6	72,7±2,5
		SBP	141,5±2,2	159,8±1,8	140,8±2,6
6	5 minute of recovery	DBP	70,0±2,2	76,8±1,4	71,3±2,7
		SBP	132,4±1,8	140,4±2,2	128,2±1,9
8	10 minute of recovery	DBP	77,1±1,4	75,3±1,8	70,8±1,8
		SBP	124,2±2,1	130,4±2,1	122,6±2,3

Note: BP is arterial pressure; DBP is diastolic arterial pressure; SBP is systolic arterial pressure.

of reaction to the functional test. One of the examined persons showed a reaction to continuous dosed bicycle ergometric load until failure with pedal rotation of the upper limbs according to the hypotonic type, and the normalization of heart rate and blood pressure was significantly ($p<0.05$) delayed.

In general, the reaction of the cardiovascular system to a continuous dosed veloergometric load to failure with pedal rotation of the upper limbs of persons who have undergone unilateral amputation at the level of the middle third of the lower leg is practically no different from healthy untrained people to the same functional test, which indicates a sufficient level of adaptation to dosed muscle work.

Therefore, individuals with unilateral amputations at the level of the middle third of the lower leg and unilateral amputations at the level of the middle third of the thigh can be recommended, taking into account individual indicators of cardiovascular health and the level of physical capacity, after carrying out at the initial stage (post-hospital period) the first sub-stage of physical rehabilitation, performing complexes physical exercises of physical rehabilitation of the second sub-stage, which belong to the zone of submaximal and high power on medium and large muscle groups of the upper limbs and trunk at a slow and medium pace in a gentle training regime with the use of physical exercises to cover as many muscle groups as possible trunk and upper limbs, ensuring harmony of impact with their performance at a medium and fast pace and basic strength exercises of bodybuilding and powerlifting, horizontal bench press and horizontal bench press from the chest.

In persons who underwent unilateral amputation at the level of the middle third of the thigh (7 persons), who also achieved a continuous dosed cycle ergometric load to failure with the performance of upper limb pedalling at 125 W with a heart rate and blood pressure response close to the hyperreactive type. However, their heart rate recovery rate was slower than the recovery rates in the group of persons with amputation at the level of the middle third of the lower leg. In comparison with the latter, in men with unilateral amputation at the level of the middle third of the thigh, the heart rate at the 5th minute was unreliably higher than the initial level by 8.5%. Recovery of blood pressure indicators occurred with a relative delay, although statistical reliability was not obtained. A positive, reliable ($p<0.05$) response of the cardiovascular system to continuous dosed veloergometric load to failure with pedal rotation of the upper limbs in persons who underwent unilateral amputation at the level of the middle third of the thigh was observed in 6 subjects and in 1 h – unsatisfactory, but it was unreliable (Table 2).

A comparison of the obtained results of a group of persons who underwent unilateral amputation at the level of the middle third of the thigh (7 people) with persons of previous and healthy untrained people on continuous dosed cycle ergometric load to failure with pedal rotation of the upper limbs showed that 6 men with unilateral amputation at the level of the middle third of the thigh, it is possible to recommend the same movement regimes as in the first group, but with an extended period of gentle training regime, which will be determined individually for each person. Individuals with an unsatisfactory reaction (1 person) to a functional test should be recommended to perform complexes of physical rehabilitation exercises for medium and large muscle groups of the limbs and trunk at a slow and medium pace with further application and exercises at a medium pace, and after repeated determination of the reaction of the cardiovascular system on a continuous dosed veloergometric load and the achievement of reliable positive changes, recommend the physical laws of a gentle training regime.

The obtained results of continuous dosed veloergometric load to failure with pedal rotation of the upper limbs of persons with different localization and extent of amputation of the lower limbs allowed us to determine by an indirect method [1; 19; 24] indicators of maximum oxygen absorption (MPC), which reflects the functional capabilities of the cardiorespiratory system and level of physical fitness.

Therefore, we established that BMD values in groups of people with different levels of amputation repeated the reaction of heart rate and blood

pressure to continuous dosed bicycle ergometric load to failure with pedalling of the upper limbs. The difference in indicators depended on localization, volume and level of amputation, functional ability to perform muscle work. In men with consequences of unilateral amputation at the level of the lower leg and at the level of the thigh, the difference in BMD indicators was unreliable and equal to 2.06 ± 0.02 l/min and 2.12 ± 0.01 l/min, respectively.

Thus, the determination of the reaction of the cardiovascular system and the level of physical capacity of persons with amputation of the lower limbs at different levels by means of continuous dosed veloergometric load to failure with the execution of pedalling with the upper limbs at the initial stage (post-hospital period) of physical rehabilitation are decisive for the individual appointment of the motor mode, formation of the volume and intensity of physical exertion, selection of appropriate forms, methods and means of physical therapy.

Conclusions

1. It has been established that the continuous dosed veloergometric load to failure with pedal rotation of the upper limbs is a reliable and informative method of examination, at the initial stage (post-hospital period) of physical therapy, the functional state of the cardiorespiratory system and the level of physical performance of persons who have undergone amputation of the lower limbs at different levels.

2. The dependence of the response of heart rate, blood pressure, and maximum oxygen absorption on the amount of continuous dosed veloergometric load to failure with pedal rotation of the upper limbs was established, depending on the localization, volume and level of amputation of the lower limbs.

3. The identified individual ability of the body to tolerate a continuous dosed veloergometric load until failure with the execution of pedal rotation with the upper limbs will allow to apply, taking into account the individual indicators of the cardiovascular system and the level of physical capacity, adequate to the functional state of the movement regime, the power of physical exercises, forms and means of physical rehabilitation for persons with different levels of amputation of the lower limbs.

Prospects for further research in this direction will be aimed at the wide implementation of the obtained results in the case of individual prescription of the movement regime, the formation of the volume and intensity of physical exertion, the selection of appropriate forms, methods and means of physical therapy of persons with different levels of loss (amputation) of the lower limbs.

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