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EC EMERGENCY MEDICINE AND CRITICAL CARE

Research Article

Determination of Physical Rehabilitation Measures by the Response of the Cardiovascular System of Persons with Lower Limb Amputations to Dosed Physical Load

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Received: February 17, 2023; **Published:** March 25, 2023

Abstract

Introduction: To determine the effectiveness of the effect of dosed bicycle ergometric exercise on the cardiovascular system of persons with lower limb amputation to substantiate the adequate functional state of the motor regimen and appropriate methods and means of physical rehabilitation.

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 the amputation of the lower extremities, variation pulsometer, determination of maximum oxygen absorption, measurement of blood pressure, dosed veloergometric load with the execution of pedal rotation of the upper extremities 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 (restorative post-hospital period) of the use of physical rehabilitation means, depending on the level of amputation of the lower extremities 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 reaction of the cardiovascular system of persons with amputation of the lower extremities at different levels using dosed veloergometric load with the use of the upper extremities at the initial stage (restorative 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 rehabilitation.

Conclusion: 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 extremities, 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 rehabilitation for persons with different levels of amputation of the lower extremities.

Keywords: *Physical Rehabilitation; Dosed Physical Activity; Cardiovascular System*

Introduction

One of the most significant consequences that occur after the loss (amputation) of the lower extremities is a sharp limitation of motor activity (hyperdynamic) [6,7,9]. To the greatest extent, this is observed in the postoperative period and during preparation for prosthet-

ics, when the person is forced to be in a lying or sitting position and move with the help of crutches or a wheelchair [1,3,6,7,10]. Limitation of motor activity causes changes in the activity of the cardiovascular, respiratory, and other systems and the body as a whole, increasing 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 [2,4-6,8,11].

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 [6,7,10,12,13]. They increase the activity, tone, and functional state of the body, and mobilize its protective and adaptive-compensatory reactions. Physical exercises applied following 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 [1,6,8,14,15]. 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 [1,6-8,19].

The analysis of the scientific and methodical literature on the use of physical rehabilitation tools for amputation of the lower extremities 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 to prevent postoperative complications, correct defects in the formation of the stump, prepare it for prosthetics and learning to use a prosthesis [11,15,17,18]. The need to strengthen the muscles of the trunk, upper extremities, the amputated limb, and the one left after unilateral amputation for walking on a prosthesis, performing physical activities of a domestic nature, and manual labor is indicated [6,7,11,17-19]. 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 extremities 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, pedaling on a bicycle ergometer, and others that involve the lower extremities. In cases of structural and functional incapacity or the absence of one or two extremities, functional dynamic tests using hands are used [1,6-9].

Purpose of the Study

The purpose of the study is to determine the effectiveness of the effect of dosed bicycle ergometric exercise on the cardiovascular system of persons with lower limb amputation to substantiate the adequate functional state of the motor regimen and appropriate methods and means of physical rehabilitation.

Materials and Methods

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 the amputation of the lower extremities, variation pulsometer, determination of maximum oxygen absorption, measurement of blood pressure, dosed veloergometric load with pedal rotation were used upper extremities.

Results and Discussion

It took in research 15 men, beginners, aged from 22 to 37 years old, who lost their extremities due to severe injuries during household or professional activities, underwent surgical interventions for amputation of the lower extremities at various levels, and passed the stage of primary care, took part in the research. prosthetics and were divided by us into two experimental groups (EG): EG1 - 8 people with unilateral amputations at the level of the middle third of the lower leg; EG2 - 7 with unilateral amputations at the level of the middle third of the thigh and one control group (CG) of 15 practically healthy untrained men.

Participants of the two experimental groups of the study agreed to undergo the initial stage (restorative post-hospital period) of physical rehabilitation using complexes of physical exercises and basic strength exercises of bodybuilding and powerlifting with free weights. The initial stage (restorative post-hospital period) lasted 12 weeks and provided 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 extremities 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 extremities 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 participants of the control group, with their consent, took part in the study before the beginning and at the end of the initial stage (restorative (restorative post-hospital period) to determine the response of the cardiovascular system to physical exercise without performing the sets of exercises offered to the participants of the experimental groups.

The study of the response of the cardiovascular system was carried out before the beginning and end of the initial stage (restorative post-hospital period) using the method of continuous dosed cycle ergometric exercise until failure with upper limb pedaling (hereinafter - continuous exercise). The power of the initial continuous exercise was equal to 25 W and gradually increased by 25W every three minutes, during which the subject maintained a constant speed of pedaling with the upper extremities, 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, and 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 pedaling with the upper extremities 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 1^{st}, 5^{th}, 10^{th} 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 [1,16,20].

The results of the study of the level of physical performance of people with different levels of localization and volume of amputation of the lower extremities by the method of continuous dosed veloergometric load to failure with the execution of pedal rotation with the upper extremities showed that in the people of the two experimental and control groups, a different level of reaction of heart rate and blood pressure indicators was found on continuous physical activity and recovery after its performance (Table 1), but the differences were unreliable (Table 1).

No	Stages of continuous physical activity (further - load)	Heart rate (bpm)		
		EG1 (n = 8)	EG2 (n = 7)	CG (n = 7)
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 minutes of recovery	105,3 ± 2,1	114,8 ± 2,4	102,5 ± 2,1
8	5 minutes of recovery	89,2 ± 1,4	91,1 ± 1,6	84,9 ± 2,6
9	10 minutes of recovery	75,3 ± 1,8	81,1 ± 1,4	72,9 ± 2,4

Table 1: *Reaction of heart rate indicators to continuous physical activity and during the recovery period (x ± m).*

Notes: EG1 and EG2 experimental groups; KG control group.

In the group of persons of EG1 who underwent unilateral amputation at the level of the middle third of the lower leg (8 persons), a level of continuous physical exertion of 125 W was achieved at a heart rate of 140.3 ± 2.4 bpm, which was 90.36% higher than the initial heart rate at rest In parallel with the increase in heart rate, systolic and diastolic blood pressure changed with an increase in pulse pressure (Table 2). A comparative analysis of EG1 indicators with those of the control group, whose heart rate was at the level of 136.3 ± 1.9, which was 99.26% higher than the initial heart rate at rest, revealed discrepancies between EG1 and CG, but they were unreliable. Therefore, there were discrepancies between the EG1 and CG heart rate indicators, both at rest and at the level of continuous physical exertion of 125 W, but they were unreliable.

In the group of EG2 persons who underwent unilateral amputation at the level of the middle third of the thigh (7 persons), a level of continuous physical exertion of 125 W was achieved at a heart rate of 147.9 ± 1.7 bpm, which was 97.99% higher than the initial heart rate at rest In parallel with the increase in heart rate, systolic and diastolic blood pressure changed with an increase in pulse pressure (Table 2). A comparative analysis of the EG2 indicators with the indicators of the control group, in which the heart rate was at the level of 136.3 ± 1.9, which was 99.26% higher than the initial heart rate at rest, revealed discrepancies, but they were unreliable.

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).

A comparative analysis of EG1 indicators with SAC and DAP indicators of the control group also revealed discrepancies, but they were unreliable. The same data were obtained by us when comparing EG2 and CG indicators (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 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 extremities 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 continuously dosed veloergometric load to failure with pedal rotation of the upper extremities of persons EG1 who have undergone unilateral amputation at the level of the middle third of the lower leg is practically

		Blood pressure indicators (mm Hg)			
No	**Stages of continuous physical activity (further - load)**	**BP**	**EG1 (n = 8)**	**EG2 (n = 7)**	**CG (n = 7)**
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 minutes 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 minutes 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

Table 2: *The reaction of blood pressure indicators to continuous physical activity and during the recovery period (x ± m).*
Note: BP is arterial pressure; DBP is diastolic arterial pressure; SBP is systolic arterial pressure.

no different from healthy untrained people to the same functional test, which indicates a sufficient level of adaptation to dosed muscle work.

The analysis of the results obtained by us after the initial stage (restorative post-hospital period) of physical rehabilitation using complexes of physical exercises and basic strength exercises of bodybuilding and powerlifting with free weights, which lasted 12 weeks in two sub-stages, made it possible to establish significant differences ($p < 0.05$) in cardiovascular reactions - of the vascular system between the beginning and the end of the initial stage of physical rehabilitation. In the group of EG1 individuals, at the level of continuous cycle ergometric load of 125 W, the heart rate was 133.7 ± 1.6 beats/min, which is significantly ($p < 0.05$) lower than the indicator it was before the beginning of the initial stage of physical rehabilitation.

In the group of EG2 individuals, after 12 weeks of using complexes of physical exercises and basic strength exercises of bodybuilding and powerlifting with free weights, a level of continuous cycle ergometric load of 125 W was achieved at a heart rate of 137.2 ± 2.1 beats/min, which is reliable ($p < 0,05$) lower than it was before the beginning of the initial stage of physical rehabilitation.

There were also significant differences ($p < 0.05$) in the response of the cardiovascular system between the beginning and the end of the initial stage of physical rehabilitation based on indicators of heart rate recovery after the failure of continuous cycle ergometric exercise, where heart rate indicators in EG1 (heart rate at rest 69.4 ± 1.8 bpm; heart rate after 5 min of recovery 72.1 ± 1.4 bpm) and EG2 (HR at rest 70.3 ± 1.7 bpm; heart rate after 5 min of recovery 71.9 ± 1.6 beats/min) recovered to the values at rest in 5 minutes.

No significant differences were found in blood pressure indicators in EG1 and EG2.

The analysis of CG indicators established unreliable differences in heart rate indicators between the beginning and the end of the initial stage of physical rehabilitation, which was applied to individuals EG1 and EG2. A comparative analysis of EG1 and EG2 indicators with those of the control group established reliable differences at the level of continuous cycling ergometric load of 125 W and during recovery. Recovery of heart rate in CG occurred for 10 minutes.

Therefore, the analysis of indicators of the response of the cardiovascular system between the beginning and the end of the initial stage of physical rehabilitation made it possible to state that individuals of EG1 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 (restorative 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 extremities and trunk at a slow and medium pace in a gentle training regime with the use of physical exercise extremities s to cover as many muscle groups as possible trunk and upper extremities, 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 EG2 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 pedaling at 125 W with a heart rate and blood pressure response close to the hyperreactive type. However, their rate of heart rate recovery before the start of the initial stage of physical rehabilitation 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 5^{th} 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 continuously dosed veloergometric load to failure with pedal rotation of the upper extremities in persons who underwent unilateral amputation at the level of the middle third of the thigh was observed in 6 subjects and 1 h - unsatisfactory, but it was unreliable (Table 2).

A comparison of the obtained results of a group of persons EG2 who underwent unilateral amputation at the level of the middle third of the thigh (7 people) with persons EG1 and KG of healthy untrained people of previous and healthy untrained people on continuous dosed cycle ergometric load to failure with pedal rotation of the upper extremities 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 extremities 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 extremities of persons with different localization and extent of amputation of the lower extremities allowed us to determine by an indirect method [1,16,20] 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 the experimental groups (EG1 and EG2) of people with different levels of amputation and the control group (CG) repeated the reaction of heart rate and blood pressure to continuous dosed cycle ergometric load until failure with

pedal rotation of the upper extremities. The difference in indicators in the experimental groups depended on the localization, volume, and level of amputation, functional ability to perform muscle work. In men with the consequences of unilateral amputation at the level of the lower leg and the level of the thigh, the difference in BMD indicators was unreliable and equal, respectively: EG1 - 2.06 ± 0.02 l/min; EG - 2.12 ± 0.01 l/min; KG - 2.14 ± 0.11 l/min.

Thus, the determination of the reaction of the cardiovascular system and the level of the physical capacity of persons EG1 and EG2 with amputation of the lower extremities at different levels using continuous dosed veloergometric load to failure with the performance of pedal rotation with the upper extremities at the initial stage (restorative post-hospital period) of physical rehabilitation and a comparative analysis was carried out of the obtained indicators with the indicators of the control group of healthy untrained people showed unreliable differences, which is decisive in the individual assignment of the movement regime, the formation of the volume and intensity of physical exertion, the selection of appropriate forms, methods and means of physical rehabilitation.

Conclusion

1. It has been established that continuous dosed veloergometric load to failure with pedal rotation of the upper extremities is a reliable and informative method of examination, at the initial stage (restorative post-hospital period) of physical rehabilitation, of the functional state of the reaction of the cardiovascular system of persons who have undergone amputation of the lower extremities at different levels.
2. The identified individual ability of the body to tolerate a continuous dosed veloergometric load until failure will allow applying, taking into account individual indicators of the cardiovascular system and the level of physical capacity, adequate to the functional state of the movement mode, power of physical exercises, forms and means of physical rehabilitation to persons with different levels of amputation of the lower extremities.

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 rehabilitation of persons with different levels of loss (amputation) of the lower extremities.

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