ASPI | Afarand Scholarly Publishing Institute; Turkey
ISSN: 2980-969X Iranian Journal of War & Public Health 2023;15(3):213-218 10.58209/ijwph.15.3.213

Effect of Aerobic and Combined Upper Body Exercise on the Heart Structure and Function in Lower Limb Amputation Veterans

ARTICLE INFO

Article Type
Original Research

Authors
Heydary M.[1] *MSc*
Keshavrz S.[2]* *PhD*
Kargarfard M.[3] *PhD*
Porheidar B.[4] *PhD*

How to cite this article
Heydary M, Keshavrz S, Kargarfard M, Porheidar B. Effect of Aerobic and Combined Upper Body Exercise on the Heart Structure and Function in Lower Limb Amputation Veterans. Iranian Journal of War & Public Health. 2023;15(3):213-218.

[1] Department of Physical Education and Sports Sciences, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[2] Sports Medicine Research Center, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[3] Department of Sports Physiology, Faculty of Physical Education and Sports Sciences, Isfahan University, Isfahan, Iran
[4] Department of Heart, Faculty of Medicine, Shahrekord University of Medical Sciences, Shahrekord, Iran

***Correspondence**
Address: Sports Medicine Research Center, Najafabad Branch, Islamic Azad University, University Boulevard, Najafabad, Iran. Postal Code: 8814143131
Phone: +98 (38) 33376061
Fax: -
keshavarz1357@gmail.com

Article History
Received: June 2, 2023
Accepted: July 24, 2023
ePublished: October 2, 2023

ABSTRACT

Aims Lower limb amputee veterans are at high risk of cardiovascular disease due to physical problems and depression after the accident caused by amputation. Aerobic and resistance training are effective interventions in improving heart structure and function. This study aimed to evaluate the effect of 12 weeks of aerobic and combined exercises on the structure and function of the heart of lower limb amputation veterans.
Materials & Methods This semi-experimental pre-test/post-test study was designed with two interventions and one control group. 45 randomly selected samples were divided into three groups: Aerobic training (15 people), combined training (15 people) and control (15 people). The experimental groups received the relevant intervention for 12 weeks. One-way analysis of variance, Tukey's post hoc test, and paired T-test were used in SPSS 25 software to analyze the data.
Findings After 12 weeks of intervention, the groups had significant differences in weight (p=0.001) and body mass index (p=0.001). There were significant weight losses in the aerobic (p=0.001) and combined (p=0.001) training groups compared to the control group. Also, a significant decrease in body mass index was observed in the aerobic (p=0.001) and combined (p=0.001) training groups compared to the control group. A significant decrease in weight and body mass index was observed in the aerobic (p=0.001) and combined (p=0.003) training groups from pre-test to post-test.
Conclusion Upper-body aerobic training alone and in combination with resistance training affects the functional and structural indicators of the heart in lower-limb amputees.

Keywords Aerobic Exercise; Combined Exercise; Heart Structure; Heart Function; Veteran

CITATION LINKS

[1] Physical Inactivity, Adverse body composition, and cardiac function in ... [2] BDNF and orexin-A response to aerobic exercise are moderated by the meal consumption ... [3] Design and evaluation of effect 8-week home-base ... [4] TVascular and skeletal muscle remodeling: Beyond physical ... [5] Why traumatic leg amputees are at increased risk for ... [6] Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the ... [7] Lower limb amputation in England: prevalence, regional variation and relationship ... [8] Cardiovascular disease in patients with chronic inflammation: Mechanisms underlying ... [9] Hemodynamic studies for lower limb amputation and ... [10] Physical fitness of lower limb ... [11] Factors influencing physical activity among individuals with lower limb ... [12] Perceptions of phantom limb pain in lower limb amputees and its effect on quality ... [13] Cardiorespiratory fitness interventions for individuals with lower limb ... [14] Cardiorespiratory fitness and physical strain during prosthetic rehabilitation ... [15] Effects of hybrid cycle and handcycle exercise on cardiovascular ... [16] Feasibility and validity of a graded one-legged cycle exercise test to ... [17] Sepsis modeling in mice: ligation length is a major severity factor in cecal ... [18] Physical activity and quality of life of amputees in ... [19] The effect of aerobic training on structure and ... [20] The effect of home-based monitored exercise protocol on cardio-respiratory ... [21] The effect of combined training on serum level of interleukin 6 and some pulmonary parameters ... [22] Effect of aerobic exercises on general health and serotonin values ... [23] Physical activity of the civilian chemical victims of Sardasht 20 years after sulfur ... [24] The effect of endurance, resistance and concurrent training on ... [25] NChanges in the structure of the heart and blood pressure ... [26] Effect of 12 weeks aquatic aerobic exercises on myocardial structure ... [27] The effect of endurance, resistance, and combined exercises ... [28] Lower extremity nontraumatic amputation among veterans ... [29] Biomarkers of cardiovascular responses among war veterans ... [30] The effect of 8-week aerobic interval training and a detraining ...

Introduction

With industry development in the 21st century, human life has rapidly changed from a fully active state to a generally inactive life [1]. Inactivity in today's societies is generally associated with poor nutrition and psycho-social problems. This inappropriate lifestyle greatly increases the risk of many chronic diseases, such as cardiovascular diseases [2]. Due to their physical limitations, veterans experience more movement limitations than healthy people. On the other hand, environmental and social restrictions and neurological and psychological problems reduce the physical activity of veterans compared to their healthy counterparts [3]. Therefore, the combination of disability and immobility in veterans causes the risk of cardiovascular diseases to increase greatly compared to healthy counterparts [4]. According to statistics, the risk of cardiovascular diseases in unilateral and bilateral lower limb amputation veterans is 1.58 and 3.5, respectively, higher than that of healthy counterparts [5]. Also, the death of amputees due to heart disease is 2.2 and 3.3 times higher than their healthy counterparts [5, 6]. Although the cause of the higher prevalence and risk of cardiovascular diseases in lower limb amputee veterans is not well defined, insulin resistance, hemodynamic changes, especially in the amputated limb, psychological stress, systemic inflammation, and increased sympathetic nervous system activity [6], cardiomyopathy, heart attacks, coronary artery disease, systolic heart failure, and heart valve disease are amputees' most common cardiovascular disorders [7]. Etiology studies in this field are divided into two categories. The first category of metabolic changes caused by the inappropriate lifestyle of a veteran is considered to be the cause of cardiovascular complications. In this context, it has been determined that insulin resistance is significantly higher in amputee veterans than in healthy counterparts. Also, bilateral amputation is more related to the incidence of insulin resistance than unilateral [6]. In addition, psychological stress, neurological problems, and increased sympathetic system activity are among the physiological reasons associated with higher cardiovascular problems in veterans [9]. The second group of studies considers the cause of cardiovascular problems in amputation veterans to be hemodynamic abnormalities caused by disturbed arterial flow near the amputation site. Hemodynamic reasons such as shear stress, environmental strain, and reflected waves at the amputation site cause hemodynamic consequences such as femoral artery blockage, atherosclerosis, and subrenal aneurysm. The same hemodynamic changes can cause blood pressure, left ventricular hypertrophy, and ischemic heart disease [10].

On the other hand, sports activity reduces weight and fat percentage and improves the inflammatory condition in healthy people and amputees, thereby reducing the risk of cardiovascular diseases [5, 11, 12]. On the other hand, it reduces stress, anxiety, and fatigue and increases the quality of life of amputees [13]. Also, growing evidence shows that exercise training can positively affect amputees' hemodynamic status [14, 15]. In this context, it has been found that 16 weeks of aerobic exercise significantly improves metabolic, inflammatory, and visceral fat conditions in disabled people [16]. Also, it has been found that a single-leg cycling training protocol significantly improves amputees' resting heart rate and fatigue [17]. The quality of life in active veterans is also reported to be much higher than in inactive veterans [18, 19]. On the other hand, it has been found that eight weeks of aerobic training does not affect the structure and function of the heart of disabled people [20].

As it is known, sports training and physical activity reduce the risk of cardiovascular diseases in veterans by improving body composition and metabolic and inflammatory status. However, the effects of exercise and physical activity on amputee veterans' heart function and structure are very limited. For this purpose, the present study aimed to evaluate the effect of 12 weeks of aerobic and combined exercises on the structure and function of the heart of lower limb amputation veterans.

Materials and Methods

This semi-experimental pre-test/post-test study was designed with two interventions and one control groups. After announcing the call and reviewing the medical files of the veterans, 45 lower-body amputees who were males between 45 and 60 years old, with 50-70% damage rate, amputation above or below the knee (classes A2-A4), not participating in regular sports activities, and no history of metabolic disease and no smoking were selected—the veterans that had the experience of participation in similar interventions and use of certain medications were not included. Getting infectious diseases (influenza or COVID-19), injury, and non-participation in exercises caused exclusion. Finally, 45 randomly selected samples were divided into three groups: Aerobic training (15 people), combined training (15 people) and control (15 people).

The samples' age, height, weight, and body mass index were evaluated and recorded. A digital scale (Beurer model BF66; Germany) was used to measure the weight with an accuracy of 0.01kg. Height was measured using a wall-mounted height meter with an accuracy of 0.1cm. Body mass index was calculated using the BMI formula.

Heart structural variables were measured using resting electrocardiography and echocardiography using one-dimensional and Doppler methods in the heart department of Imam Reza Clinic in Shahrekord City by a cardiologist using an electrocardiograph (Araz 630 Raahian; IRAN) and an echocardiography machine (Eko7; South Korea). First, a resting electrocardiogram was recorded while the subjects were lying on their backs on the bed and in a completely free position. Heart rate (numbers per minute) and PR interval (seconds) were calculated from the recorded tape of the heart's electrical activity. Then, each subject was asked to lie on his left side after choosing the most appropriate image of the heart chambers in the resting state, the variables of ejection fraction (percentage), end-diastolic and systolic diameters (mm), thickness of the posterior wall of the left ventricle and thickness. The interventricular septum (mm) was measured by the one-dimensional method. The left ventricular mass (gram) was also measured using the two-dimensional method.

The experimental groups received the relevant intervention for 12 weeks. The control group continued their usual activities for 12 weeks.

Aerobic group exercises were three weekly sessions, each between 30 and 50 minutes, with an increased load. Each training session consisted of three parts; Warm-up, main exercise (Table 1), and cool-down. The exercises started in the first week with an intensity of 40% of the maximum heart rate and finally reached 70% of the maximum heart rate in the twelfth week. Maximum heart rate measurement was evaluated using the formula (220-sen). Exercise heart rate was evaluated using an hourly Polar heart rate monitor (S-series Tolkit; Finland).

Table 1. Upper body aerobic training (wheelchair riding) protocol (all sessions have warm-up and cool-down parts 10 minutes each)

Week	Maximum heart rate (%)	Periods	Total time (min)
1-2	40-45	One 10 minutes	10
3-4	45-50	One 15 minutes	15
5-6	50-55	Two 8 minutes (4 minutes rest between)	20
7-8	55-60	Two 8 minutes (4 minutes rest between)	20
9-10	60-65	Three 6 minutes (3 minutes rest between)	24
11-12	65-70	Three 6 minutes (3 minutes rest between)	24

Combined group exercises, including aerobic and resistance exercises, three sessions per week, each between 30 and 60 minutes with overload. Each training session consisted of three parts; Warm-up, main exercise (Table 2), and cool-down. The aerobic part of the exercises was performed the same way as the aerobic exercise group but with half the time of the aerobic exercise group. The resistance exercises section included upper body resistance exercises with machines and free weights for the upper body's main and large muscle groups (Shoulder, forearm, chest, armpit, back of the arm, abdomen). In the first week, resistance training started as two sets with 8-12 repetitions and with 40% of 1 repetition of the maximum, and in the twelfth week, it reached four sets with 6-8 repetitions and with an intensity of 70% of 1 repetition of the maximum.

Table 2. Upper body combined exercise protocol (all sessions have warm-up and cool-down parts 10 minutes each)

Week	Maximum heart rate (%)	Periods/Repeats (Set)	Total time (min)
Aerobic exercise			
1-2	40-45	One 5 minutes	5
3-4	45-50	One 7 minutes	7
5-6	50-55	Two 4 minutes (2 minutes rest between)	10
7-8	55-60	Two 4 minutes (2 minutes rest between)	10
9-10	60-65	Three 3 minutes (90 seconds rest between)	12
11-12	65-70	Three 3 minutes (90 seconds rest between)	12
Resistance training			
1-2	40-45	8-12 (2)	5
3-4	45-50	8-12 (2)	7
5-6	50-55	8-10 (3)	10
7-8	55-60	8-10 (3)	10
9-10	60-65	6-8 (4)	12
11-12	65-70	6-8 (4)	12

All statistical analyses were performed using SPSS 25 software. The Shapiro-Wilk test was used to check the normality of the data distribution, and the Lune test was used to check the homogeneity of variances between groups. One-way analysis of variance was used to check the differences between groups. If the one-way analysis of variance test was significant, Tukey's post hoc test was used for pairwise comparisons of groups. Also, to examine intra-group changes from pre-test to post-test, the paired T-test was used.

Findings

There was no significant difference in the subjects' age (p=0.814; F=27.698) and height (p=0.526; F=27.068) between the groups (Table 3).

Table 3. Comparison of anthropometric indices mean±SD in (paired T-test) and between (one-way analysis of variance) the groups after 12 weeks of aerobic and combined exercises

Parameter	Aerobic	Combined	Control	F	Intergroup p-value
Age (year)	56.80±2.86	56.20±2.94	53.00±3.10	0.207	0.814
Height (cm)	170.40±2.42	171.80±2.74	171.46±2.94	0.675	0.526
Weight (kg)					
Pre-test	75.74±6.61	80.29±13.06	75.01±10.01	27.691	0.001
Post-test	72.37±6.56#	76.84±13.09#	75.27±10.06		
Intragroup p-value	0.001	0.003	0.103		
BMI (kg/m^2)					
Pre-test	26.09±2.10	27.22±3.63	25.52±3.63	27.068	0.001
Post-test	24.92±2.05#	26.03±4.55#	25.61±3.65		
Intragroup p-value	0.001	0.003	0.51		

#significant difference with the control group

Table 4 shows the structural and functional changes in cardiovascular risk factors in and between the groups before and after 12 weeks of aerobic and combined exercises.

Table 4. Examining changes in cardiovascular risk factors mean±SD in (paired T-test) and between (one-way analysis of variance) the groups following 12 weeks of aerobic and combined exercises

Parameter	Aerobic	Combined	Control	F	Intergroup p-value
Resting heart rate (beats per minute)					
Pre-test	8.28±77.00	9.27±75.20	8.49±75.66	6.895	0.004
Post-test	7.31±74.70#	9.35±73.80	7.89±75.91		
Intragroup p-value	0.003	0.005	0.889		
Systolic blood pressure (mmHg)					
Pre-test	6.31±131.50	13.47±132.10	9.98±128.33	18.498	0.001
Post-test	7.75±121.40#	14.07±124.90#	9.85±131.67		
Intragroup p-value	0.001	0.001	0.135		
Diastolic blood pressure (mmHg)					
Pre-test	3.18±82.10	8.34±84.00	5.78±82.31	4.680	0.017
Post-test	2.44±79.22#	7.59±81.20#	4.98±83.91		
Intragroup p-value	0.001	0.001	0.393		
Left ventricular end-diastolic internal diameter (mm)					
Pre-test	6.13±48.31	6.90±45.72	5.25±45.41	20.826	0.001
Post-test	4.73±50.80#	6.71±49.9#	5.03±45.08		
Intragroup p-value	0.005	0.001	0.392		
Left ventricular end-systolic inner diameter (mm)					
Pre-test	4.08±32.59	3.13±34.10	2.59±33.31	21.741	0.001
Post-test	4.57±30.60#	2.97±30.80#	2.80±33.25		
Intragroup p-value	0.001	0.001	0.833		
Left ventricular ejection fraction (%)					
Pre-test	4.71±55.06	4.74±56.50	4.43±56.66	28.714	0.001
Post-test	4.79±58.50#	4.50±61.40#	4.11±56.33		
Intragroup p-value	0.011	0.001	0.586*		
Interventricular septum wall thickness (mm)					
Pre-test	2.52±8.13	2.23±8.08	3.15±7.78	-	0.057
Post-test	2.46±8.19	2.10±8.28	3.08±7.97		
Intragroup p-value	0.329	0.006	0.941		
The thickness of the posterior wall of the left ventricle (mm)					
Pre-test	2.25±7.98	1.99±7.80	2.92±7.39	1.507	0.238
Post-test	2.01±8.05	1.92±8.01	2.83±7.33		
Intragroup p-value	0.669	0.071	0.306		
Discharge fraction (%)					
Pre-test	4.11±56.50	4.59±56.00	4.82±56.25	24.101	0.001
Post-test	3.56±58.40#	3.87±59.10#	4.52±55.83		
Intragroup p-value	0.001	0.001	0.269		

#significant difference with the control group

Discussion

The aim of the present study was to investigate the effect of 12 weeks of aerobic and combined exercises on the structure and function of the heart of lower limb amputation veterans. The results of the present study showed that 12 weeks of both aerobic and combined exercises led to significant improvement in body weight, body composition, heart rate, systolic and diastolic blood pressure, end-systolic and diastolic internal diameters of the left ventricle, left ventricular ejection fraction and percentage of cardiac ejection fraction. A significant improvement was observed in the combined exercise group compared to aerobics only in the case of the internal end-systolic diameter of the left ventricle. Nevertheless, there was no significant difference in the thickness of the interventricular wall and the thickness of the posterior wall of the left ventricle after 12 weeks of intervention.

The present study's weight and body mass index decreased significantly due to aerobic and combined exercises. In this context, Rouhi & Debidi Roshan showed that eight weeks of supervised combined exercises at home significantly reduced the weight of veterans of Mazandaran province [21]. Babaei & Yaqoubi reported that ten weeks of combined training leads to weight loss, body mass index, and fat percentage of veterans [22]. Rohi *et al.* showed that eight weeks of combined exercises at home significantly improves body composition indices in veterans of Mazandaran province and their spouses [3]. Tawfighi & Nozadgajin reported that 12 weeks of aerobic training significantly improves the fat percentage of inactive veterans [23]. All studies on the effect of combined and aerobic exercises on body weight, body mass index, and indicators related to body composition align with the current research. The relationship between body composition and cardiovascular risk factors has been fully confirmed, and lifestyle is important in body composition [2]. In the case of veterans, it is well known that reducing physical activity related to physical condition causes obesity and overweight, which is a risk factor for cardiovascular diseases [23]. In lower limb amputation veterans, on the one hand, movement restrictions are caused by amputation; on the other hand, environmental and social restrictions cause a decrease in physical activity, an increase in overweight and obesity [3], and finally increase the risk of cardiovascular diseases [4]. On the other hand, sports training, especially combined training, in addition to reducing body fat percentage, improves lipid profile and blood sugar and reduces inflammation, which generally reduces the risk of cardiovascular diseases [24].

Another result of the present study was the significant improvement of functional and structural indicators of the heart of lower limb amputation veterans after 12 weeks of aerobic and combined training. Studies are very limited on the effects of exercise training on the structure and function of the heart of amputee veterans. In this context, it has been determined that a one-legged cycling training protocol significantly improves amputees' resting heart rate and fatigue [17]. On the other hand, it has been found that eight weeks of aerobic training does not affect the structure and function of the heart of disabled people [20]. However, some studies investigated the effects of exercise training on the structure of heart function in other groups. In this context, it has been determined that eight weeks of endurance and combined training (Endurance and resistance) significantly improves the heart structure of middle-aged women [25]. Also, a significant improvement in blood pressure, heart rate, and heart structural indices of patients with chronic heart failure has been reported after eight weeks of combined exercises [26]. Also, it has been found that 12 weeks of combined sports training in water significantly improves the structural and functional indicators of the heart of patients with type 2 diabetes [27]. On the other hand, it has been reported that eight weeks of aerobic and combined exercises do not significantly affect the structural indices of the heart of university girls [28].

Cardiovascular complications such as cardiomyopathy, heart attacks, coronary artery disease, systolic heart failure, and heart valve disease are lower limb amputees' most common cardiovascular disorders [7]. Several factors can increase the risk of cardiovascular diseases in lower limb amputees. On the other hand, metabolic changes caused by a veteran's sedentary lifestyle can cause cardiovascular complications [29]. Insulin resistance and metabolic syndrome are the most important risk factors caused by inactivity in amputees, which greatly increases the risk of cardiovascular diseases in these people [6]. On the other hand, it has been found that psychological stress, neurological problems, and increased activity of the sympathetic system are among the physiological reasons associated with the higher incidence of cardiovascular problems in veterans [9]. It has been found that post-traumatic stress, depression, and other factors related to these two, i.e., smoking, physical inactivity, and bulimia, can be another reason for increasing the risk of cardiovascular diseases in lower limb amputees [6, 30]. Another group of studies also considers the causes of cardiovascular problems in amputation veterans to be hemodynamic abnormalities caused by impaired arterial flow near the amputation site. Hemodynamic reasons such as shear stress, environmental strain, and reflected waves at the amputation site cause hemodynamic consequences such as femoral artery blockage, atherosclerosis, and subrenal aneurysm. On the other hand, the same hemodynamic changes can cause blood pressure, left ventricular hypertrophy, and ischemic heart disease [10].

Sports training, especially aerobic training, increases the volume load on the heart and thus increases the diameter of the heart cavities, especially in the left ventricle. A relative increase in the heart walls will also occur following these changes. An increase in the thickness of the heart walls generally causes an increase in the left body mass. In general, it has been found that the left ventricle is more affected by exercise than other parts of the heart [31]. As in the present study, we observed an increase in the inner diameter of the end of the diastole and a decrease in the inner diameter of the end of the left ventricle systole. It has also been found that due to exercise, the diastolic filling volume increases, the diameter and mass of the left ventricle increases, the capacity of the ventricles increases, and myocardial contraction is stronger. All these cases can describe the decrease in heart rate and blood pressure due to exercise [24]. Therefore, structural changes in the end-systolic and diastolic internal diameter of the left ventricle as a result of exercise training in the present study seem to be the reason for the increase in the left ventricular ejection fraction and the total ejection fraction of the heart. Also, the improvement in resting heart rate and blood pressure has been a result of the structural and functional changes of the heart as a result of exercise.

Conclusion

Upper-body aerobic training alone and in combination with resistance training (Not using a prosthesis during training) affects the functional and structural indicators of the heart in lower-limb amputees.

Acknowledgments: Thanks to all the veterans who participated in this research.

Ethical Permissions: All stages of the research have been approved by the Research Ethics Committee of the Islamic Azad University, Najafabad branch (Code: IR.IAU.NAJAFABAD.REC.1400.048). All research steps were carried out according to the 1964 Helsinki Declaration.

Conflicts of Interests: There is no conflict of interest.

Authors' Contribution: Heydary M (First Author), Introduction Writer/Main Researcher (70%); Keshavrz S (Second Author), Methodologist (10%); Kargarfard M (Third Author), Assistant Researcher/Statistical Analyst (10%); Porheidar B (Fourth Author), Assistant Researcher/Discussion Writer (10%)

Funding/Support: There is no content.

References

1- Kirkham AA, Power C, Pituskin E. Physical Inactivity, Adverse body composition, and cardiac function in breast cancer survivors: Triple Jeopardy?. JACC Cardio Oncol. 2022;4(2):192-4.

2- Mardaniyan Ghahfarrokhi M, Habibi A, Alizadeh AA, Negaresh R, Mohammad Shahi M, Earnest CP. BDNF and orexin-A response to aerobic exercise are moderated by the meal consumption before exercise in overweight men: Effect of high-carbohydrate, high-protein and high-fat meals. Sci Sport. 2020;35(4):228-36.

3- Rohi H, Shad N, Dabidi Roshan V. Design and evaluation of effect 8-week home-base combined exercise on visceral obesity and cardiovascular function of veterans from different regions of Mazandaran province and their wives: A strategy to reduce inactivity during the Covid-19 pandemic. J Mil Med. 2022;23(11):901-12. [Persian]

4- Pedrinolla A, Cavedon V, Milanese C, Barbi C, La Ginestra F, Giuriato G, et al. Vascular and skeletal muscle remodeling: Beyond physical inactivity. FASEB J. 2022;36(S1).

5- Naschitz J, Lenger R. Why traumatic leg amputees are at increased risk for cardiovascular diseases. QJM. 2008;101(4):251-9.

6- Mann S, Beedie C, Jimenez A. Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: Review, synthesis and recommendations. Sports Med. 2014;44(2):211-21.

7- Ahmad N, Thomas GN, Gill P, Chan C, Torella F. Lower limb amputation in England: prevalence, regional variation and relationship with revascularisation, deprivation and risk factors. A retrospective review of hospital data. J R Soc Med. 2014;107(12):483-9c.

8- Mason JC, Libby P. Cardiovascular disease in patients with chronic inflammation: Mechanisms underlying premature cardiovascular events in rheumatologic conditions. Eur Heart J. 2015;36(8):482-9.

9- Dong R, Jiang W, Zhang M, Leung A, Wong MS. Hemodynamic studies for lower limb amputation and rehabilitation. J Mech Med Biol. 2015;15(4):1530005.

10- Chin T, Sawamura S, Fujita H, Nakajima S, Oyabu H, Nagakura Y, et al. Physical fitness of lower limb amputees. Am J Phys Med Rehabil. 2002;81(5):321-5.

11- Lee LS, Hitzig SL, Mayo A, Devlin M, Dilkas S, MacKay C. Factors influencing physical activity among individuals with lower limb amputations: A qualitative study. Disabil Rehabil. 2023;45(9):1461-70.

12- Trevelyan EG, Turner WA, Robinson N. Perceptions of phantom limb pain in lower limb amputees and its effect on quality of life: A qualitative study. Br J Pain. 2016;10(2):70-7.

13- van Kammen K, Seves B, Vrieling AH, Dekker R, van Dijk A, Dijkstra PU, et al. Cardiorespiratory fitness interventions for individuals with lower limb amputation: A scoping review. MedRxiv. 2022.

14- Wezenberg D, Dekker R, van Dijk F, Faber W, van der Woude L, Houdijk H. Cardiorespiratory fitness and physical strain during prosthetic rehabilitation after lower limb amputation. Prosthet Orthot Int. 2019;43(4):418-25.

15- Bakkum AJ, Paulson T, Bishop N, Goosey-Tolfrey V, Stolwijk-Swuste JM, van Kuppevelt DJ, et al. Effects of hybrid cycle and handcycle exercise on cardiovascular disease risk factors in people with spinal cord injury: A randomized controlled trial. J Rehabil Med. 2015;47(6):523-30.

16- Wezenberg D, de Haan A, van der Woude LH, Houdijk H. Feasibility and validity of a graded one-legged cycle exercise test to determine peak aerobic capacity in older people with a lower-limb amputation. Phys Ther. 2012;92(2):329-38.

17- Deans SA, McFadyen AK, Rowe PJ. Physical activity and quality of life: A study of a lower-limb amputee population. Prosthet Orthot Int. 2008;32(2):186-200.

18- da Silva R, Rizzo JG, Gutierres Filho PJB, Ramos V, Deans S. Physical activity and quality of life of amputees in southern Brazil. Prosthet Orthot Int. 2011;35(4):432-8.

19- Mohebbi BB, Nikbakht H. The effect of aerobic training on structure and function of heart in the disabled with spinal cord injury. Harkat. 2007;31(2):27-39. [Persian]

20- Rohi H, Dabidi Roshan V. The effect of home-based monitored exercise protocol on cardio-respiratory parameters and physical activity of veterans of Mazandaran province. J Sport Biosciences. 2020;11(4):393-411. [Persian]

21- Babai A, Yaghoubi A. The effect of combined training on serum level of interleukin 6 and some pulmonary parameters in chemical veterans caused by mustard gas. Nafas J. 2021;7(4)37-42. [Persian]

22- Tofighi A, Nozad-Gajin J. Effect of aerobic exercises on general health and serotonin values of inactive veterans. Res Sport Med Tech. 2016;21:75-86. [Persian]

23- Ghazanfari Z, Ghazanfari T, Araghizadeh H, Soroush MR, Yaraee R, Mahdavi MRV, et al. Physical activity of the civilian chemical victims of Sardasht 20 years after sulfur mustard exposure. Toxin Rev. 2009;28(1):48-53. [Persian]

24- Khani F, Nikbakht H, Ghazalian F, Barzegar M. The effect of endurance, resistance and concurrent training on the structure of the heart of healthy middle-aged women. J Jiroft UnivMed Sci. 2020;7(1):255-65. [Persian]

25- Mahmoodi Z, Shabani R, Zidashti ZH, Gholipour M. Changes in the structure of the heart and blood pressure after a period of concurrent endurance-resistance training in patients with chronic heart failure. Med Sci. 2020;30(3). [Persian]

26- Amirsasan R, Vakili J, Salehi R, Akbari M. Effect of 12 weeks aquatic aerobic exercises on myocardial structure and function in type 2 diabetic women with heart failure. Med J Tabriz Univ Med Sci. 2020;42(1):15-23. [Persian]

27- Hosseini M, Agha Alinejad H, Piri M, Haj Sadeghi Sh. The effect of endurance, resistance, and combined exercises on the heart structure of university girls. Biol Sport. 2008;44(16):29-38. [Persian]

28- Collins TC, Johnson M, Henderson W, Khuri SF, Daley J. Lower extremity nontraumatic amputation among veterans with peripheral arterial disease: Is race an independent factor?. Med Care. 2002;40(1 Suppl):I106-16.

29- Amirpour B, Aghayousefi A, Goli R, Abdolmaleki L. Biomarkers of cardiovascular responses among war veterans with posttraumatic stress disorder. Neuroscience J Shefaye Khatam. 2015;3(4):57-64. [Persian]

30- Gaeini A, Kazemi F, Mehdiabadi J, Shafiei-Neek L. The effect of 8-week aerobic interval training and a detraining period on left ventricular structure and function in non-athlete healthy men. Zahedan J Res Med Sci. 2012;13(9):24-37.