REVIEW ARTICLE

Effects of aerobic physical activity to cardio-respiratory fitness of the elderly population: systematic overview

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection.

Abstract

Purpose: Aerobic training is effective manner of exercising aimed at improving cardio-respiratory fitness of young people. However, its effects to the elderly population (over the age of 60), depending on characteristics of the participant (gender, health status, lifestyle, etc.), is still unclear. Aim of this research is systematic overview of the available literature dealing with the topic of effects of aerobic training to cardio-respiratory fitness of the elderly population over the age of 60, depending of gender (male/female), BMI (overweight/normal weight), lifestyle (active/sedentary), health status (diabetes/hypertension/metabolic syndrome).

Material: Total number of papers with published research results which met the criteria was 32. Walking is effective manner of exercising which influences improvement of maximum oxygen consumption (mean value: ±SD:12.91±7.40%). Introduction of activities with greater impact (bicycle and jogging) provides more effect to the cardio-respiratory fitness (mean value: ±SD:14.28±7.48%).

Results: Aerobic training intensity level (moderate vs. high) makes no significant difference to the adaptive response of the cardio-respiratory fitness in elderly population. Training in duration of 6 weeks may significantly influence increase in maximum oxygen consumption, but longer training duration, however, has better effect. Endurance training has similar effects to improvement of cardio-respiratory fitness in both men and women. On the other hand, it seems that active people have lower adaptive response in comparison to sedentary people (8.3% vs. 18.84%). Effect is similar between overweight and normal weight participants (18.48% vs. 8.6%). Positive influence of aerobic training was also observed in participants with hypertension, metabolic system and diabetes type 2.

Conclusions: Results clearly suggest benefits of aerobic training on cardio-respiratory fitness of elderly population. The effect may, however, vary depending of duration, type of activity, as well as characteristics of the sample.

Keywords: training, sedentary, VO2max, walking, health, HRmax.

Introduction

Epidemiological studies indicate tight connection between exercising, health and fitness and the role of lifestyle to health of general population [1, 2]. Term *physical fitness* is related to certain level of being in physical shape. Additionally, it is used as synonym to certain types of exercising. Important fitness component linked to health status is cardio-respiratory fitness [3] . Cardio-respiratory fitness is the ability of cardio-vascular system and respiratory system to maintain oxygen supply to engaged muscles in duration of prolonged physical activity, as well as the ability of muscles to provide required energy in aerobic processes [4]. Maximum oxygen consumption (VO_{2max}) is the best indicator of aerobic capabilities of the organism and functional ability of cardio-vascular system, respiratory system and tissue to use the available oxygen [5], which all reduces with aging. After the age of 25–30 sedentary people experience reduction of VO_{2max} 8–15% per decade [6] . Reduced capability to perform everyday activities after the age of 60 is caused by gradual reduction of VO_{2max} [8]. Aerobic training or endurance training is recommended for improving cardio-respiratory fitness and health benefits of elderly population. It may be defined as activity in minimal duration of 20 minutes where values of heart rate frequency are 60–80% of maximum heart rate frequency (HR_{max}) [9] Previously performed meta-analyses confirmed the positive effect of training to VO_{2max} in elderly population. Despite important results obtained [10, 11] value of moderator in meta-regression analysis took value of 50 for independent variable *age*. Value for elderly people was (>50), which is an indicator of high variability among the participants. In the aforementioned study was also used common statistical method for calculation of the magnitude of effect of

doi:10.15561/26649837.2020.0501

various types of training (aerobic training, training with the load, etc.) to cardio-respiratory fitness. Second meta-analysis [10] included papers published in the period 1980–2002 and due to lack of available data, meta-regression analysis was not performed for the following variables: gender (male/female), BMI (overweight/normal weight), lifestyle (active/sedentary), health status. Up to date, the number of conducted research on the topic of effects of aerobic training to elderly population is low and requires information update. More sophisticated tools for assessment of performances and improved quality of research have also been developed. Therefore, aim of research is systematic overview of the available literature linked to effects of aerobic training to cardio-respiratory fitness of elderly population over the age of 60, depending of gender (male/female), BMI (overweight/normal weight), lifestyle (active/sedentary), health status (diabetes/hypertension/metabolic syndrome).

Material and methods

Data sources and search strategy

For the purpose of searching the available literature, following data bases were used: PubMed, MEDLINE, Google Scholar, ScienceDirect, ERIC from 1986 to August 2016. Searching was performed using following terms (individually or in combination): *physical activity, cardio-respiratory fitness, older adults, aerobic training,* VO_{2max}*, effects, endurance training, walking, running, elderly.* Searching strategy was modified for each electronic database, where it was possible, with the aim of increasing sensitivity. All the papers and abstracts were evaluated for selection of potential papers to be included in the systematic overview. Lists of references and original research were also included in the analysis. One author performed literature search (EC). Relevant studies were obtained after detailed search if they met the criteria. The criteria are described in the following section.

Inclusion criteria

Type of study

Controlled randomised and non-randomised studies about effects of aerobic training to cardio-respiratory fitness in English language were included in the analysis.

Sample

Included participants are men and women aged over 60 regardless of lifestyle (active/sedentary), BMI (overweight/normal weight), health status (diabetes, metabolic syndrome, hypertension).

Type of intervention

Research establishing the effect of aerobic training.

Type of output results

Studies were included if the results present influence of aerobic training to VO_{2max} before and after aerobic training.

Exclusion criteria

Exclusion criteria were: 1) studies in languages other than English; 2) Age of participants under 60; 3) combination of aerobic training with training under load.

Data acquisition

Format used for data acquisition was PICO (**P**articipants, **I**ntervention, **C**omparison or control group, **O**utcomes) [12]: participants (and their health status, gender, BMI, lifestyle age), sample size, comparison of groups, training program (frequency, duration, type of activity, intensity) and acquired results (absolute and relative VO_{2max}). Data extraction was performed using Cochrane Consumers and Communication Review Group's data extraction protocol. Selection and assessment of data was performed by single author in order to maintain precision and to be comprehensive. All the selected papers were assessed in detail to collect required data. Authors of included papers were not contacted for missing data.

Results

In search results there were 785 identified potentially relevant studies, and 15 more after covering the references. After removal of double papers and abstracts there were 88 papers remaining. Upon completion of assessment of whole texts only 32 papers remained where all the criteria were met (Fig 1).

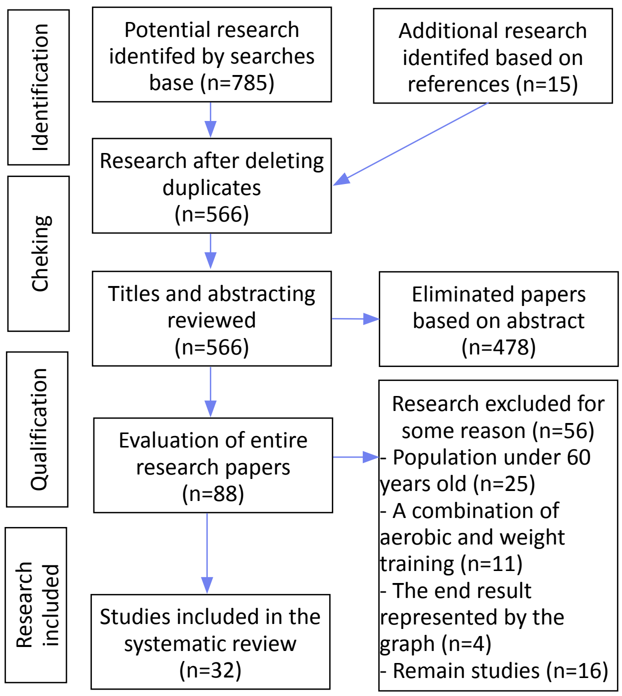

Figure 1. Flow Diagram

Aerobic training

Aerobic physical training triggers positive adaptive response to absolute and relative VO_{2max}. It seems that the simplest and most acceptable form of aerobic training is walking. Choice of this type of physical activity can be prescribed to less chance of injury, no supervision required and universal availability, which is why majority of authors researched influence of aerobic training in this training regime [13, 16, 20, 23]. Results of this systematic overview suggest that walking significantly improves absolute VO_{2max} values. Average improvement is 12.91±7.40% (range 1%–27 %). Additionally, results of previous meta-analysis confirmed significant effect of walking to cardio-respiratory fitness in healthy sedentary population [25]. Contemporary studies [26, 27, 30,

Table 1. Systematic overview and characteristics of papers included in the research

Study	Population							Training program				Output results	
	Health status	Gender	BMI (kg/m²)	Lifestyle	Age	Sample size	Group comparison (*n*)	Frequency/ duration (days/ weeks)	Intensity	Training duration (min)	Type of activity	VO_{2max} (ml kg⁻¹ min⁻¹)	VO_{2max} (l min⁻¹)
1	2	3	4	5	6	7	8	9	10	11	12	13	14
[26] Blumenthal et al. (1989)	healthy	♂/♀	/	/	67±4.9	101	EG (n= 33; M=17/F=16) KG1 (n=34; M=17/F=17) KG2 (n=34; M=16/F=18)	EG: 3/16 KG1: 2/16	70% HRmax	60	EG : bicycle, ergometer, walking, jogging KG1 : Yoga	EG: 11.6 M=14.4%↑*; F=8.6%↑* KG1: 1%↓ KG2: 2%↓	
[18]Foster et al. (1989)	healthy	♀	/	sedentary	EG1: 78.4±4.6 EG2: 78.4±6.4	16	EG1 (n=9) EG2 (n=7)	3/10	EG1: 60% HRR EG2: 40% HRR	EG1: 45 EG2: 60	EG 1,2: Walking	EG1: 15%↑* EG2: 12.6%↑*	EG1: 21%↑* EG2: 12%↑*
[14]Belman and Gaesser (1991)	healthy	♂/♀	/	sedentary	65-75	27	EG1 (n=8; M=4/F=4) EG2 (n=9; M=5/F=4) KG (n=8; M=4/F=4)	4/8	EG1: 82% VO_{2max} EG2: 53% VO_{2max}	30	EG 1,2: Walking	EG1: 7%↑* EG2: 7.5%↑* KG: 2.3%↓	
[27] Blumenthal et al. (1991)	healthy	♂/♀	/	sedentary	67 (60-83)	100	EG1 (n= 28) EG2 (n=31) EG3(n=31)	EG1: 3/32 EG2: 3/16 EG3:3/16	70% HRmax	60	EG1,2,3:Hand bicycle, ergometer, walking or jogging EG2: + yoga	EG1: 11%↑* M=15%↑*; F=8%↑* EG2: 6%↑ M= 4%↑*; F=9.5%↑* EG3: 14%↑ M=16 %↑*; F=14.5 %↑*	
[22]Probart et al. (1991)	healthy	♀	EG:25.5±1.3 KG:23.3±1.1	sedentary	EG:72±0.6 KG:72±0.68	16	EG (n=10) KG (n=6)	3/26	70% HRmax	20	Walking	EG:8.4↑* KG:6.1↓*	EG:6.6↑* KG:5↓

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[29]Kohrt et al. (1991)	healthy	♂/♀	/	sedentary	60-71	145	EG1 (n=41) EG1 (n=69) KG (n=35)	EG1: 4/52 EG2: 4/40	60-85% HRmax	30-50	EG 1,2: Walking and running, bicycle, ergometer	EG1: M=27.5%↑* F=20.5%↑* EG2: M=21.7%↑* F= 22%↑* EG: M=2%↓ F= 1%↓	EG1: M=22%↑* F= 15%↑* EG2: M=15%↑* F=17%↑* EG: M=2%↓ F=1%↓
[35]Posner et al. (1992)	healthy	♂/♀	/	sedentary	68.6±5.1	247	EG (n=166) KG (n=81)	1/16	70% HRmax	40	Bicycle ergometer	EG: 8.5%↑* KG: 3↓	
[19]Nieman et al. (1993)	healthy	♀	/	sedentary	73.4±0.8	14	EG (n=14)	5/12	60%HRR	30-40	Walking	12.6%↑*	
[23]Warren et al. (1993)	healthy	♀	25.5±1.1	sedentary	73±0.7	16	EG(n=14)	5/12	60% HRmax	30-40	Walking	12.6↑*	
[15]Braith et al. (1994)	healthy	♂/♀	/	sedentary	EG1: 66±5 EG2: 65±4 KG: 66±5	44	EG1 (n=19) EG2 (n=14) KG(n=11)	3/26	EG1: 70% HRmax EG2:80-85% HRmax	40	EG 1,2: Walking	EG1: 16%↑* EG2: 27%↑* KG: ~	
[33]Vitiello et al. (1997)	healthy	♂/♀	/	/	M 66.9±1 F67± 1.3	52	EG (n= 30; M=18/F=12) KG (n=22; M=13/F=9)	3/26	60-85% HRR	50-75	EG: walking, jogging, bicycle KG:frexibility	EG: 14.5%↑* KG: 1%↓	
[49]Vitiello et al. (1996)	healthy	♂	/	/	69±1.3	15	EG (n=15)	5/26	60-85% HRR	50-75	Walking, jogging, bicycle	EG: 17.5↑*	

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[17]De Vito et al. (1999)	healthy	♀	/	active	EG63.1±3.1 KG63.5±3.3	20	EG (n=11) KG (n=9)	3/12	60 -70% HRmax	60	Walking	EG: 1%↑ KG:2.5%↑	
[24]Woods et al. (1999)	healthy	♂/♀	/	sedentary	65.3±0.8	29	EG (n=14) KG (n=15)	3/24	50-65% HRmax	40	EG:Walking KG:flexibility	EG:20%↑* KG:9%↑	EG:19:%↑* KG:9%↑
[32]Turner et al. (2000)	hypertension	♂/♀	EG:30.2 KG:29.6	sedentary	EG65.2±1.4 KG68.5±1	18	EG (n=11; M=9/F=2) KG (n=7; M=5/F=2)	4/28	60-80% HRmax	40-60	Walking, jogging bicycle	EG:17%↑* KG:~	EG:16%↑* KG:~
[31]Pruchnic et al. (2004)	healthy	♂/♀	28±1	sedentary	67.3±0.3	13	EG (n=13; M=5/F=8)	3/12	50-70% VO_{2max}	30-40	Walking, jogging or stationary bicycle		12%↑*
[46]Broman, Quintana, Lindberg, Jansson, and Kaijser (2006)	healthy	♀	/	/	69±4	29	EG (n=18) KG (n=11)	2/8	75% HRmax	45	Walking, running in deep water	EG:11%↑* KG:3.6↑	EG:10.3%↑* KG:4.2%↑
[28]DiPietro et al. (2006)	healthy	♀	EG1 26.3±3 EG2 28±4.5 KG 27.7±4.7	sedentary	73±10	25	EG1 (n=9) EG2 (n=9) KG(n=7)	4/40	EG1: 80% VO_{2max} EG2: 65% VO_{2max}	60	EG1,2: Walking, jogging, bicycle or ergometer	EG1: 2%↓ EG2: 0.5%↓ KG: 2%↑	
[47]Coker, Williams, Kortebein, Sullivan, and Evans (2009)	healthy	♂/♀	EG1:30±1 EG2:28±1 KG:31±1	sedentary	71±1	18	EG1 (n= 6; M=3/F=3) EG2 (n=6; M=3/F=3) KG (n=6; M=3/F=3)	4-5/12	EG1: 75% VO_{2max} EG2: 50% VO_{2max}	30	EG1,2: Bicycle, ergometer	EG1:21%↑* EG2: 30%↑* KG: ~	

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[30]Madden et al. (2009)	Diabetes type 2, hypertension, hypercholesterolemia	♂/♀	EG: 30.1±1.1 KG: 27.7±1	sedentary	71.4±0.7	36	EG (n=18) KG (n=18)	3/12	60-75% HRR	60	Bicycle, ergometer and treadmill	EG: 16.5%↑ KG: 4%↓	
[43]Yassine et al. (2009)	Metabolic syndrome	♂/♀	34.3±5.2	sedentary	65.5±5	24	EG1 (n=12) EG2 (n=12)	5/12	60-85% HRmax	60	EG: Walking, bicycle EG2: EG1+ calorie restriction		EG1:15%↑* EG2:10%↑*
[20]Ozaki et al. (2010)	healthy	♀	EG:22.5±0.9 KG: 23.2±1	sedentary	EG:64±1 KG:68±1	18	EG (n=10) KG (n=8)	4/10	45% HRR~70% VO_{2max}	20	Walking	EG: 9.7%↑* KG: 10.9%↑*	EG:9%↑* KG:10.2%↑*
[13]Atcharaporn et al. (2011)	healthy	♂/♀	25.1	sedentary	75±7	14	EG (n=14)	3/12	50-100% VO_{2max}	60	Walking	EG: 25%↑*	
[34]Niederseer et al. (2011)	healthy	♂/♀	EG:27.1±3.3 KG:25.4±2.8	active	EG66.6±2.1 KG67.3±4.4	42	EG (n= 27; M=14/F=13) KG (n=20; M=10/F=10)	2-3/12	/	207.5±14.1	Skiing	EG: 7%↑* KG:0.5%↓	
[44]Nuttamonwarakul, Amatyakul, and Suksom (2012)	Diabetes type 2	/	EG: 25.7±3.4 KG27.1±2.8	/	>60	40	EG (n=20) KG (n=20)	3/12	70% HRmax	50	Exercises in water	EG:2%↑* KG:1%↓	
[37]Lovell et al. (2012)	healthy	♂	/	active	EG75.2±3 KG73.5±3.3	24	EG (n= 12) KG (n= 12)	3/16	50-70% VO_{2max}	30-45	Bicycle ergometer		EG:16.9%↑* KG: 1%↓

Table 1 (continued).

1	2	3	4	5	6	7	8	9	10	11	12	13	14
[21]Predovan et al. (2012)	healthy	♂/♀	/	sedentary	67.96 ±6.25	50	EG (n= 25) KG (n= 25)	3/12	/	60	Fast walking, dance	EG: 24%↑* KG: 1%↑	
[39]Standley et al. (2013)	/	♀	/	/	70±2	9	EG (n=9)	3-4/9	60-80% HRR	20-45	Bicycle ergometer	EG: 30%↑*	
[45] Nuttamonwarakul, Amatyakul, and Suksom (2014)	Diabetes type 2	♀	/	/	60-70	19	EG1 (n=10) EG2 (n=9)	3/12	70% HRmax	50	EG1: exercises in water EG2: out of water	EG1: 1.7%↑* EG2: 2.6%↑	
[16]Chmelo et al. (2015)	hypertension	♂/♀	34.1±3.1	sedentary	69 ±3.6	40	EG (n=40)	4/20-21	65-70% HRR	30-40	Walking	EG:7.9%↑*	
[36]Vigelsø et al. (2015)	healthy	♂	27±1	sedentary active	60-75	15	EG (n=15)	3-4/6	85%HRmax	48-58	Bicycle ergometer	EG: 10%↑*	
[48]Duffy (2016)	healthy	♂/♀	/	sedentary	60-80	247	EG1 (n=54) EG2 (n=54) EG3 (n=69) KG (n=70)	3/26	/	60	EG1: walking EG2 :walking + beta alanine EG3: dance KG: flexibility	EG1:7↑* EG2:6.1↑* EG3:0.5%↑ KG: 1.5%↑	

Legend: ♂--male; ♀-female; /-no data; ↑- significant p< .05; ↑*-significant p< .01; ↓- significant p>.05; n–number of participants; EG-experimental group; KG-control group; HRR-heart rate reserve; HRmax- maximum heart rate; VO2max– maximum oxygen consumptio.

31] also suggest that aerobic training may have more benefits to VO_{2max} when complemented with high impact activities such as jogging and bicycle ergometer (mean value±standard deviation 14.28±7.48%). Skiing is yet another form of physical activity which reduces possibility of developing cardio-vascular conditions [34], but it is recommended to more active people due to risk of injury. Belman, & Gaesser [14] and Foster, et al., [18] state that in elderly population there is no difference, or there is slight difference, in adaptation to endurance training with various intensities (moderate vs. high intensity). These findings are to great extent in line with previous meta-analysis [10]. Results indicate that 60% intensity of VO_{2max} is adequate stimulus for improving cardio-respiratory endurance of elderly population. In addition to that, this overview revealed that trainings at low frequency (once a week) have positive effect to aerobic endurance [35]. Also, endurance training in duration of 6 weeks may significantly influence the increase in VO_{2max} (10%) [36]. However, numerous research performed validated that long duration endurance training (>16 weeks) can have greater effect to cardio-respiratory system [15, 29, 37, 32].

Discussion

There are numerous morphological and physiological differences between men and women connected to cardio-respiratory fitness [38]. Women have lower blood volume, lower count of red blood cells, lower haemoglobin, which all leads to lower oxygen capacity and hence ability to increase arterial and vain differences in O_2. Despite number of physiological differences, it seems that aerobic training contributes significant increase in VO_{2max} levels in both men and women [18, 37, 39, 36]. Women show similar level of adaptation to one stimulus as elderly men [26, 29]. Similar adaptive response (increase in VO_{2max}) to endurance training in men was prescribed to increase in maximum minute volume (2/3) and increase in arterial-vein oxygen difference (1/3). On the other hand, women expressed no central adaptation, but only peripheral, due to the fact that increase in VO_{2max} levels was caused by increase in arterial-vein O_2 difference [40], whereas the increase of arterial-vein O_2 difference was caused by capilarisation of skeletal muscles and activity of mitochondrial enzymes [41]. It seems that hormones may influence lack of increase of minute and stroke volume, because women in post-menopause develop no hypertrophy of left chamber [40]. Changes contributing reduction in VO_{2max} level are numerous. VO_{2max} is very sensitive to changes in individual's lifestyle (active/sedentary). Cardio-vascular system oxygen transport capacity reduces with reduction in physical activity [42], and it increases as response to endurance training [16, 39, 36]. Niederseer et al. [34] performed research on influence of skiing to cardio-respiratory system of healthy elderly participants. In the research they applied training program in duration of 12 weeks where daily activity lasted for 3.5 hours twice or three times a week. Upon completion of three months of training, experimental group had significant increase in absolute VO_{2max} 7%, whereas no changes had been observed in the control group. Positive effect of aerobic exercising was also presented by Lovell, et al., [37]. Research authors stated that endurance training in duration of 16 weeks, with intensity 50–70 VO_{2max}, three times a week significantly increases relative VO_{2max} (16.9%). However, training programs of similar capacity with similar load intensity lead to no improvement whatsoever in VO_{2max} of elderly women [17]. Authors found that the reason behind failure to have cardio-vascular adaptation was due to insufficiently long maintaining of intensity of physical activity in duration of training. Studies dealing with the effect of aerobic training to healthy active people show different findings, possibly due to type of physical activity performed as well as maintaining the intensity of physical activity in duration of training. Average improvement rate for active elderly individuals was 8.3%. However, these results should be interpreted with caution due to relatively small number of studies performed. People with sedentary lifestyle showed better adaptation to endurance training (mean value of absolute VO_{2max} 14.84%), probably due to lower baseline fitness. In majority of research sample consisted of healthy participants (77%), whereas other research (23 %) had patients with diabetes, hypertension or metabolic syndrome (see Table 1). Number of healthy participants was 1337, versus 177 (1 research had no health status included in the parameters n=9). Despite small number of research dealing with effect of aerobic training to people with hypertension, similar positive effect to cardio-respiratory system to healthy individuals was observed [16, 30, 32]. The effect was also observed in patients with metabolic syndrome [43]. On the other hand, even though participants with diabetes type 2 showed statistically significant increase in VO_{2max} in response to aerobic training in water, this increase is lower than in case of healthy individuals (around 2% vs. 15%) [44, 45]. Factor which contributes reduction in VO_{2max} is higher weight, especially in form of fat tissue. It seems that the effect of aerobic training in overweight individuals (BMI>30) is higher in comparison to individuals with normal weight (18.48 vs. 8.6% absolute VO_{2max}). Better adaptive response to aerobic training may also be prescribed to lower baseline fitness, as in case of inactive individuals. However, lower baseline fitness of overweight individuals is caused by higher fat mass.

Conclusion

In this systematic overview we have briefly discussed practical application of aerobic training to elderly people over the age of 60, with focus on achieved effect depending of characteristics in the sample. In that sense we have to take into consideration that participants in the used studies were overweight (BMI>30), with hypertension, diabetes type 2, metabolic syndrome, with different lifestyles (active/sedentary) and gender. Despite all that, results suggest clear benefits of aerobic training to cardio-respiratory system. Certain discrepancies may however be prescribed to characteristics of the sample. American College of Sport Medicine drafted guidelines for improving cardio-respiratory fitness. In line with the guidelines, training should be held three times a week in duration 30–40 minutes with minimum intensity 50% VO_{2max} or 60% Hrmax. As it has already been observed, aerobic training of such intensity seems to be strong incentive for improvement of cardio-respiratory fitness in aging process. Available results suggest that training in duration of only 6 weeks may significantly influence increase in VO_{2max} [36], but that trainings in longer duration (>16 weeks) contribute to even greater extent to the cardio-respiratory fitness [7, 18, 22, 33]. Certain limitations of the systematic overview should be stated here. There are limitations in the external validity because majority of studies included in the overview examined influence of aerobic training to healthy individuals, whereas smaller number of studies was performed on individuals with hypertension, diabetes or metabolic syndrome. Further research on effects of aerobic training to active elderly population is required. Hence, limited number of researches conducted in required sample makes difficult drafting final conclusions. It should also be emphasized that average improvement of cardio-respiratory fitness depending on characteristics of participants was expressed using absolute oxygen consumption, due to variability among studies. Despite limitations linked with effects of aerobic training of individuals with different health status, lifestyle and gender, endurance training can be recommended as safe and effective form of exercising used for improvement of cardio-respiratory fitness of elderly population.

Funding

This research received no external funding.

Conflicts of Interest

The authors declare no conflict of interest.

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Cite this article as:
Aksović N, Bjelica B, Joksimović M, Skrypchenko I, Filipović S, Milanović F, Pavlović B, Ćorluka B, Pržulj R. Effects of aerobic physical activity to cardio-respiratory fitness of the elderly population: systematic overview. *Pedagogy of physical culture and sports,* 2020;24(5):208-218.
https://doi.org/10.15561/26649837.2020.0501

Received: 26.02.2020
Accepted: 27.03.2020; Published: 30.10.2020