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Review paper
Pregledni rad

The Influence of Professional Sport on Changes in the Athlete's Cardiovascular System After the end of Career

Tanja Nikolić[1], Sanja Zbućnović[2], Darijan Ujsasi[2], Zoran Milić[3]
[1]Student of Faculty of Sport and Physical Eeducation, Novi Sad, Serbia
[2]Student of doctoral studies, Faculty of Sport and Physical Education, Novi Sad, Serbia
[3]Educons University, Novi Sad, Serbia

Correspondence:
Zoran Milić,
Educons University, Novi Sad, Serbia, zoranmilic@yahoo.com

Abstract: *The benefits of sports activities on almost all physiological systems are immense and of wide spectrum. However, a large number of recent studies deals with the consequences of long-term professional engagement in sports activities and present opposite results. The review was based on the assumption that intense physical activity to which top athletes are exposed brings with it changes in the cardiovascular system. The methodological procedure has included a review of previous research through the Google Scholar, PubMed, Scopus and Web of Science search engines over the past twenty years. Athletes who have played endurance sports have lower blood pressure values compared to athletes who have played strength sports, as well as compared to the non-athlete population. Athletes who have been involved in strength sports have more pronounced left ventricular values. As a general conclusion, it can be pointed out that intense physical activity contributes to changes in the cardiovascular system, but further monitoring of the athlete's condition is needed after a professional career, in order to obtain even clearer results, because sport is performed at an extremely intensive level, higher than 50-60 years ago.*
Keywords: *professional sports, cardiovascular system, sports impact.*

Introduction

Athletes are exposed to enormous physiological and psychological efforts during the training process. A very important, if not key aspect that determines cardiovascular adaptation, is the load (intensity, volume, but also the type of sport, the presence of strength and endurance training) to which the athlete is exposed during his/her professional life. In this regard, moderate-intensity physical activity is recommended for the prevention and treatment of cardiovascular diseases (Khanji et al, 2018). The beneficial effects of physical training are primarily the result of peripheral adaptations. In trained skeletal muscles, the capillary network, the content of oxidative enzymes, the concentration of myoglobin and the number and size of mitochondria increase (De Bacquer, De Backek & Kornitzer, 2000). These changes increase skeletal muscle perfusion and oxygen extraction by up to 20%. Reduced arterial vascular resistance and better redistribution of minute volume also contribute to the beneficial effects of physical training. Training of higher intensity, especially in younger people, leads to central (cardiac) adaptations. Myocardial oxygenation and systolic function are improved during exercise. Limm et al. (2012) indicate great health benefits that increase linearly with the degree of that activity. If only intensive physical activity is observed, it is important to point out the results of the author (Schnohr et al., 2006; Shortreed, Peeters & Forbes, 2013), showing linear relationship with a reduced incidence of cardiovascular disease. This mainly refers to better efficiency of the heart and improvement of endothelial function and metabolic profile (Hoch et al., 2011), as well as a reduced chance of hypertension (O'Keefe et al., 2012). On the other hand, if the skeletal system is observed, physical activity can affect the process of osteoporosis (Meczekalski et al., 2014).

However, intense physical activity can also be seen in a negative context. Study (Joy et al, 2014) points out that intense physical activity with restrictive diets can affect health where low energy intake is associated with amenorrhea and osteoporosis, with possible occurrence of endothelial dysfunction (Joy et al., 2014).

The degree and types of changes in the cardiac system correlate with age, gender of the athlete, as well as the type of sport in which the athlete is engaged (De Innocentiis, 2018). Individual studies (Krol, 2016) indicate the influ-

ence of the type of contraction on the morphological changes of the cardiovascular system, i.e. that in sports where the static component is dominant, enlargement of the left atrium occurs more often.

In endurance sports, some studies (D'Andrea et al., 2010) show a tendency to enlargement of both left and right atria. When it comes to active athletes, some of the most common changes in the cardiovascular system caused by sports are sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm (Dresner, 2013; Pagourelias et al., 2013), in other words, training in younger athletes leads to morphological changes in the heart (Ruegsegger & Booth, 2017).

Professional sport carries with it far greater physiological demands due to the ultimate motive that clearly draws the line between amateurism and professionalism. Accordingly, it is assumed that the morphological changes of the cardiovascular system in retired athletes are indispensable. The aim of this paper is to critically review and analyze studies dealing with mentioned cardiovascular changes in former athletes.

Method

The methodological procedure included the grouping of primary and secondary sources, domestic and foreign scientific literature, professional papers and electronic journals. The search for relevant scientific studies involved the use of primarily Internet databases *Kobson, Web of Science, Google Scholar and Pubmed.* Journals in the field of sports sciences and sports medicine were searched. Internet domain searches were limited to studies conducted in the last 25 years, and the following keywords were used: changes, cardiovascular system, former athletes, effects, consequences.

Table 1. *Cardiovascular changes in former professional athletes and non-athletes*

Author	Monitoring of the cardiovascular system	Respondents	Endurance sports	Strength sports	Control group
Mengelkochet al. (1997)	blood pressure	N=30	123/79		144/82
	resting electrocardiogram (ECG)		No abnormality detected		No abnormality detected
	total serum cholesterol (mg/dl)		187.5±29.9		149±.7±70
	plasma glucose (mg/dl)		102.2±5.3		103.5±2.1
Pluim et al. (2000)	Left ventricular mass (g)	N=1451	237.36	247.15	177.75
Stuhr, Gerdts&Nordrehaug (2000)	The thickness of the anterior and posterior wall of the left ventricle	N=20 former divers N=20 non-athlete respondents	/	No difference were observed compared to the control group	Diastolic functional parameters were the same as in divers
Hernelahti et al. (2002)	Hypertension	N=69 former athletes N=319 non-athletes	Lowest frequency of hypertension in the 10-year follow-up period (23.6%)	Incidence of hypertension in 10-year follow-up - 33%	Incidence of hypertension in the population - 32%
Parssinen& Seppala (2002)	Ischemic heart disease, hypertension	/	Lower risk of ischemic heart disease	Lower risk of ischemic heart disease, higher obesity in later life	The higher the risk of developing ischemic heart disease, the higher the frequency of hypertension

Hagmar et al. (2006)	Echocardiographic results	N=20 former professional female athletes, 10 medal winners (17 runners, 1 swimmer and 1 cross country competitor) 56±3.5 years and 19 female non-athletes	Larger diameter of the left ventricle (2.9±0.3 cm/m^2)		Smaller diameter of the left ventricle (2.6±0.2 cm/m^2)
Lynch et al. (2007)	Cholesterol levels (mM)	N=16 professional footballers N=16	LDL=3.10±0.48 HDL=1.30±0.23 HDL$_2$=0.21±12		LDL=3.04±0.61 HDL=0.95±0.19 HDL$_2$=0.05±0.04
Luthi et al. (2007)	Systolic velocity of mitral and tricuspid annulus	134 Swiss cyclists	Reduced		Enlarged
Johansson et al (2015)	Hypertension (%)	N=49 endurance-type athletes N=50 strength-type athletes N=49 control group	22	/	18
	Age		74.9±5.3	73.7±5.0	74.2±5.0
	BMI (kg/m^2)		24.8±3.4	27.6±3.8	25.9±3.4
	Diabetics (%)		6.1	6	14.3
	High blood pressure (%)		57.1	72	79.6
	Heart rate (freq./min)		66.3±10.8	63.8±10.2	65.6±11.4
	Left ventricular mass (g/m)		128.6±28	137.3±56.3	128.4±31.3
	Carotids (mm)		0.93±0.18	0.97±0.97	0.91±0.17
	Level of physical activity obtained by MET min.		20.4±16.4	15.2±12.5	9.9±9.3
Laine et al (2014)	Type 2 diabetes	N=392 former athletes N=207 non-athletes	Lower risk of diabetes	Lower risk of glucose tolerance	Higher incidence of type 2 diabetes
Laine et al (2015)	Hypertension	N=3434, 2037 former professional male athletes	Lowest blood pressure	With drugs lower value than in the control group	The highest values of blood pressure with the use of drugs
Sanchis-Gomar et al. (2016)	Indexed left ventricular mass in relation to the body surface (g/m^2)	N=53 former athletes, 42 cyclists, 11 runners N=33 control group of non-athletes	115.2±23.1 87±9	/	94.8±21 88±7
Åsmul et al. (2017)	Incidence of angina pectoris	N=768 former divers		Increased incidence of cardiovascular disease	
Zadvorev et al. (2018)	Hemodynamic changes	N=155 endurance-type athletes N=102 non-athletes	Higher frequency of hemodynamically significant asystolic pauses		Lower frequency of permanent pacemakers

Kim et al. (2019)	Systolic pressure, left ventricular thickness	N=126 American football players	Left ventricular hypertrophy, increased systolic blood pressure	/	/
Ermolao et al. (2019)	Condition of the cardiovascular system	N=525 respondents	/	/	Over 100 cardiovascular changes, arterial hypertension, complex arrhythmia were detected
Melekoğlu et al. (2019)	Condition of the cardiovascular system	N=60 former professional footballers	12 respondents have intraventricular conduction arrest		Poorer lipid composition results, LDL elevated
Moris et al. (2019)	Cardiometabolic disease	N=3745 former American football players	1/4 reported post-career cardiovascular problems	/	/

Discussion

The aim of the study was to analyze changes in the cardiovascular system (CVS) in former athletes. Based on the results of the research, changes in the cardiovascular system can be expected after retirement of professional athletes. In most of the analyzed studies, the changes were characterized as positive, especially in endurance sports. Former athletes who were exposed to training activities where the dominant component of endurance was a priority were less likely to develop hypertension (Johansson et al., 2015; Laine et al., 2014). Studies (Fogelholm, Caprio & Sarna, 1994; Parssinen& Seppala, 2002), although not included in the table, indicate the positive effects of intense exercise on the cardiovascular system. Given the fact that intense physical activity has a positive effect on CVS, the study (Garatechea, 2014) showed that athletes have a longer life expectancy compared to the standard population. Also, the same study shows the importance of intensive physical activity in the prevention of CV diseases. Although in a slightly smaller sample, study (Teramoto, 2010) highlights the impact of intense physical activity on the mortality rate.

Sanchis-Gomar et al. (2016) indicate morphological changes in muscle structure where endurance as a motor ability was dominant during a sports career. Long-term training efforts that are sometimes of very high intensity, primarily endurance sports (cycling), can affect the difference in the indexed left ventricular mass in relation to body surface area (g/m^2). Study (Prakken et al., 2011) indicates the influence of highly demanding training activities on the larger cross-section of the heart cavities compared to non-athletes. Changes in the heart muscle after sports career in American football players were related to fatal outcomes, i.e. myocardial infarction (Lincoln, 2018).

Changes in the heart muscle, which were later fatal for former American football players, were the main causes of myocardial infarction and deaths (Lincoln isar., 2018). After retirement, top athletes continued to engage in recreational sports, more than respondents who did not engage in professional sports during their lifetime (Laine et al., 2013). One such study was also Laine et al. (2015) which indicated that the former career of an elite-top athlete may be associated with a lower prevalence of hypertension in later life (these were athletes who were engaged in endurance-type, general strength-type and mixed sports). The amount of current physical activity and free time was inversely proportional to the prevalence (frequency) of hypertension in later life.

Zadvorev et al. (2018) observed the frequency of cardiac arrhythmias and blood flow conduction in professional athletes after the end of their careers and compared them with the standard population. The results indicated that the group of former athletes had a higher frequency of hemodynamically significant asystolic pauses ($p=0.044$), SA node blocks ($p=0.02$) and required the implantation of permanent pacemakers. The same study indicates a higher frequency of arrhythmias in athletes who have had longer careers in high-load sports as well as the association of cardiac muscle hypertrophy with the length of sports career (Zadvorev et al., 2018). Åsmul et al. (2017) on the sample of divers found a higher incidence of high blood pressure, i.e. they came to the conclusion that professional diving can have negative consequences for the cardiovascular system, while on the other hand when it comes to the general frequency of health problems Morris et al. (2019) found in a large sample that 27% of former American football players showed higher frequency than the regular population.

Based on the presented research results, it can be assumed that in the future, after a sports career, professional athletes will have positive attitudes about life, which will stem from sports habits, but also positive changes in the cardiovascular system. The changes and habits acquired through the engagement in sports will provide them with a healthier continuation of life and may provide them with a longer life if they adhere to all the recommendations received from experts. It is essential to undergo regular medical examinations, wellness exams in adequate health care institutions and monitor health condition. Of course, it can be seen from the results of research that there are certain changes in the cardiovascular system that have left negative consequences in the form of the need for greater interventions on the heart, the introduction of pacemakers (Ermolao et al., 2019). But the changes are partly individual or hereditary, so in further research of this type, the anamnesis of the athlete and genetic preconditions should be analyzed in more detail and taken into account.

It would be good to increase the number of studies that can follow former athletes in later life, a longitudinal study, which would include several factors that can affect the state of this system in later life. Cardiovascular screening of former professional athletes also has a number of objective difficulties. History taking and physical examination have little specificity for detecting diseases of the cardiovascular system that can lead to sudden death caused by a heart attack, or they can cause ventricular tachyarrhythmia, coronary artery abnormalities, and coronary heart disease that generally have a negative physical result.

Conclusion

Professional sports definitely have negative aspects related to changes in the cardiovascular system. A large number of studies indicate the benefits of long-term engagement in sports, but it should be emphasized that sports where strength and endurance are key components can lead to consequences for the cardiovascular system after the end of a sports career. These consequences are mostly related to the left ventricular hypertrophy, as well as to various types of arrhythmias. The recommendation for further research includes the observations related to the correlation of training volume and changes in the cardiovascular system, as well as the connection between early involvement in professional sports and the mentioned changes. It can be assumed that professional sports will at some point affect cardiovascular changes in later life, but one should keep in mind the way and lifestyle as well as the social environment in which the person (former athlete) will continue to live and work. All of these factors can affect the condition and lifespan of former athletes and the condition of the cardiovascular system.

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