

PROGNOSTIC VALUE OF MITRAL VALVE PROLAPSE AND MILD MITRAL REGURGITATION IN COMPETITIVE ATHLETES

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ПРОГНОСТИЧНА СТОЙНОСТ НА МИТРАЛНИЯ КЛАПЕН ПРОЛАПС И ЛЕКОСТЕПЕННАТА МИТРАЛНА РЕГУРГИТАЦИЯ ПРИ СЪСТЕЗАТЕЛНИ СПОРТИСТИ

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Abstract. Mitral valve prolapse (MVP) and mild mitral regurgitation (MR) are ones of the most common structural changes of the heart and affect many young individuals, who aspire to partake in competitive sport or high intensity recreational exercise. These two conditions are associated with a different prognosis and possible complications such as heart failure (HF), malignant arrhythmias and sudden cardiac death (SCD). Therefore it is essential to determine the risk factors predicting these complications and to define a follow-up algorithm. The objective is to present a literature review of consensus recommendations addressing criteria for eligibility and disqualification from organized competitive sports for the purpose of ensuring the health and safety of young athletes.

Key words: competitive sports, eligibility, mild mitral regurgitation, mitral valve prolapse

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Резюме. Митралният клапен пролапс (МКП) и лекостепенната митрална регургитация са едни от най-често срещаните структурни промени на сърцето и засягат много млади хора, които желаят да участват в състезателни спортове с висока физическа натовареност. Тези две състояния се свързват с различна прогноза и възможни усложнения като сърдечна недостатъчност (СН), малигнени аритмии и внезапна сърдечна смърт (ВСС). Затова е важно да се определят рисковите фактори, които предсказват появата на тези усложнения, както и да се определи алгоритъм за проследяване. Целта е да се представи литературен обзор на консенсусни препоръки относно критерии за допускане до организирани състезателни спортове, с което да се осигури здравето и безопасността на младите атлети.

Ключови думи: състезателни спортове, допускане, лекостепенна митрална регургитация, митрален клапен

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INTRODUCTION

According to the 3 Bethesda Conferences {16 (1985), 26 (1994), and 36 (2005)}, that addressed eligibility and disqualification criteria for competitive athletes with cardiovascular diseases, all sponsored by the American College of Cardiology (ACC) [1-3], the basic definition of a competitive athlete is the following: One who participates in an organized team or individual sport that requires regular competition against others as a central component, places a high premium on

excellence and achievement, and requires some form of systematic (and usually intense) training. Therefore, organized competitive sports are regarded as a distinctive activity and lifestyle [4].

MVP occurs sporadic in most cases. However, it can also be hereditary – an autosomal-dominant disorder with incomplete penetrance and variable expression. Familial clusters have been reported in several studies [5]. It has two distinct phenotypes – fibroelastic deficiency (FED) and myxomatous MVP, also known as Barlow's disease [6]. Mitral valve with FED is char-

acterized by leaflets thinning, which is thought to be due to impaired production of connective tissue, with deficiency of collagen, elastin, and proteoglycans. It is the most common form of MVP [6]. Barlow's disease is characterized by fibro-myxomatous changes of the mitral valve leaflets. Myxomatous transformation concerns disruption and loss of normal valvular architecture with thickening of the spongiosa and accumulation of proteoglycans in it. The thickened spongiosa encroaches on the fibrosa, interrupting it focally and causing a basic weakness of this supporting structure, leading to redundancy, chordal elongation, prolapse and annular dilatation [7, 8]. The diagnosis MVP is defined as > 2 mm displacement of one or both leaflets of the mitral valve beyond the annulus within the left atrium in end-systole [9]. In classic MVP the maximal leaflet thickness is at least 5 mm during diastasis, and in non-classic MVP the maximal thickness is less than 5 mm [10].

MVP is the most important cause of primary MR (degenerative mitral valve disease). Other common causes are rheumatic heart disease, infective endocarditis, and connective tissue diseases (such as Marfan or Ehlers-Danlos syndrome). Secondary forms of MR can develop in patients with coronary artery disease and dilated cardiomyopathy [4].

According to the Johns Hopkins Institute MVP is a common disorder, affecting 2-3% of the general population or around 176 million individuals worldwide [11]. The European Registry of mitral regurgitation (EuMiClip) in 2018 shows that mild MR is present in 28.5% of 63,463 patients studied in Europe [12]. Because of the wide prevalence of these conditions and possible complications such as HF, malignant arrhythmias and SCD, we present a literature review of possible risk factors and recommendations relating to criteria for eligibility in competitive sports of young athletes with MVP or mild MR.

COMPLICATIONS OF MVP AND MILD MR

Both MVP and mild MR are considered benign conditions. However, they can have some serious cardiac complications. MVP can most commonly lead to chronic severe MR and HF in 5-10% of individuals with MVP. Other complications include pulmonary hypertension, infective endocarditis, supraventricular and ventricular arrhythmias (VAs), SCD, cerebrovascular accidents like transient ischemic attacks and ischemic strokes [9]. Mild MR can progress in time to severe MR and cause atrial enlargement, onset of atrial fibrillation (AF), increase of left ventricle (LV) -end diastolic pressure, LV-dilatation, impaired LV function with preserved or reduced ejection fraction (EF), pulmonary hypertension and HF. There are several studies that evaluate the natural history and clinical outcome of MVP and mild MR.

Their conclusions consider that individuals with MVP and trace or mild MR with normal LV sizes and volumes and preserved LV function do not have more frequently complications than people without MVP and mild MR. Therefore after appropriate evaluation of the cardiac status of young athletes with MVP with or without mild MR they can participate in competitive sports. According to the current recommendations of the European Society of Cardiology (ESC), all individuals should be assessed with a clinical history, physical examination, electrocardiography (ECG), echocardiography, and exercise stress test [9].

The Framingham Heart Study was established in 1948 as a prospective epidemiologic investigation of a large cohort of men and women. The fifth examination of the offspring cohort of the Framingham Heart Study (from January 1991 to January 1995) studied the prevalence of MVP in the general population and its complications. 1845 women and 1646 men (mean [\pm SD] age, 54.7 \pm 10.0 years) were examined. The authors used current two-dimensional echocardiographic criteria based on the three-dimensional shape of the annulus and clinical correlations to diagnose MVP according to the maximal superior displacement of the mitral leaflets during systole relative to the line connecting the annular-hinge points. A total of 84 subjects (2.4%) had MVP: 47 (1.3%) had classic prolapse and 37 (1.1%) had non-classic prolapse. Their age and sex distributions were similar to those of the subjects without prolapse. None of the subjects with prolapse had a history of HF, one (1.2%) had AF, one (1.2%) had cerebrovascular disease, and three (3.6%) had syncope, as compared with these findings in the subjects without prolapse of 0.7%, 1.7%, 1.5%, and 3.0%, respectively. The frequencies of chest pain, dyspnea, and ECG-abnormalities were similar among subjects with prolapse and those without prolapse. ECG-variables assessed included the presence of atrial and ventricular ectopy, left atrial (LA) enlargement (defined as a terminal P-wave force of 1 mm by 1 mm in lead V1), and LV hypertrophy (defined by the presence of increased voltage with a pattern indicating strain). The subjects with prolapse had a greater degree of MR than those without prolapse, but on average the regurgitation was classified as trace or mild.

In conclusion, the fifth examination of the offspring cohort of the Framingham Heart Study found that the rates of complications such as HF, AF, cerebrovascular disease, and syncope were no higher among subjects with MVP than among those without prolapse. In this study there were relatively low sensitivity of clicks and murmurs for prolapse and absence of a significant difference in the prevalence of ventricular ectopy between those with prolapse and those without prolapse. This shows the relatively mild nature of prolapse in the

general population. The clinical profile of subjects with MVP was more benign than previously indicated by the available literature [10].

Duren et al. found complications such as the need for mitral-valve surgery, stroke, infectious endocarditis, and SCD in one third of patients with mitral-valve prolapse (100 of 300) who were followed for an average of 6.1 years, with an average complication rate of 5.4% per year [13]. Marks et al. reported complications in 27% of patients with classic MVP (86 of 319) [14].

Jeresaty RM investigates MVP and its complications among children, adolescents, and athletes [7]. In his study the author points out that prognosis in MVP is generally favorable [15, 16], particularly in children [17, 18]. Bisset et al. studied 119 children and adolescents for a mean follow-up period of 6 to 9 years. No progression of MR was observed and there were no sudden deaths. One patient developed infective endocarditis and one had a cerebrovascular accident [18]. Furthermore, in his study Jeresaty RM reports only 60 cases of SCD, of which only five were 20 years or younger (age 9, 14, 17, 19 and 20, respectively). Two children not included in this sudden death series developed VA and cardiac arrest and were successfully resuscitated [19]. The author reports only one case of SCD in a trained competitive athlete during physical activity [20]. Jeresaty RM suggests a diagnostic work-up of athletes with MVP including ECG (performed to determine the presence of repolarization changes that may be associated with complex arrhythmias), Holter monitoring and stress testing (especially in the presence of symptoms such as palpitation, dizziness, near-syncope, or syncope). He emphasizes that observation of the athlete during exercise is invaluable for adequate clinical assessment and sound recommendations [7].

Bonow et al. make a scientific statement from the American Heart Association (AHA) and ACC. They investigate the myxomatous mitral valve disease as the most common cause for primary MR and point out that the severer the MR is, the greater the regurgitant volume is. This results in LV dilation and increases LA pressure and volume. The increased LV diastolic volume enhances total LV stroke volume enough to accommodate the regurgitant volume and to maintain the forward stroke volume within normal limits. The low impedance presented by regurgitation into the LA unloads the LV during ventricular systole, such that measures of LV pump function, such as EF, tend to overestimate true myocardial performance. Therefore, LV systolic dysfunction in subjects with MR is defined as LVEF < 60% or LV end-systolic dimension (LVESD) > 40 mm. LV end-diastolic dimension (LVEDD) measurements > 60 mm strongly suggest the presence of severe MR. The authors suggest that athletes with MR should undergo yearly physical examinations, echo-

cardiography, including Doppler-echocardiograms and measurement of the systolic pulmonary artery pressure (sPAP), and exercise stress testing to at least the level of activity that approximates the exercise demands of the sport. They recommend that athletes with mild to moderate MR who are in sinus rhythm with normal LV size and function and with normal PAP can participate in all competitive sports [4].

The current recommendations of the ESC are very much alike these of the AHA and ACC. They suggest that asymptomatic individuals with mild or moderate MR may compete in all sports if they have good functional capacity, preserved LV function, sPAP < 50 mmHg and absence of complex arrhythmias during exercise [9]. As regards to recommendations addressing criteria for eligibility in competitive sports in case of MVP, the ESC as well as several studies point out some specific risk factors for SCD that have to be evaluated before giving permission for participating in high intensive physical activities.

RISK FACTORS FOR SCD IN MVP

Although MVP is considered a benign condition, the most serious and examined in many studies complication is SCD. There are several risk factors that suggest such an unfortunate outcome in people with MVP. These are myocardial scarring, myocardial fibrosis affecting the infero-basal wall, mitral valve annular disjunction (MAD), T-wave inversion in the inferior leads, prolongation of the QT interval, VAs arising from the LV [right bundle branch block (RBBB) morphology], prolapse of both mitral leaflets, severe MR, severe LV-dysfunction, family history of SCD.

Sriram et al. investigated in their study the prevalence of MVP and its association with VAs in a cohort with “unexplained” out-of-hospital SCD. The authors evaluated 24 patients (16 women, median age 33.5 years) between July 2000 and December 2009 in the Mayo Clinic’s Long QT Syndrome/Genetic Heart Rhythm Clinic with SCD that was negative for ischemia, cardiomyopathy, and channelopathy. Bileaflet MVP was found in 10 (42%). Compared with patients with normal mitral valves, patients with bileaflet MVP: 1) were mostly women (9 of 10 [90%] vs. 7 of 14 [50%]); 2) had a higher prevalence of biphasic or inverted T waves (7 of 9 [77.8%] vs. 4 of 14 [29%]); and 3) on Holter monitoring had higher prevalence of ventricular bigeminy (9 of 9 [100%] vs. 1 of 10 [10%]), ventricular tachycardia (VT) (7 of 9 [78%] vs. 1 of 10 [10%]), and ventricular premature beats (VPBs) originating from the outflow tract alternating with the papillary muscles (PMs) or fascicular region (7 of 9 [78%] vs. 2 of 10 [20%]). This study describes a “malignant” phenotype of MVP that supposes a higher risk of SCD.

It is characterized by bileaflet MVP, female sex, and frequent complex ventricular ectopic activity [21].

Basso et al. researched VAs and SCD in individuals with MVP in the absence of hemodynamic impairment. They investigated two different groups. The first group consisted of 650 young adults (≤ 40 years of age) with SCD in the Veneto region in northeast Italy in the time interval from 1982 to December 2013. Cases with MVP as the only cause of SCD were re-examined. Forty-three patients with MVP (26 females; age range, 19-40 years; median, 32 years) were identified. They represent 7% of all SCD patients and 13% of women who died suddenly. Among 12 cases with available ECG, 10 (83%) had inverted T waves on inferior leads, and all (100%) had RBBB VAs. A bileaflet involvement was found in 70%. Microscopic examination of the LV myocardium showed an increased endoperimysial and patchy replacement-type fibrosis at the level of PMs and adjacent free wall in all (100%). Similar findings were detected in the inferobasal wall under the posterior mitral valve leaflet in 38 patients (88%). The second group that was examined consisted of 30 consecutive patients referred to the Cardiology Clinic from January 2010 to December 2013 with complex VAs detected on 12-lead 24-hour Holter monitoring and echocardiographic diagnosis of MVP. VT of an LV origin (RBBB morphology), either nonsustained ($n = 29$) or sustained ($n = 1$), was present in all. All patients had normal QTc (mean ms, 423; range, 409-440). Exercise stress test, performed in 20 patients, was negative for effort-induced VAs. Bileaflet MVP was present in 21 patients (70%) with complex VAs. These 30 living patients with MVP with complex VAs and another 14 control subjects with MVP without complex VAs underwent a study protocol including contrast-enhanced cardiac magnetic resonance (CE-CMR). LV late gadolinium enhancement (LGE) was identified in 93% of patients versus 14% of control subjects, with a regional distribution overlapping the histopathology findings in the SCD cases. The LGE was localized on the PMs in 25 patients (83%), with a midapical distribution in 16 and basal adjacent free wall in 24 cases, and on the LV inferobasal segment under the posterior leaflet in 22 (73%). The LV myocardial scarring is qualitatively different from that observed in ischemic heart disease, where it is usually compact and confluent, instead being patchy and interspersed within surviving, hypertrophic cardiomyocytes. The authors demonstrate that CE-CMR can detect LV LGE in patients with MVP with complex VAs, closely overlapping the histopathological features observed in SCD victims. The arrhythmogenic role of the LV myocardial scarring is supported by the morphology of arrhythmias and by electrophysiological studies in MVP indicating that the most common site of VPBs origin is the inferobasal LV wall. The hallmark

of arrhythmic MVP is fibrosis of PMs and inferobasal LV free wall, which correlates well with arrhythmia morphology, pointing to a myocardial stretch by the prolapsing leaflets and elongated chordae. Therefore, according to this study, it is reasonable CE-CMR to be performed in individuals with MVP and ECG depolarization abnormalities on inferolateral leads (inverted T waves), complex VAs (≥ 3 VPB run) with RBBB morphology on 12-lead ECG Holter monitoring, a history of presyncope/syncope and aborted SCD. The authors of the study conclude that a patient with MVP at risk of SCD is usually a young adult woman with a midsystolic click at auscultation, bileaflet involvement of the mitral valve, T-wave abnormalities on inferior leads, and RBBB-type or polymorphic VAs on ECG, without significant regurgitation [8].

Furthermore, Basso et al. research the so-called arrhythmic MVP and its pathophysiologic mechanisms of electrical instability [22]. They discuss these are LV fibrosis in the PMs and inferobasal wall, MAD, and systolic curling, which have been described by pathological and CMR studies. In addition, the authors point out that VPBs arising from the Purkinje tissue as ventricular fibrillation triggers have been documented by electrophysiologic studies in MVP patients with aborted sudden death. They suggest that the genesis of malignant VAs in MVP probably recognizes the combination of the substrate (regional myocardial hypertrophy and fibrosis, Purkinje fibers) and the trigger (mechanical stretch) eliciting VPBs because of a primary morphofunctional abnormality of the mitral valve annulus. MVP-related and MVP-unrelated factors for VAs/SCD in MVP patients, both functional and structural, have been suggested. As MVP-related factors Basso et al. point elongated mitral leaflet, bileaflet MVP, mitral annulus dilatation, MAD, mitral annulus hypermobility/curling, diastolic depolarization of muscle fibers in redundant leaflets, spontaneous chordal rupture, excessive PMs traction by the prolapsing leaflets, mechanical stimulation of the endocardium by elongated chordae, endocardial friction lesions, connective tissue myxoid changes, myocardial ischemia due to platelet/fibrin microembolization, fibromuscular dysplasia of small coronary arteries, LV fibrosis at the level of PMs/postero-basal wall, LV remodeling due to mitral regurgitation with volume overload and QT dispersion. As MVP-unrelated factors they point autonomic nervous system dysfunction, conduction system abnormalities, long QT, cardiomyopathy and Purkinje fibers ectopy foci.

MAD is a structural abnormality of the mitral annulus and is defined as a spatial displacement between the LA wall, the attachment of the mitral leaflets, and the top of the LV free wall, manifested as a wide separation between the atrial wall-mitral valve junction and the top of the LV free wall [23, 24]. The mitral annu-

lus position is best recognized in the long axis view by transthoracic echocardiography zoomed on the mitral valve using the highest frame rate possible and by reviewing the images frame by frame. In this way, the thin structure of the annulus can be observed from early to late systole. In turn, the precise location of the mitral annular position allows measurement of the MAD trench width and of MVP depth. Accordingly, the upper limit of MAD is defined at the level of posterior leaflet insertion on the annulus/left-atrial-wall, whereas the lower limit is defined at the level of the LV myocardium. Without dynamic examination, excessive posterior leaflet tissue arising from a normally implanted annulus could falsely be interpreted as MAD. Such dynamic analysis is required both on echocardiographic and CMR examinations [25].

In the 2000s Erikson et al. [23] and Carmo et al. [24] found an increased frequency of VPBs and non-sustained VT (NSVT) in patients with MAD in comparison to those without MAD. Carmo et al. evaluated 38 patients with MVP. MAD was present in 21 patients (55%) and was more common in women (61%). The authors found out that the severity of MAD significantly correlated with the occurrence of NSVT on Holter monitoring: MAD > 8.5 mm was a strong predictor for NSVT. In these patients the mitral annular diameter was larger in systole than in diastole. This results in an increased diameter of the mitral valve circumference during systole, and hence impaired annular function due to coaptation deficit [24].

Basso et al. provided evidence that MAD is associated with arrhythmic MVP [22]. They found out that in MVP patients with arrhythmias and LGE MAD was more pronounced. The end-systolic and end-diastolic mitral annular diameters were larger than in those without arrhythmias and LGE. At the same time, histological analysis revealed a longer MAD in 50 SCD cases with MVP and LV fibrosis as compared with that in control hearts.

Furthermore, in 1976, Gilbert et al. provided the first echocardiographic demonstration of a peculiar functional abnormality of the mitral annulus in MVP patients (i.e. an unusual systolic curling of the posterior mitral annulus on the adjacent myocardium, such that the systolic movement of the annulus was primarily downward with little, if any, anterior motion, thereby resulting in a curled appearance when visualized in real-time motion) [27]. Basso et al. explored this aspect in series of arrhythmic MVP patients. They demonstrated that the curling of the mitral annulus is typically associated with MAD and leads to annular hypermobility [22]. According to the authors' morphofunctional data, the arrhythmic MVP is characterized by MAD, systolic curling, and myxomatous leaflet thickening. Therefore, they suggest a cascade of events, starting with mor-

phofunctional abnormalities of the mitral annulus (the Padua hypothesis): MAD and systolic curling motion are the basis for the paradoxical increase in annulus diameter during systole, progressive myxomatous degeneration of the leaflets, and myocardial stretch in the LV inferobasal segment and PMs (Table 1). The genesis of malignant arrhythmias in MVP probably recognizes the combination of the substrate (myocardial fibrosis) and the trigger (mechanical stretch) eliciting VPBs. The mid-systolic click or late systolic murmur in patients with MVP is the result of an abrupt tension in the mitral leaflet caused by the abnormal posterior leaflet systolic curling attributable to MAD. Thus, patients with MVP and mid-systolic click more frequently have stress-induced inferobasal lesions [26].

Table 1. The Padua hypothesis: Pathophysiology of ventricular arrhythmias in MVP patients: the combination of mechanical trigger and abnormal substrate

Mitral annular disjunction (MAD)		
Systolic "curling" motion		
Abnormal mitral leaflet traction ("click")		
Regional LV myocardial stretch/friction (postero-basal and papillary muscles)		Mitral valve myxomatous degeneration
Hypertrophy and fibrosis	Purkinje fibers/ectopy foci	Mitral valve incompetence with LV remodeling
Malignant ventricular arrhythmias		

Based on all those findings, Basso et al. suggest a risk stratification algorithm. In patients with MVP and risk factors such as female sex, presyncope/syncope, mid-systolic click, T-wave inversion in infero-basal leads, QT prolongation, VAs with RBBB morphology, MAD, systolic curling should be performed CE-CMR for detecting myocardial scarring and fibrosis and electrophysiological study for detecting any possible source of arrhythmias [22, 26]. This algorithm should be applied when assessing young athletes with MVP and giving permission for participating in competitive sports. Basso et al. comment that it has recently been demonstrated that only a small proportion of competitive athletes with MVP develop adverse cardiovascular events (0.5% per year) [28]. The worst prognosis was reported in those who had both regurgitation and VAs, suggesting a cautious restriction of competitive sports. However, when MVP is isolated, the prognosis is excellent, and no exercise or sport restriction is required. Noteworthy, SCD in MVP patients usually occurs while at rest or during sleep [22].

Caselli et al. researched the prevalence and long-term outcome of MVP in a large cohort of competitive athletes, consecutively evaluated from 2000 to 2010. Of 7449 athletes, MVP was found in 215 (2.9%). Six-

ty-two of them (29%) had evidence of VAs. The research shows that athletes with MVP and VAs had higher systolic blood pressure (BP), larger LV size (29 ± 2 versus 28 ± 2 mm/m²), LV mass (99 ± 25 versus 90 ± 22 g/m²), and LA size (36 ± 5 versus 34 ± 5 mm) in comparison with those without VAs. LV function was not different and within normal limits in all. MAD was more frequent (16% versus 3%) in MVP athletes with VAs. Complete follow-up data were available in 188 athletes (87%). Over 8 ± 2 years, the authors recorded 8 clinical events (0.5%/y), no SCD occurred. Athletes with events were more frequently male ($n = 8$) and older (40 ± 5 versus 31 ± 14 years) with higher systolic BP (130 ± 4 versus 121 ± 11 mmHg) in comparison with those without events. All of them had VAs on baseline evaluation. Echocardiography showed larger LV size (30 ± 2 versus 28 ± 2 mm/m²) and mass (127 ± 22 versus 91 ± 22 g/m²), LA size (41 ± 6 versus 34 ± 5 mm), and higher sPAP (26 ± 5 versus 21 ± 5 mm Hg) in those with events. The study shows that MVP usually carries a benign prognosis; however, a small proportion of 0.5%/y may incur adverse cardiovascular events. The worst prognosis was reported in athletes that had MVP associated with both MR and VAs, which suggests a cautious restriction from competitive sports. In addition, MAD, higher systolic BP, and larger LV and LA size could be considered additional prognostic markers. Conversely, when MVP is isolated, the prognosis is excellent, and therefore, no sport restrictions should be applied [28].

CONCLUSIONS

This literature review of consensus recommendations shows that mild MR and MVP are usually benign conditions. However, young athletes should be thoroughly evaluated before participating in competitive sports because of the possible cardiac complications that these conditions might cause. All individuals should be assessed with a clinical history, physical examination, ECG, echocardiography, and exercise stress test.

As regards to MR, the numerous studies suggest that asymptomatic individuals with mild or moderate MR may compete in all sports if they have good functional capacity, preserved LV function, sPAP < 50 mmHg and absence of complex arrhythmias during exercise.

Young athletes with MVP should be also assessed with a clinical history, physical examination, ECG, echocardiography, exercise stress test and additionally 24h Holter ECG monitoring. Studies point out SCD as the most serious complication and outline several high-risk markers that should be taken into consideration. These are T-wave inversion in the inferior leads, prolongation of the QT interval, VAs arising from the LV

[RBBB morphology], bileaflet prolapse, MAD and systolic curling. In patients with MVP who have risk factors for SCD CE-CMR should be performed for detecting myocardial scarring and fibrosis of the infero-basal wall as well as electrophysiological study for detecting any possible source of arrhythmias (Table 2). Recent recommendations suggest that asymptomatic individuals with MVP with mild MR and absence of risk factors for SCD can participate in all kinds of competitive sports.

Table 2. Follow-up algorithm for examination and evaluation of athletes with MVP

Patient	Examination	Risk factors for SCD	Further examination
MVP	Clinical history	Presyncope/syncope	CE-CMR for detecting myocardial scarring and fibrosis / electrophysiological study for detecting a possible source of arrhythmias
		Aborted SCD	
	Physical examination	Mid-systolic click	
	ECG	Inverted T waves in the inferior leads	
		Prolongation of QT interval	
	Echocardiography	Bileaflet prolapse	
		MAD	
Systolic curling			
12 leads 24-hour Holter ECG monitoring	VAs arising from LV (RBBB morphology)		

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References

1. Nishimura RA, Otto CM, Bonow RO et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation*, 2014;129:e521-e643.
2. Siu SC, Silversides CK. Bicuspid aortic valve disease. *J Am Coll Cardiol*, 2010;55:2789-2800.
3. Maron BJ. Sudden death in young athletes. *N Engl J Med*. 2003;349:1064-1075.
4. Bonow RO, Nishimura RA, Thompson PD et al. Eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities: Task Force 5: Valvular Heart Disease. A scientific statement from the American Heart Association and American College of Cardiology. *Circulation*, 2015; 132:e292-e297.
5. Delling FN, Rong J, Larson MG et al. Familial Clustering of Mitral Valve Prolapse in the Community. *Circulation* 2015;131:263-268.
6. Van Wijngaarden AL, Kruihof BPT, Vinella T et al. Characterization of Degenerative Mitral Valve Disease: Differences between Fibroelastic Deficiency and Barlow's Disease. *J Cardiovasc Dev Dis*, 2021 Feb 22;8(2):23. doi: 10.3390/jcdd8020023.
7. Jeresaty RM. Mitral valve prolapse: definition and implications in athletes. *J Am Coll Cardiol*, 1986;7:231-236.

8. Basso C, Perazzolo Marra M, Rizzo S et al. Arrhythmic mitral valve prolapse and sudden cardiac death. *Circulation* 2015;132:556-566.
9. Pelliccia A, Sharma S, Gati S et al. 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease. The Task Force on sports cardiology and exercise in patients with cardiovascular disease of the European Society of Cardiology (ESC). *Eur Heart J*, 2021;42:17-96.
10. Freed LA, Levy D, Levine RA et al. Prevalence and clinical outcome of mitral-valve prolapse. *N Engl J Med* 1999;341:1-7.
11. Delling FN, Vasan RS. Epidemiology and pathophysiology of mitral valve prolapse: new insights into disease progression, genetics, and molecular basis. *Circulation*, 2014; 129: 2158-2170.
12. Ruiz JMM, Galderisi M, Buonauro A et al. Overview of mitral regurgitation in Europe: results from the European Registry of mitral regurgitation (EuMiClip). *European Heart Journal - Cardiovascular Imaging*, 2018, 19,5:503-507.
13. Duren DR, Becker AE, Dunning AJ. Long-term follow-up of idiopathic mitral valve prolapse in 300 patients: a prospective study. *J Am Coll Cardiol*, 1988;11:42-47.
14. Marks AR, Choong CY, Sanfilippo AJ et al. Identification of high-risk and low-risk subgroups of patients with mitral-valve prolapse. *N Engl J Med*, 1989;320:1031-1036.
15. Jeresaty RM. *Mitral Valve Prolapse*. New York: Raven Press, 1979;4.19.38;45.76,187
16. Barlow JB, Pocock WA. The mitral valve prolapse enigma-two decades later. *Mod Concepts Cardiovasc Dis*, 1984;53:13-7.
17. Cohen M, Pocock WA, Lakier JB et al. Four years follow-up of black school children with nonejection systolic clicks and mitral systolic murmurs. *Am Heart J*, 1978,95:697-701.
18. Bisset GS, Schwartz DC, Meyer RA et al. Clinical spectrum and long-term follow-up of isolated mitral valve prolapse in 119 children. *Circulation*, 1980;62:423-429.
19. Rocchini AP, Chun PO, Dick M. Ventricular tachycardia in children. *Am J Cardiol*, 1981;47:1091-1097.
20. Bharati S, Bauernfeind R, Miller LB et al. Sudden death in three teenagers: conduction system studies. *J Am Coll Cardiol*, 1983;13:879-886.
21. Sriram CS, Syed FF, Ferguson ME et al. Malignant bileaflet mitral valve prolapse syndrome in patients with otherwise idiopathic out-of-hospital cardiac arrest. *J Am Coll Cardiol*, 2013, 62,3:222-230.
22. Basso C, Iliceto S, Thieme G et al. Mitral Valve Prolapse, Ventricular Arrhythmias, and Sudden Death. *Circulation*, 2019 Sep 10;140(11):952-964. doi: 10.1161/CIRCULATIONAHA.
23. Eriksson MJ, Bitkover CY, Omran AS et al. Mitral annular disjunction in advanced myxomatous mitral valve disease: Echocardiographic detection and surgical correction. *J Am Soc Echocardiogr*, 2005; 18:1014-1022.
24. Carmo P, Andrade MJ, Aguiar C et al. Mitral annular disjunction in myxomatous mitral valve disease: a relevant abnormality recognizable by transthoracic echocardiography. *Cardiovasc Ultrasound*. 2010; 8:53.
25. Sabbag A, Essayagh B, Barrera JDR et al. EHRA expert consensus statement on arrhythmic mitral valve prolapse and mitral annular disjunction complex in collaboration with the ESC Council on valvular heart disease and the European Association of Cardiovascular Imaging endorsed cby the Heart Rhythm Society, by the Asia Pacific Heart Rhythm Society, and by the Latin American Heart Rhythm Society. *EP Europace*, December 2022, 24,12:1981-2003.
26. Perazzolo Marra M, Basso C, De Lazzari M et al. Morphofunctional abnormalities of mitral annulus and arrhythmic mitral valve prolapse. *Circ Cardiovasc Imaging*. 2016.
27. Gilbert BW, Schatz RA, VonRamm OT et al. Mitral valve prolapse. Two-dimensional echocardiographic and angiographic correlation. *Circulation*. 1976; 54:716-723.
28. Caselli S, Mango F, Clark J et al. Prevalence and clinical outcome of athletes with mitral valve prolapse. *Circulation*. 2018; 137:2080-2082.