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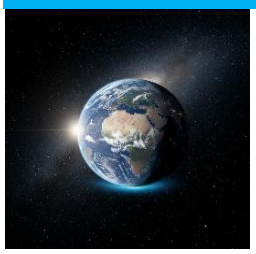

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Physical Activity in Bicuspid Aortic Valve: Balancing Cardiovascular Benefits and Aortic Risk

AUTHORS

Michał Kuryłek, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0005-6013-9682
m.kurylek@outlook.com

Anna Dziegciarczyk, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0008-5233-4826
dziegciarczyk.ania@gmail.com

Kacper Kozdęba, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0008-7920-9400
kacperkzd@gmail.com

Alicja Bala, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0009-9072-2309
alicjab12344@gmail.com

Seweryn Korzeniak, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0007-7084-518X
seweryn23288@gmail.com

Andrzej Dziegciarczyk, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0007-4204-2398
andrzejdzieg@wp.pl

Fabian Krauze, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0003-8128-4147
fabiankruaze11@gmail.com

Michał Chybiorz, Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warsaw, Poland
https://orcid.org/0009-0009-8713-5840
chybiorzmichal@gmail.com

ABSTRACT

Bicuspid aortic valve (BAV) is the most common congenital cardiac malformation and is associated with progressive valvular dysfunction and thoracic aortopathy, including ascending aortic dilation and, less frequently, dissection. As many individuals with BAV are diagnosed in childhood or early adulthood and remain asymptomatic for long periods, questions regarding the safety of physical activity and sports participation are common. Although the cardiovascular benefits of regular exercise are well established, recommendations for patients with BAV are still largely based on expert consensus rather than robust longitudinal evidence.

Available evidence suggests that individuals with BAV engage in lower levels of moderate-to-vigorous physical activity and accumulate fewer daily steps than matched controls, with inactivity increasing alongside disease severity. Psychological uncertainty about safe exercise levels may further limit participation. Importantly, current observational studies do not demonstrate an association between regular physical activity, including high training volumes, and accelerated progression of aortic dilation or valvular dysfunction in adults with uncomplicated BAV.

Similarly, paediatric studies show that participation in regular physical activity or competitive sports is not associated with increased aortic diameters over mid-term follow-up. Current guidelines therefore support individualized risk stratification. In the absence of valvular dysfunction, aortic dilation, ventricular impairment, arrhythmias, or other high-risk features, individuals with BAV may safely participate in physical activity and, in selected cases, competitive sports under structured surveillance.

Overall, available evidence does not support routine physical activity restriction in asymptomatic individuals with uncomplicated BAV. Exercise recommendations should be individualized, and further long-term prospective studies are needed to refine risk stratification.

Keywords:
bicuspid aortic valve; physical activity; exercise; sports cardiology; aortic dilation; valvular heart disease; competitive athletes; aortopathy.

Introduction

Bicuspid aortic valve (BAV) is the most common congenital cardiac defect, with an estimated prevalence of approximately 0.5–2% in the general population and a clear male predominance of roughly 3:1 [1]. It is characterized by the presence of two aortic valve cusps instead of the normal three. Although BAV may initially be compatible with normal valve function and remain clinically silent for many years, it is associated with a range of potential complications that may develop over time [2].

The natural history of BAV includes progressive valvular dysfunction, most commonly aortic regurgitation in younger individuals and aortic stenosis in older patients, often resulting from progressive calcification of the valve [3]. In addition to valvular disease, patients with BAV are at increased risk of infective endocarditis and structural abnormalities of the thoracic aorta, including progressive dilation of the ascending aorta, aneurysm formation, and aortic dissection [4]. Importantly, BAV is increasingly recognized as a condition affecting not only the valve itself but also the aortic wall. Degenerative changes such as elastic fiber fragmentation, smooth muscle cell loss, and accumulation of mucoid extracellular matrix contribute to intrinsic aortic wall weakness and predispose affected individuals to aortopathy. The coexistence of valvular and aortic abnormalities is thought to reflect shared embryological origins, as neural crest cells contribute to the development of both the semilunar valves and the proximal aorta [5,6].

The clinical presentation of BAV is highly heterogeneous and may range from severe disease detected early in life to asymptomatic individuals diagnosed incidentally in adulthood. Despite the potential for significant cardiovascular complications, large contemporary cohort studies suggest that overall life expectancy in adults with BAV is generally comparable to that of the general population [7,8]. Nevertheless, the burden of disease remains substantial, as many patients eventually develop clinically significant valve dysfunction or aortic pathology requiring medical management and, in a considerable proportion of cases, surgical intervention such as aortic valve replacement, frequently combined with repair or replacement of the ascending aorta [9].

Management of BAV primarily focuses on regular clinical and imaging surveillance to monitor the progression of valvular dysfunction and aortic dilation [10]. Transthoracic echocardiography is the cornerstone of diagnosis and follow-up, while advanced imaging

modalities such as computed tomography or magnetic resonance imaging are often used to assess the thoracic aorta in greater detail [11]. Pharmacological treatment is mainly directed toward controlling cardiovascular risk factors and associated conditions, whereas definitive management of severe valvular disease or significant aortopathy typically requires surgical intervention, including valve repair or replacement and, when indicated, surgical treatment of the ascending aorta [12].

Given that many individuals with BAV are diagnosed in childhood or early adulthood and often remain asymptomatic for long periods, questions frequently arise regarding the safety of physical activity and participation in sports. While regular exercise is widely recognized as an important component of cardiovascular health, recommendations for individuals with BAV are not always clear and may vary depending on the presence and severity of valvular dysfunction or aortic dilation. As a result, patients frequently receive inconsistent advice or remain uncertain about safe levels of physical activity, which may lead either to unnecessary restriction of exercise or to participation in potentially unsafe activities. Consequently, clarifying the relationship between BAV and physical activity has become an important topic in contemporary cardiovascular and sports medicine research [13].

Methods

A literature search was conducted to identify scientific publications addressing physical activity, exercise, and sports participation in individuals with bicuspid aortic valve (BAV). The search was performed using combinations of the keywords *"bicuspid aortic valve"*, *"exercise"*, *"physical activity"*, *"sport"*, and *"training"*. No restrictions regarding the year of publication were applied.

The following electronic databases were searched on 5 March 2026: PubMed, Scopus, and Cochrane Library. Only publications available in English were considered.

Titles and abstracts of all retrieved records were screened independently by two reviewers to assess their relevance to the topic. Studies that did not address physical activity, exercise participation, or sports eligibility in individuals with BAV were excluded. Publications without an available abstract were not considered. In addition, the reference lists of all eligible articles were manually screened to identify further relevant studies that may not have been captured in the initial search.

Original research articles, observational studies, reviews, and clinical guideline papers relevant to the relationship between BAV and physical activity were considered for inclusion. Studies focusing exclusively on surgical techniques or postoperative outcomes without addressing exercise or physical activity were excluded.

Following the screening process, the full texts of potentially relevant articles were reviewed by the authors. After this selection procedure, the publications considered most relevant to the topic were included in the final qualitative synthesis.

Results

Physical Activity Patterns in Patients with BAV

Physical activity patterns in adults with bicuspid aortic valve (BAV) have been investigated in a prospective observational study including 100 adults with BAV and 100 age- and sex-matched controls [14]. The mean age of participants was 45 ± 16 years and 59 % were male. Physical activity and sedentary behaviour were objectively assessed using a thigh-worn accelerometer over eight consecutive days, allowing precise quantification of daily movement patterns.

Overall, individuals with BAV demonstrated significantly lower levels of physical activity compared with matched controls. Sedentary behaviour was comparable between groups, with a median sedentary time of 9.3 hours/day in both cohorts (interquartile range [IQR] 8.5–10.2 in BAV vs. 8.2–10.2 in controls; *p* = 0.84). However, time spent in moderate-to-vigorous physical activity (MVPA) was significantly reduced in the BAV group, reaching a median of 72 minutes/day (IQR 59–89), compared with 98 minutes/day (IQR 75–116) in controls (*p* < 0.001). Similarly, daily step counts were substantially lower among individuals with BAV, with a median of 4,826 steps/day (IQR 4,004–5,801), compared with 6,252 steps/day (IQR 4,784–7,484) in controls (*p* < 0.001).

Differences were also observed in lifestyle characteristics related to physical activity. Participation in leisure-time sports was significantly less common among individuals with BAV (70 %) compared with controls (90 %, *p* < 0.001). In addition, fewer BAV participants reported performing light or moderate physical activities during work (56 % vs. 72 %, *p* = 0.021). Active commuting, such as walking or cycling to work, was reported by 38 % of individuals with BAV and 46 % of controls, although this difference did not reach statistical significance (*p* = 0.29).

Importantly, the degree of physical inactivity appeared to be associated with disease severity. Participants with BAV were categorized into two subgroups: none-to-mild disease severity (n = 46), defined as none-to-mild valvular dysfunction and aortic diameters <40 mm, and moderate-to-severe disease (n = 54), characterized by moderate or severe valvular dysfunction or the presence of aortic dilatation (≥40 mm). Compared with controls, individuals with none-to-mild disease demonstrated a reduction in MVPA of approximately 16.9 minutes/day and a reduction in daily step count of 967 steps/day. In contrast, individuals with moderate-to-severe disease exhibited a greater reduction in activity levels, with MVPA decreased by approximately 27 minutes/day and step count reduced by 1,685 steps/day. These findings suggest a clear disease-severity–dependent gradient in physical inactivity among individuals with BAV.

Psychological and informational factors may also contribute to these observed differences. Nearly half of the BAV participants (48 %) reported uncertainty regarding the level of physical activity considered safe for their condition, and 56 % expressed interest in receiving additional information regarding exercise recommendations. Higher levels of physical activity were positively associated with mental quality-of-life scores, whereas no significant association was observed between physical activity levels and cardiac anxiety.

Evidence from pediatric populations further supports the clinical relevance of maintaining adequate physical activity in individuals with BAV. In a study of children aged 8–17 years with isolated BAV, participation in competitive sports was not associated with increased aortic diameters compared with non-athletes [15]. Importantly, both competitive sports participation and higher levels of daily physical activity were associated with a significantly lower risk of obesity, with an odds ratio of 0.24 (95 % CI 0.078–0.73) for competitive sports participation and 0.24 (95 % CI 0.081–0.71) for overall daily activity. These findings suggest that physical activity may confer important metabolic benefits without apparent adverse effects on aortic dimensions in pediatric BAV populations.

Taken together, available evidence indicates that individuals with BAV engage in lower levels of physical activity than the general population, despite comparable sedentary time. This reduction is particularly evident in moderate-to-vigorous activity and daily step counts and appears to worsen with increasing disease severity. At the same time, emerging evidence—particularly from pediatric cohorts—suggests that participation in sports may provide important health benefits without necessarily increasing aortic dilation risk, highlighting the importance of balanced and individualized exercise recommendations in this patient population.

Physical activity and the risk of valvular and aortic complications in BAV patients

Early theoretical considerations suggested that repetitive haemodynamic stress during intense exercise might accelerate degeneration of the bicuspid valve or promote progressive dilation of the ascending aorta [13]. However, these concerns were largely based on pathophysiological reasoning rather than longitudinal clinical data.

Several studies have investigated whether regular physical activity contributes to the progression of valvular dysfunction or aortic dilation in patients with bicuspid aortic valve (BAV). Overall, current evidence does not support a detrimental association between exercise exposure and the occurrence of major BAV-related complications.

In a cross-sectional study including 407 patients with BAV (mean age 42 ± 17 years), Schreurs et al. examined the relationship between lifelong exercise characteristics and structural cardiovascular outcomes [16]. Participants were stratified according to weekly exercise volume into sedentary (<500 MET-min/week), active (500–1000 MET-min/week), and highly active (≥1000 MET-min/week) groups. Moderate-to-severe aortic stenosis and aortic regurgitation were present in 23.7% and 20.0% of the cohort, respectively. Mean diameters at the sinuses of Valsalva and ascending aorta were 34.8 ± 6.6 mm and 36.5 ± 8.1 mm, with aortic dilation identified in 21.6% and 53.4% of patients, respectively. Exercise volume was not associated with the presence of valvular dysfunction or aortic dilation. Interestingly, vigorous exercise intensity and participation in mixed-type sports were associated with a lower prevalence of moderate-to-severe aortic stenosis (adjusted OR 0.43 and 0.47, respectively), whereas no relationship was observed between exercise characteristics and aortic regurgitation or aortic dilation.

Longitudinal data from athletic populations provide similar observations. In a retrospective cohort study including 47 athletes with uncomplicated BAV (median age 21 years) followed for a median of 11.6 years, Bianco et al. evaluated the influence of training volume on the echocardiographic progression of the disease [17]. Participants were classified at follow-up as either “trained” or “untrained” based on physical activity levels assessed with the International Physical Activity Questionnaire. During follow-up, no significant differences were observed between groups in the rate of aortic growth, left ventricular dimensions, or progression of aortic stenosis and regurgitation. Furthermore, weekly training volume was not significantly correlated with echocardiographic parameters reflecting cardiac size or valve function. These

findings suggest that sustained athletic training does not accelerate structural cardiovascular changes in athletes with uncomplicated BAV.

Taken together, the available evidence suggests that regular physical activity, including high training volumes, does not appear to accelerate valvular dysfunction or aortic dilation in patients with BAV. While these findings are reassuring, most available studies are observational in design, and data on very high-intensity or elite-level training remain limited. Therefore, although current evidence does not support routine exercise restriction in asymptomatic individuals with uncomplicated BAV, ongoing longitudinal research is warranted to further clarify potential long-term effects across different exercise intensities and phenotypes of the disease.

Paediatric patients with BAV – effects of physical activity on aortic diameter progression

In a prospective cohort of 90 paediatric patients with isolated BAV (mean age 11.5 ± 3.4 years), 53 individuals (59%) were classified as physically active and 37 (41%) as sedentary [18]. Over a 2-year follow-up period, no significant differences were observed between groups in changes of aortic dimensions at the level of the sinus of Valsalva or the mid-ascending aorta.

Aortic diameter progression, defined as an increase ≥10% from baseline accompanied by a corresponding increase in z-score, occurred with similar frequency in both groups. Progression of the sinus of Valsalva diameter was observed in 13% of physically active patients and 8% of sedentary patients ($p = 0.449$), whereas progression of the ascending aorta was documented in 9% and 13%, respectively ($p = 0.545$). Among individuals with documented progression, the magnitude of diameter increase was comparable between groups for both the sinus of Valsalva (3.7 ± 1.0 mm vs. 3.5 ± 0.8 mm; $p = 0.673$) and the ascending aorta (3.0 ± 0.8 mm vs. 3.2 ± 1.3 mm; $p = 0.830$).

In patients with baseline aortic dilation, longitudinal changes in aortic dimensions were also similar between physically active and sedentary subjects. Changes in sinus of Valsalva diameter were 1.6 ± 1.6 mm in the active group versus 0.0 ± 2.9 mm in the sedentary group ($p = 0.216$). In patients with ascending aortic dilation at baseline, the corresponding changes were 1.4 ± 1.6 mm and 1.4 ± 1.3 mm, respectively ($p = 0.957$).

Overall, echocardiographic follow-up demonstrated stable mean aortic diameters in both groups, with no significant differences in longitudinal changes between physically active and sedentary

patients. These findings suggest that regular physical activity was not associated with accelerated aortic diameter progression in paediatric patients with BAV during the 2-year observation period. This observation is consistent with recent literature indicating that recreational physical activity appears to be safe for most paediatric individuals with BAV, although long-term prospective data on bicuspid aortopathy progression remain limited.

Competitive athletes with BAV - clinical course and risk profile

Management of competitive athletes with bicuspid aortic valve (BAV) requires individualized risk stratification, as the hemodynamic demands of high-intensity training may interact with valvular and aortic abnormalities. Although exercise is generally cardioprotective, participation in elite or highly dynamic sports warrants careful evaluation in athletes with structural heart disease, particularly when BAV is present [19].

The principal clinical concerns in competitive athletes with BAV include progression of valvular dysfunction, aortic dilatation, and, in rare cases, aortic dissection. The incidence of aortic dissection in BAV has been estimated at 3.1 cases per 10,000 patient-years (95% confidence interval: 0.5–9.5), representing the most relevant complication of bicuspid aortopathy [20]. Although uncommon, this risk justifies structured surveillance in athletes who continue competitive participation. Additionally, BAV may coexist with anomalous coronary artery origins, which can increase the risk of myocardial ischemia, syncope, or sudden cardiac death, particularly during or after intense exercise due to potential coronary compression [21,22]. Therefore, comprehensive imaging assessment is mandatory in competitive athletes with BAV, including detailed evaluation of aortic dimensions and coronary ostia.

Valve morphology may influence disease trajectory in athletes. Fusion of the right and non-coronary cusps (Type 2 BAV) has been associated with more rapid progression of aortic stenosis (AS) and aortic regurgitation (AR) [23], whereas fusion of the right and left coronary cusps (Type 1 BAV) is more frequently linked to greater aortic wall degeneration and may be associated with coarctation of the aorta. Recognition of BAV phenotype is therefore relevant in competitive athletes, as it may inform surveillance intensity and eligibility decisions.

Concerns have been raised regarding potential exercise-induced aortic enlargement in athletes with BAV. However, data from athletic populations suggest that clinically significant aortic dilatation is uncommon in trained individuals and does not typically represent physiological remodeling. In a longitudinal cohort of 2,317 athletes followed for 8 years, only 1.3% of males

and 0.9% of females demonstrated an aortic root diameter ≥40 mm and ≥34 mm, respectively [24]. These thresholds were considered unlikely to reflect normal athletic adaptation and instead warranted close clinical monitoring [25,26]. Furthermore, athletes with enlarged aortic roots showed greater subsequent dimensional progression over time, particularly in midlife [24]. In another study including 3,781 athletes, only 0.3% exhibited enlarged aortic diameters, and medium-term follow-up did not reveal progressive enlargement indicative of developing aortopathy [27]. Overall, available evidence suggests that competitive training has limited influence on aortic dimensions in athletes, and significant enlargement should prompt careful evaluation rather than attribution to training effects alone.

Data specifically addressing athletes with BAV indicate that regular high-intensity training does not necessarily accelerate structural deterioration during athletic careers. In short- and medium-term follow-up studies, no significant differences were observed between athletes and comparison groups regarding progression of aortic dimensions or valve function [28]. Boratia et al. reported that elite athletes with BAV engaged in high-intensity training did not demonstrate worsening of morphologic or hemodynamic parameters over a 3-year follow-up compared with matched athletes with tricuspid valves or non-athletic individuals. Moreover, longitudinal data from 81 Olympic athletes with BAV followed for 13 years showed that disease progression in high-risk individuals occurred independently of prior athletic exposure, while the majority of low-risk athletes maintained a benign course [29]. Importantly, in medium-term studies, competitive training did not adversely affect left ventricular structure or systolic function in athletes with BAV [28].

Eligibility decisions in competitive athletes with BAV should be based on symptom status, valve severity, aortic dimensions, ventricular function, pulmonary pressures, and arrhythmic risk. According to the American Heart Association (AHA) and American College of Cardiology (ACC) recommendations, symptomatic athletes should be excluded from competitive sports irrespective of lesion severity [30]. In asymptomatic athletes, individualized assessment is required.

Current European Society of Cardiology guidance indicates that, in the absence of aortopathy and significant valve dysfunction, athletes with BAV may participate in competitive sports according to the same principles applied to athletes with tricuspid valves [31]. When aortic dilatation is present, risk stratification determines eligibility, and competitive sports are generally restricted to low-risk individuals, excluding high-static (power) disciplines. Detailed

recommendations are provided in contemporary AHA/ACC and national sports cardiology guidelines [30,32].

Athletes with uncomplicated BAV—defined by absence of relevant AS, AR, significant aortic enlargement, ventricular dysfunction, pulmonary hypertension, or arrhythmias—may participate in all sports. When complications are present, restriction from competitive participation is indicated. Regular echocardiographic follow-up or advanced imaging is strongly recommended in athletes allowed to continue competition, alongside periodic risk reassessment and exercise testing with blood pressure monitoring [33]. Surgical intervention should follow standard clinical indications, and return-to-sport decisions after aortic or valve surgery depend on postoperative risk classification.

In summary, current evidence suggests that carefully selected competitive athletes with BAV—particularly those with mild disease and without significant aortic involvement—may safely engage in high-intensity sports under structured surveillance. Continuous monitoring and adherence to established eligibility criteria remain essential to minimize the risk of adverse outcomes.

Exercise recommendations in patients with BAV

Current recommendations regarding physical activity in patients with valvular heart disease are largely derived from expert consensus, reflecting the limited number of studies evaluating the natural history of these conditions in physically active individuals [34]. Nevertheless, available guidance consistently emphasizes the importance of avoiding sedentary behaviour. Patients with valvular heart disease are generally encouraged to engage in regular physical activity, with a target of approximately 150 minutes of exercise per week, including resistance training.

In individuals with mild valvular dysfunction, exercise restrictions are typically not required. Regurgitant lesions are usually better tolerated than stenotic lesions, which is reflected in more permissive recommendations for patients with moderate-to-severe regurgitation. For example, patients with severe aortic regurgitation may still participate in moderate-intensity physical activity provided that left ventricular size and aortic dimensions remain within acceptable limits and left ventricular ejection fraction is preserved. Similarly, individuals with severe mitral regurgitation may engage in moderate exercise when ventricular size, systolic function, pulmonary pressures, and rhythm status remain within defined safety thresholds.

In contrast, patients with severe stenotic valve lesions are generally advised to limit physical activity to low-intensity exercise due to the higher risk of adverse haemodynamic responses during exertion [35]. In the context of bicuspid aortic valve, current guidance suggests that in the absence of significant aortopathy, recommendations for physical activity should follow those established for dysfunction of a tricuspid aortic valve.

Conclusion

Bicuspid aortic valve represents the most common congenital cardiac malformation and is frequently diagnosed in otherwise asymptomatic individuals during childhood or early adulthood. As a result, questions regarding the safety of physical activity and participation in recreational or competitive sports arise early in the clinical course of the disease. Historically, concerns have been raised that the hemodynamic stress associated with intense physical exercise could accelerate valvular degeneration or promote progressive dilation of the ascending aorta. However, contemporary evidence increasingly suggests that these concerns may have been overstated, particularly in individuals with uncomplicated forms of the disease.

Available observational studies consistently demonstrate that patients with BAV tend to engage in lower levels of moderate-to-vigorous physical activity compared with the general population. This reduction in activity appears to be partly related to uncertainty regarding safe exercise intensity and, in some cases, overly restrictive recommendations. Importantly, current data do not indicate that regular physical activity is associated with accelerated progression of valvular dysfunction or enlargement of the thoracic aorta in individuals with uncomplicated BAV. Similar findings have been reported in athletic populations, where long-term participation in structured training programs has not been shown to independently promote adverse structural cardiac remodeling or faster disease progression.

Evidence from paediatric cohorts further supports the safety of physical activity in this population. Participation in regular exercise and even competitive sports has not been associated with increased aortic diameter progression during mid-term follow-up. On the contrary, higher levels of physical activity appear to be associated with favorable metabolic outcomes, including a lower prevalence of obesity. These findings highlight the importance of encouraging appropriate physical activity in young individuals with BAV, provided that regular clinical monitoring is maintained.

In competitive athletes, the management strategy should focus on individualized risk assessment rather than universal restriction from sport. Comprehensive cardiovascular evaluation—including detailed imaging of the aortic valve, thoracic aorta, and coronary anatomy—is essential for appropriate risk stratification. In the absence of significant aortic dilation, severe valvular dysfunction, ventricular impairment, arrhythmias, or other high-risk features, many individuals with BAV may safely participate in athletic activities under structured surveillance. Conversely, restrictions remain appropriate in patients with advanced valvular disease or clinically significant aortopathy, where the potential risk of adverse cardiovascular events may outweigh the benefits of high-intensity exercise.

Despite generally reassuring findings, several limitations of the current literature should be acknowledged. Most available studies are observational in design and involve relatively small cohorts, particularly in the context of elite athletes. Additionally, long-term prospective data evaluating the effects of very high training loads across different BAV phenotypes remain limited. Given the substantial heterogeneity of the condition, further large-scale longitudinal studies are needed to better define exercise-related risk profiles and refine evidence-based recommendations for different patient subgroups.

In summary, current evidence suggests that routine restriction of physical activity is not justified in most individuals with uncomplicated bicuspid aortic valves. Regular exercise appears to be safe and may confer important cardiovascular and metabolic benefits. Clinical management should therefore emphasize individualized evaluation, balanced counseling, and regular follow-up rather than unnecessary limitation of physical activity.

Disclosure

Author's contribution

Conceptualization: M. Kuryłek; methodology: M. Kuryłek, F. Krauze; software: S. Korzeniak, M. Kuryłek; check: A. Dziegciarczyk; formal analysis: A. Dziegciarczyk, F. Krauze; investigation: A. Bala; resources: A. Dziegciarczyk, M. Kuryłek; data curation: K. Kozdęba, M. Chybiorz; writing-rough preparation: K. Kozdęba, S. Korzeniak; writing –review and editing: A. Bala; visualization: A. Dziegciarczyk; supervision: M. Chybiorz; project administration: M. Kuryłek.

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