Established in 1871

Swiss Medical Weekly

Formerly: Schweizerische Medizinische Wochenschrift

An open access, online journal • www.smw.ch

Review article: Medical guidelines | Published 18 February 2022 | doi:10.4414/SMW.2022.w30128
Cite this as: Swiss Med Wkly. 2022;152:w30128

Paediatric and adolescent athletes in Switzerland: age-adapted proposals for pre-participation cardiovascular evaluation

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Summary

High-level sports competition is popular among Swiss youth. Even though preparticipation evaluation for competitive athletes is widespread, screening strategies for diseases responsible for sudden death during sport are highly variable. Hence, we sought to develop age-specific preparticipation cardiovascular evaluation (PPCE) proposals for Swiss paediatric and adolescent athletes (under 18 years of age). We recommend that all athletes practising in a squad with a training load of at least 6 hours per week should undergo PPCE based on medical history and physical examination from the age of 12 years on. Prior to 12 years, individual judgement of athletic performance is required. We suggest the inclusion of a standard 12-lead electrocardiogram (ECG) evaluation for all post-pubertal athletes (or older than 15 years) with analysis in accordance with the International Criteria for ECG Interpretation in Athletes. Echocardiography should not be a first-line screening tool but rather serve for the investigation of abnormalities detected by the above strategies. We recommend regular follow-up examinations, even for those having normal history, physical examination and ECG findings. Athletes with an abnormal history (including family history), physical examination and/or ECG should be further investigated and pathological findings discussed with a paediatric cardiologist. Importantly, the recommendations provided in this document are not intended for use among patients with congenital heart disease who require individualised care according to current guidelines.

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Why screen paediatric and adolescent athletes?

The number of children and adolescents in Switzerland performing sports remains at a high level. According to the last federal sports report of the young from 2014, two thirds of the Swiss youth between 10 and 19 years of age are physically active for more than three hours per week and one third even for more than seven hours [1]. Cardiac adaptions to intensive exercise, termed “the athlete’s heart”, represent a benign physiological response to training [2]. However, distinguishing cardiac adaptions to sport from pathology remains challenging [3]. In presence of an underlying cardiac disease, sudden cardiac death (SCD) may occur. SCD remains the leading medical cause of death across all sports among young athletes (<35 years) with a strong male predominance [4]. Before implementation of a mandatory screening programme, athletes in the Italian region of Veneto had an increased risk of SCD com-

pared with non-athletes [5]. The SCD incidence then decreased by 89% following implementation of preparticipation cardiovascular screening [6]. Data characterising the incidence of SCD among paediatric athletes are sparse despite the fact that a US-based sudden death registry reported 65% of all victims to be younger than 18 years [7].

In Switzerland, preparticipation evaluation has been performed for several years, promoting several aspects of the athlete's health and wellbeing [8]. This review focuses on the cardiovascular part, termed preparticipation cardiovascular examination (PPCE). Nevertheless, we acknowledge the importance of a comprehensive screening of the young performing high level sports.

Proposal: Identification of individuals at risk of SCD is of paramount importance during the preparticipation cardiovascular evaluation (PPCE) of competitive athletes, not only in adults, but also in the paediatric/adolescent age range.

How to define the "paediatric/adolescent athlete"?

The development of a universally acceptable definition of paediatric and adolescent athletes presents numerous challenges. The term "athlete" refers to an individual who participates in competitive sports on a high level [9], but defining competitive sports performance under the age of 12 years may require individual judgement [9], as regular training can start from the age of six years [10]. However, general physical activity levels are higher in children than adults. The World Health Organization recommendation on physical activity in children advocates an average of 60 minutes daily, including at least three days a week of vigorous-intensity and strengthening activities [11]. Therefore, in order to differentiate paediatric and adolescent athletes from recreational "exercisers" and normally active children, we suggest including individuals practising in a squad with a training load of at least six hours of structured training per week beyond leisure activities. Intensive exercise for at least four hours a week induces adaptive cardiac changes in adults [3]. Limited data suggest that similar adaptations can be observed in adolescents [12].

Even though biological age determined by puberty stages according to Tanner [13, 14] is more appropriate than chronological age and should be used in the young athlete's assessment, we suggest an upper cut-off age of 18 years for the definition of paediatric and adolescent athletes. The lower cut-off is based on the onset of athletic performance, as mentioned above [9].

Proposal: Paediatric/adolescent athletes (younger than 18 years) are defined by competitive sports participation on high level, practising in a squad for at least six hours per week.

Whom do we need to screen?

A key issue is the cut-off age for the implementation of PPCE in paediatric and adolescent athletes. SCD-related cardiac pathologies develop with age, resulting in a relatively low risk of SCD before puberty [15]. The incidence of SCD in the general population between 1 and 35 years of age in Australia and New Zealand was 1.3/100,000, with a nadir between 6 and 15 years. However, unexplained SCD (i.e., unidentified by comprehensive autopsy) peaked between 16 and 20 years [16]. Comparable data in Europe were found in Denmark [17] and Sweden [18]. Sports-related SCD rates are generally lower [19, 20]. Nevertheless, in a UK-based registry, the so-called "sudden arrhythmic death" accounted for more than half of all sports-related cases under 18 years [21]. This entity may be related to primary arrhythmias including genetic channelopathies and congenital pre-excitation that are detectable by 12-lead electrocardiography (ECG) [21]. Although PPCE in prepubertal paediatric athletes can detect occult disease associated with SCD, there are currently no data to support starting screening before puberty. The economic implications are considerable: in an Italian study, cost per diagnosis in PPCE was more than three times higher among children (7–11 years) than among adolescents (12–18 years) [15]. Due to the high variability between biological and chronological age in the process of puberty, notably between male and female athletes, it is practically impossible to set numerical cut-offs for paediatric and adolescent athletes. In order to distinguish pre- from post-pubertal athletes, we recommend evaluation of the biological age by the use of Tanner stages (table 1). Although we acknowledge that some may advocate PPCE at younger ages, we suggest starting screening from 12 years on with a medical history and physical examination, corresponding to the lower age range on regional level for Swiss Olympic Talent Card holders in most sports categories [22]. Prior to that age, athletic performance requires individual judgement [9]. We recommend the inclusion of a 12-lead ECG among athletes who are post-pubertal according to Tanner stages or from 15 years, corresponding to the starting age on national level for Swiss Olympic Talent Card holders in most sports categories [22].

The incidence of SCD is consistently higher for males in both the general population [16] and among competitive athletes [20, 23]. Despite an increasing participation of women in competitive sports, this gap persists [24]. The degree to which this sex difference is applicable to the paediatric and adolescent age range, remains to be definitively determined, although one UK-based study including children reported lower SCD rates among females than males [21]. However, an argument supporting ECG screening in females was shown in young Swiss females (<35 years), where the leading cause of SCD were cardiomyopathies that are potentially identifiable by 12-lead ECG [25]. As long as the impact of female sex on SCD risk in paediatric and adolescent athletes is not established, we recommend

Table 1:
Tanner stages evaluating maturity stages [13, 14].

	Male	Female
1	No pubic hair	No pubic hair
	Testis of childhood size	Elevated papilla
2	Sparse, long hair	Sparse, long hair
	Testis enlarged	Breast buds present
3	Darker, curled hair	Darker, curled hair
	Penis enlarged	Areolar diameter enlarged
4	Small area of adult-type hair	Small area of adult-type hair
	Scrotum darkened	Secondary mound
5	Mature male	Mature female

that male and female paediatric and adolescent competitive athletes be screened in an identical fashion.

Ethnicity also plays a role on SCD risk, as shown in the US, where African-American athletes and other non-Caucasian ethnicities demonstrate a nearly five-fold increased death rate compared with Caucasians [23]. In the absence of data defining markedly high-risk ethnic groups in Switzerland, we recommend equal screening policies in Swiss paediatric and adolescent athletes of all ethnicities.

Patients with congenital heart disease who wish to participate in competitive sports may be at the highest risk of SCD during exercise [26]. These patients require an individualised shared decision-making approach involving experts in paediatric cardiology, congenital heart disease and sports medicine. Importantly, regular exercise in accordance with physical activity guidelines is recommended for individuals with stable forms of congenital heart disease [27].

Proposal: From the age of 12 years on, we suggest screening by history and physical examination. Prior to this age, individual judgement of athletic performance is required. Post-pubertal athletes (or older than 15 years) should have ECG-inclusive PPCE, independently of sex and ethnicity. Patients with congenital heart disease should be managed individually by their attending paediatric cardiologist.

Which is the best screening tool?

Medical history and physical examination remain the cornerstones of PPCE. Importantly, standardised questionnaires such as the American Heart Association 14-Element Screening [28], the American Academy of Pediatrics 5th PPE Monograph [29] or equivalent should be used in order to ensure comprehensive and consistent evaluation, including blood pressure measurement (table 2). Importantly, any abnormal finding on history and/or physical examination including abnormal prior cardiovascular testing results and a positive family history including premature death (<50 years) and/or known genetic cardiomyopathy in a first degree relative requires further investigations, as suggested by large international guidelines [27, 30, 31].

ECG has proven to increase sensitivity and negative predictive value for SCD-related cardiac pathologies in PPCE of athletes [32]. The European Society of Cardiology (ESC) recommends ECG as an inherent part of preparticipation screening [31]. Interestingly, although the American Heart Association (AHA) does not recommend routine ECG-inclusive screening, it still states that ECG "may be considered in relatively small cohorts of young healthy people 12 to 25 years of age" underlining the peculiarity of this age group [28]. ECG evaluation is currently widely used during PPCE among Swiss athletes (table 3). However, as described previously, the risk of SCD is lowest in individuals before they reach puberty [16]. Hence, instead of using a numerical cut-off for chronological age, we strongly recommend evaluation of the pubertal status of an athlete by the use of Tanner stages (table 1). This is particularly important when considering the earlier pubertal onset in females. Only if Tanner stages cannot be used for major reasons (self-determination, pudency, legal implications), we suggest a chronological cut-off of 15 years or older. Taken together, we recommend that ECG be considered standard of care for all post-pubertal athletes (or from 15 years on).

Echocardiographic screening in healthy adolescents with a mean age of 13 years demonstrated a 3.6% rate of previously unknown cardiac abnormalities of which the vast majority are not known to increase the risk of SCD during sports [33]. Several studies suggest that echocardiography does not provide any additional diagnostic value to medical history, physical examination and ECG during PPCE [34, 35]. In a study on Italian male paediatric football players, ECG proved to be a powerful diagnostic tool for detecting cardiomyopathies and identified all athletes requiring sports disqualification, thus limiting the value of echocardiography as first-line tool [36]. In line with current ESC and American Society of Echocardiography guidelines [27, 37], we suggest reserving echocardiography for second-line evaluation.

Proposal: PPCE relies on a comprehensive medical history and physical examination, as well as a 12-lead ECG in post-pubertal athletes (or from age 15 years).

Table 2:
Comprehensive evaluation by medical history and physical examination according to the American Heart Association 14-Element Screening (AHA-14) [28] or the American Academy of Pediatrics 5th PPE Monograph (5th PPE Monograph) [29].

	AHA-14	**5th PPE Monograph**
Personal History	Exertional chest pain/discomfort	Exertional chest pain/discomfort
	Unexplained syncope or near-syncope	Exertional syncope or near-syncope
	Exertional dyspnoea/fatigue/palpitations	Exertional tachycardia/palpitations
	Priorly known heart murmur	Priorly known cardiac disease
	Elevated systemic blood pressure	Exertional dyspnoea/numbness
	Prior restriction from sports	Prior seizure
	Prior heart testing by a physician	Prior heart testing by a physician
Family History	Premature cardiac death in a relative (<50 years)	Sudden death in a relative (<35 years)
	Disability from heart disease in a relative (<50 years)	Pacemaker or implanted defibrillator in a relative (<35 years)
	Specific cardiac conditions in family members: hypertrophic or dilated cardiomyopathy, long-QT syndrome or other ion channelopathies, Marfan syndrome, clinically significant arrhythmias, genetic cardiac conditions	Specific cardiac conditions in family members: hypertrophic or arrhythmogenic right ventricular cardiomyopathy, long-QT syndrome, short-QT syndrome, Marfan syndrome, Brugada syndrome, catecholaminergic polymorphic ventricular tachycardia
Physical Exam	Heart murmur	Heart murmur
	Femoral pulses	Pulse
	Physical stigmata of Marfan syndrome	Physical stigmata of Marfan syndrome
	Brachial artery blood pressure	Brachial artery blood pressure

Table 3:
Current PPCE standards for major sport types in paediatric and adolescent athletes in Switzerland.

Sport type	Method	Starting age	Follow-up interval
Football	H&P 1×/year	"junior elite" (≈ 14–16 years)	At transfer to "elite"
	ECG 1×/2 years		
Unihockey*	H&P 1×/2 years	"U19" (17–18 years)	1×/2 years
	ECG 1×/2 years		
	Blood tests 1×/2 years		
Ice Hockey	H&P 1×/year	"U17" (14–16 years)	1×/year
	ECG 1×/year		
Swimming	H&P 1×/year	regional: boys: 13 years, girls: 12 years	1×/year
		national: boys: 15 years, girls: 14 years	

ECG: 12-lead electrocardiogram; H&P: history and physical examination.

* National team U19 (aged 17–18 years), prior testing as stated by the respective sports club.

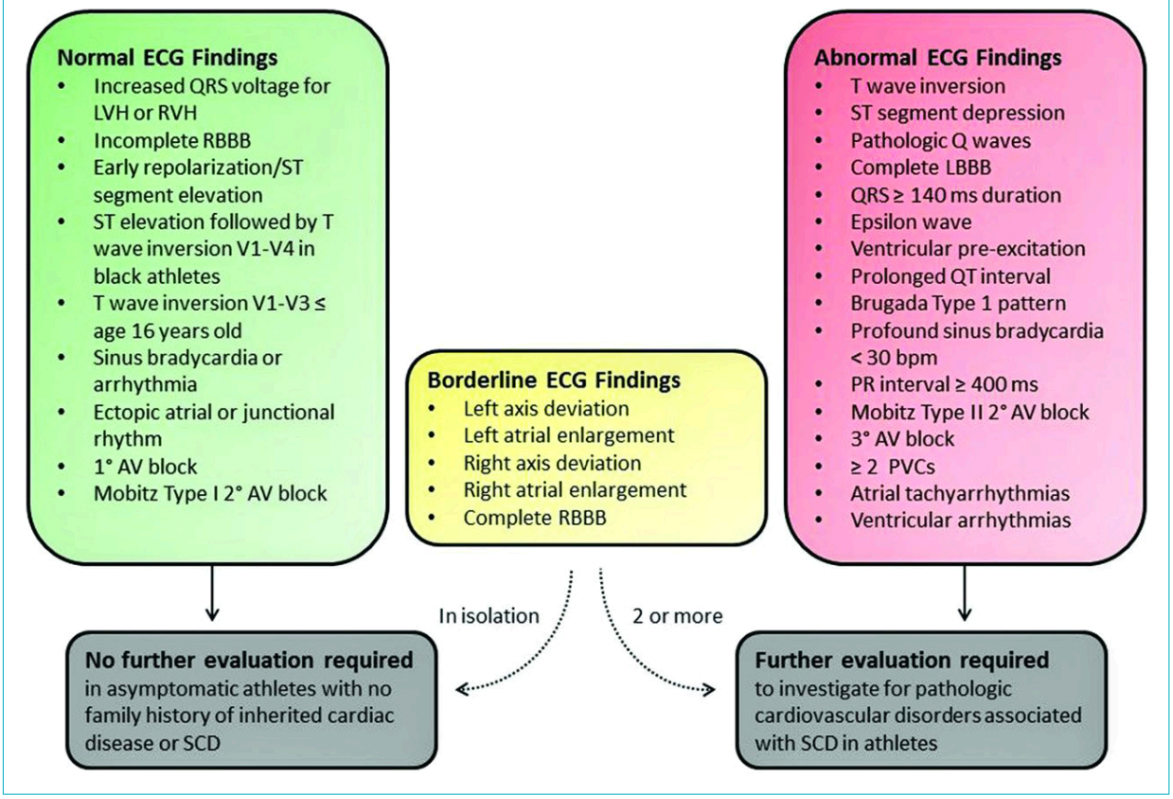
Do we have appropriate ECG criteria for PPCE in paediatric and adolescent athletes?

Appropriate, age-specific criteria are required to differentiate benign, training-induced ("normal") from potentially malignant, training-unrelated ("abnormal") ECG findings. In 2016, Perrin et al. demonstrated a low prevalence (1.4%) of abnormal findings in a cohort of young Swiss athletes (≥14 years) including adults [38]. In the interim, ECG interpretation criteria for athletes have been revised and now achieve high values of specificity (93.0%) and sensitivity (95.9%) in adults [39].

The latest version of athlete specific ECG interpretation criteria, the International Criteria for Electrocardiographic Interpretation in Athletes (2017) (fig. 1), were developed for use among asymptomatic athletes aged 12–35 years [30].

An initial study performed in paediatric athletes demonstrated only moderate values of diagnostic accuracy for these criteria [40]. However, this study was realised in Middle Eastern and African athletes, who are known to exhibit more abnormal findings on ECG [41]. Further, the diagnostic value of modern ECG interpretation standards highly depends on appropriately educated medical staff [42]. This implies a critical need for age-specific knowledge in ECG interpretation as part of paediatric and adolescent athletes' screening, given the presence of specific paediatric electrocardiographic variants, such as isolated complete right bundle branch block in patients with Ebstein's anomaly [43]. High inter-observer agreement using

Figure 1: International consensus standards for ECG interpretation in athletes, reprinted with permission from: from: Drezner JA, Sharma S, Baggish A, Papadakis M, Wilson MG, Prutkin JM, et al. International criteria for electrocardiographic interpretation in athletes: consensus statement. Br J Sports Med. 2017 May;51(9):704–31 [30]. AV: atrioventricular; LBBB: left bundle branch block; LVH: left ventricular hypertrophy; PVC: premature ventricular contraction; RBBB: right bundle branch block; RVH: right ventricular hypertrophy; SCD: sudden cardiac death.



the International Criteria for Electrocardiographic Interpretation in Athletes was demonstrated in Swiss athletes [44]. Application of these criteria to 891 Swiss paediatric athletes from 45 different sports demonstrated a low rate (2.1%) of abnormal ECG findings [45], congruent to results from Italian male peri-pubertal football players [36]. A recent study in Caucasian paediatric athletes showed a low false-positive rate (2.2%) [43]. In sum, the International Criteria for Electrocardiographic Interpretation in Athletes appear to perform with sufficient accuracy to use among paediatric and adolescent athletes.

Proposal: The International Criteria for Electrocardiographic Interpretation in Athletes are appropriate to use in paediatric/adolescent athletes.

What is the cost of ECG-inclusive PPCE?

Frequently cited arguments against ECG-inclusive PPCE include enlarged financial burden and increased need for downstream testing to address ECG findings [46]. Paediatric athlete data from Switzerland revealed costs of CHF 103 per athlete for basic ECG-inclusive PPCE, which increased to CHF 116 when further investigations of abnormal findings were included [64]. PPCE without ECG reduced the costs from CHF 116 to CHF 72, owing to less expensive baseline screening and a lower rate of abnormal findings requiring further evaluation. However, large-scale trials in young athletes from the US and Italy demonstrated that ECG-inclusive PPCE was more cost-effective than history and physical examination alone [47]. Data from Italy in a mixed paediatric-adult population demonstrated costs of approximately EUR 80 per athlete, including second-line investigations [15]. This is comparable to figures from the UK and Canada [15]. Nevertheless, children had the highest cost per diagnosis because of the low disease prevalence in this age group [15].

Proposal: Costs for PPCE in Switzerland are comparable to other countries and seem appropriate to potentially decrease the SCD rate among young athletes.

What are the limits of PPCE?

The limits of one-time PPCE were demonstrated in a study among adolescent football players (n = 11,168; age = 16.4 ± 1.2 years; 95% male) from the UK screened by ECG and echocardiography [48]. First, there was a low prevalence (0.38%) of SCD-associated cardiac disorders diagnosed, of which 86% were identified by ECG, 29% by echocardiography and less than 10% by history and physical examination. Second, 2% of screened athletes had abnormal or borderline abnormal ECG findings for which no explanatory cardiac diagnosis could be established. This is similar to the results observed in a cohort of Swiss paediatric athletes [45]. Third, over a mean follow-up period of over 10 years, there were eight cases of SCD, resulting in an SCD incidence in screened athletes of 6.8 per 100,000 athletes. Out of the eight SCD victims, seven had a post-mortem diagnosis of cardiomyopathy. Importantly, six of the eight athletes had been cleared for sports participation on initial PPCE, suggesting subsequent emergence of phenotypic disease. Taken together, this study substantiates the critical need for follow-up screenings, as a one-time PPCE may miss individuals at risk of SCD. Even though only two thirds of SCDs manifest by abnormal ECG [31], ECG detects substantially more pathologies than medical history and physical examination alone, as presented in this large-scale study [48].

Proposal: The main limit of ECG-inclusive PPCE is a low prevalence (<1%) of findings with one single screening, highlighting the substantial need for follow-up ECGs.

Do we need follow-up examinations?

The heart continues to develop during childhood and adolescence with major developmental steps taking place during puberty [49]. This includes the phenotypic emergence of several cardiomyopathies. Whereas congenital cardiomyopathies such as Noonan syndrome [50], offspring of mothers suffering from diabetes [51] or related to metabolic disorders are usually diagnosed before and in part are only transient, two of the major cardiomyopathies with risk of SCD (hypertrophic and arrhythmogenic right ventricular cardiomyopathies) may manifest only after the onset of puberty [52]. One of the electrocardiographic findings of cardiomyopathies, a T-wave inversion in the anterior precordial leads, is considered a physiological ("juvenile pattern") in athletes younger than 16 years [30]. Therefore, follow-up is of crucial importance in the screening process of paediatric and adolescent athletes. The best example is stated by the UK football players mentioned above [48]. Hence, the potential of relevant cardiovascular conditions to cause SCD in athletes and their emergence over time imply a need for regular follow-up. Furthermore, follow-up allows prevention of complications arising from pathologies without immediate risk of cardiac mortality [36]. Based on experience from professional football players in the UK, Speers et al. suggested follow-up at a maximum 2-year interval even for the lowest risk category with completely normal screening results [53]. As mentioned above, data on SCD in the paediatric age range are scarce. This implies a lack of evidence for exact determination of adequate follow-up intervals.

Proposal: Follow-up should be performed regularly because of the emergence of SCD-related pathologies over time, notably during growth of paediatric and adolescent athletes.

Athlete counselling and shared decision making

Even the best PPCE does not fully eliminate the remaining risk of SCD in athletes. Athletes and their caregivers should therefore be educated about the limitations of screening including the risk of false positive and false negative findings.

There are mounting data to suggest that numerous cardiac conditions previously associated with SCD indicate minimal and non-prohibitive risk during sport participation [54, 55]. Accordingly, clinicians are increasingly utilising shared decision-making models to educate patients about the risks and benefits of sport participation following a cardiac diagnosis. Examples include hypertrophic cardiomyopathy without any markers of increased risk [27], frequent ventricular arrhythmias with no underlying structural heart disease, asymptomatic Brugada syndrome or selected pacemaker/implantable cardioverter defibrillator carriers

[15]. In the paediatric age range, there is a similar trend regarding simple shunting lesions or aortic stenosis [26]. This trend is of importance as many competitive athletes may choose to accept some levels of risk in order to continue participating in sport. However, we admit the legal peculiarities of this process, as illustrated previously [56]. Furthermore, the importance of self-determination and autonomy of adolescents, as well as the role of parents, should be considered. Hence, the long-term outcomes associated with shared decision making with the concerned athletes and their parents, both favourable and adverse, have yet to be documented and represent an important area of future research.

Following the 2019 COVID-19 pandemic, a number of considerations emerged on the resumption of high-level physical activity in general [57–59] and specifically for children and adolescents [60]. Furthermore, *Sport & Exercise Medicine Switzerland* edited a specific flowchart for return to play after COVID-19 [61].

Proposal: Individualised counselling with shared decision making including parents' advice and close follow-up may enable athletes with abnormal findings to continue their sport on a lower level considering their own benefit-harm balance.

Further efforts to prevent SCD in athletes

Prevention in the form of emergency action planning should extend beyond screening to encompass training in cardiopulmonary resuscitation and the use of an automated external defibrillator. The benefit of a prompt response is evidenced by data documenting that survival after sports-related sudden cardiac arrest is 1.7–2.7 more common than in the general population [34]. However, survival to hospital discharge in trained athletes with a median age of 17 years remained low at 25%, even though resuscitation was initiated within three minutes, compared with 3% when this time delay was longer [32].

Proposal: Other preventive measures such as resuscitation training and use of automated external defibrillator remain of paramount importance.

Swiss Paediatric Athletes Database (Swiss PAED)

In this rapidly evolving field, more data are required not only to elucidate the clinical implications of cardiac adaptation in pre-, peri- and post-pubertal athletes, but notably to identify markers of increased risk. Therefore, the national registry Swiss Paediatric Athletes ECG Database (Swiss PAED) was initiated as a collaborative project between paediatrics, paediatric cardiology, cardiology and sports medicine. It is anticipated that this registry will serve as a common platform for further research topics in this area. All stakeholders implied in the care for paediatric and adolescent athletes are encouraged to join this database for research purposes relevant to the safety of sports.

Proposal: The Swiss Paediatric Athletes ECG Database (Swiss PAED) will serve as national registry for athletes younger than 18 years.

Suggested PPCE and follow-up algorithm

Based on the presented findings, we suggest an algorithm for PPCE and follow-up in paediatric and adolescent competitive athletes in Switzerland (fig. 2). We recommend screening of all athletes under 18 years of age with medical history and physical examination utilising comprehensive questionnaires, such as the American Heart Association 14-Element Screening [28] or the American Academy of Paediatrics 5th PPE Monograph [29]. Abnormal findings on history and physical examination should be further evaluated by a paediatric cardiologist, which may include an ECG if indicated. Among pre-pubertal athletes as measured by Tanner stages, or younger than 15 years, PPCE should be limited to history and physical examination and be conducted serially at 2-year intervals. Given the low incidence of SCD in pre-pubertal individuals, we suggest ECG-inclusive PPCE, using the International ECG Interpretation Criteria for Athletes [30] be applied in post-pubertal athletes according to Tanner stages, or from 15 years. Among athletes with normal ECG findings, we recommend repeat ECG-inclusive PPCE at 2-year intervals. In the case of an isolated borderline ECG finding, we suggest yearly follow-up including ECG. In cases of two borderline or any abnormal ECG finding, we recommend a comprehensive evaluation under the supervision of a paediatric cardiologist. Of note, the detailed investigation of these assessments must be individualised as a function of the nature of the suspected pathology and go beyond the scope of this article [30]. For athletes with abnormal ECG findings that are not found to have explanatory pathology after comprehensive evaluation, we recommend yearly follow-up to rule out the emergence of phenotypic cardiomyopathic disease [30]. Athletes with abnormal findings on further investigations are subject to treatment according to the ESC guidelines on sports cardiology and exercise in patients with cardiovascular disease [27]. Depending on the type of pathology, limiting sports participation or even temporary restriction from athletic activity may be indicated as advised by a paediatric cardiologist and/or sports medicine physician [30]. As mentioned above, this document is not intended for use among patients with congenital heart disease who require individualised risk stratification and activity prescription under the supervision of a paediatric cardiologist. Of note, these proposals (table 4) are confined to how and when to perform the PPCE. Alternative screening topics including nutritional behaviour, psychological impact, substance abuse, etc. may best be approached by different strategies. For individuals older than 18 years, we suggest transition to adult sports cardiology institutions listed by Sport & Exercise Medicine Switzerland or the Swiss Working Group for Cardiovascular Prevention, Rehabilitation and Sports Cardiology.

Conclusion

Guidelines delineating PPCE among adults have evolved over several decades and now represent clinically accepted standard of care [31]. The use of routine ECG for screening remains the major controversy between the ESC approach [31] and American protocols [62]. With the development of new ECG criteria, identification of individuals at risk becomes more accurate [39]. In contrast, PPCE protocols

Table 4:
Overview of proposals for preparticipation evaluation in Swiss paediatric and adolescent athletes.

Issue	Proposal
Indication	Identification of paediatric/adolescent athletes at risk for SCD
Definition	Competitive sports participation in a squad for at least 6h/week
Target group	Under 18 years, any sex, any ethnicity, excluding patients with CHD
Methods	Under 15 years: medical history and physical examination
	From 15 years on: ECG-inclusive screening
ECG criteria	International Criteria for Electrocardiographic Interpretation in Athletes
Costs	Comparable to other countries, appropriate to avoid SCD in the young
Limits	Low prevalence of SCD requires regular follow-up
Follow-up	Regularly due to emergence of pathologies over time and with growth
Counselling	Individualised approach and shared decision-making
SCD prevention	Resuscitation training and AED use on the field
Swiss PAED	National electrocardiographic registry for athletes under 18 years

AED: automated external defibrillator; CHD: congenital heart disease; ECG: electrocardiogram; SCD: sudden cardiac death

for use among paediatric and adolescent aged athletes (< 18 years) have yet to be universally established. A first model was presented by the Association of European Paediatric Cardiology [63]. In our proposals, we precise the target group, analyse costs and limits and evolve the algorithm with a focus on follow-up and further investigations among paediatric and adolescent athletes in Switzerland (fig. 2).

Class of recommendation: IIa (should be considered)

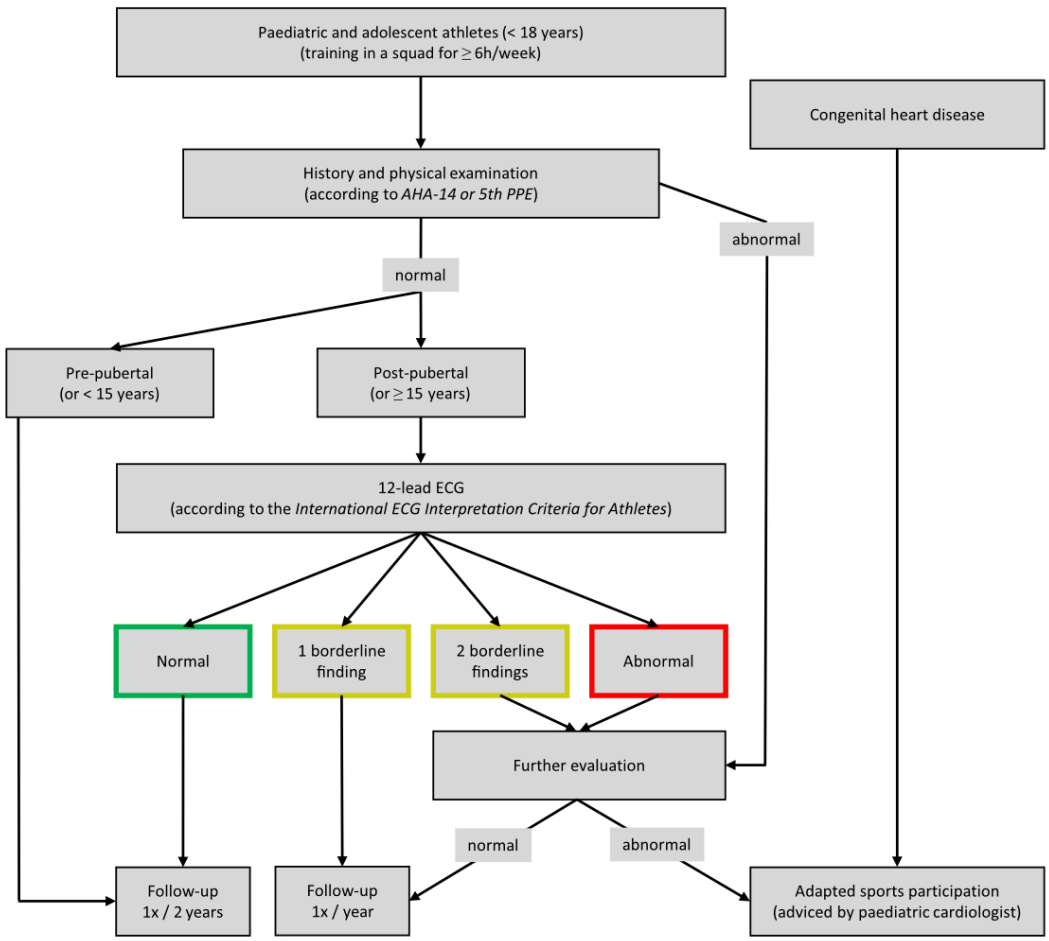
Level of evidence: C (expert opinion)

Endorsed by the Swiss Society of Paediatric Cardiology, the Sport & Exercise Medicine Switzerland and the Swiss Working Group for Cardiovascular Prevention, Rehabilitation and Sports Cardiology (branch of the Swiss Society of Cardiology)

Acknowledgement
We thank Dr Roland Grossen (Swiss Football Association), Dr Gery Büsser (Swiss Ice Hockey Federation), Remo Manser (Swiss Unihockey) and David Burckhardt (Swiss Aquatics) for providing information regarding current screening procedures in their sports federations. Furthermore, we thank Mrs Staubli from the Children's Hospital Zürich for graphical assistance.

Conflicts of interest
All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. Professor Matthias Wilhelm declared payments as unrestrict-

Figure 2: Preparticipation cardiovascular evaluation and follow-up algorithm for paediatric and adolescent athletes in Switzerland.



ed educational grants from various pharmaceutical companies for national and international educational events, not influencing personal views and decisions, in particular not with regard to this manuscript, chairing and participating in advisory boards from Böhringer, Astra Zeneca and Novartis (unpaid) with time compensation payment to his institution. Furthermore, he is the current president of the Swiss Working Group for Cardiovascular Prevention, Rehabilitation and Sports Cardiology, a board member of the EAPC and a foundation member of the Swiss Heart Foundation. Dr. Matthias Gass declared consulting fees from Abbot Medical Germany and Proctor Pediatric EP. Dr. Dominik Stambach declared his function as a board member of the Swiss Society of Paediatric Cardiology (unpaid).

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