

# The Pre-Participation Examination in Sports: EFSMA Statement on ECG for Pre-Participation Examination

*Die sportärztliche Vorsorgeuntersuchung: Stellungnahme der EFSMA zur Bedeutung des EKG in der Vorsorgeuntersuchung*

## Summary

- › **Goals of pre-participation examination (PPE)** in athletes are primarily to protect health of athletes. This applies for children, adolescents, leisure time and top athletes. To recognise early possible risks, history and clinical examination is agreed to be the basis of PPE. However, there is a long-standing controversy about whether ECG at rest should also be mandatory for all athletes. ECG is rejected in the US but included in most European countries.
- › **In addition, some large sports organisations also require ECG** in PPE of athletes. The resting ECG can detect potential life-threatening diseases such as cardiomyopathies or ion-channel diseases, thus avoiding sudden cardiac events or even death. The present paper discusses many arguments pro and contra ECG in athlete's screening. Arguments against are organisational problems, as sports physicians are not present nationwide in the US. Main arguments against are the lack of large prospective studies demonstrating reduced mortality by ECG, and the low sensitivity, specificity and predictive values of the ECG.
- › **However, current studies**, new stringent and reliable criteria for ECG interpretation (e.g. Seattle criteria) increased the validity: false positive and negative findings decrease significantly. This is also supported by new, athlete-related ECG interpretation software in ECG devices, which are more reliable than visual analysis. This also may reduce legal problems, whereas psychological problems are of low importance as has been shown recently. Therefore, ECG recording in all athletes is strongly recommended in Europe. ECG is superior to history and clinical exam in detecting hidden and congenital diseases.
- › **However, special education in sports cardiology** is advised, courses and training in ECG interpretation in athletes, as well as special ECG devices are mandatory for correct ECG interpretation in athletes.

## KEY WORDS:

ECG, Athlete, Pre-Participation Examination, PC-Analysis of ECG, Sports Cardiology,

## Introduction

Regular physical activity is an evidence based approach to prevention and treatment of many diseases with highest class level of evidence (IA) (10, 19, 34). Physical activity reduces not only cardiovascular mortality, but also mortality and morbidity for all-cause mortality, including metabolic disorders and certain kinds of cancer.

## Zusammenfassung

- › **Ziel einer sportärztlichen Vorsorgeuntersuchung** ist die Gesundheitsvorsorge. Sportler sollen vor möglichen Risiken und Erkrankungen geschützt werden. Dies betrifft sporttreibende Kinder, Jugendliche, aber auch Freizeit-, Alters-, und Leistungssportler. Während Erhebung der Anamnese und klinische Untersuchung allgemein anerkannt sind, ist die Ableitung eines Ruhe-EKG umstritten, letzteres wird in USA abgelehnt, in Europa aber fast überall routinemäßig durchgeführt.
- › **Verschiedene Sportorganisationen fordern** ebenfalls ein EKG (IOC, FIFA, FISO). Argumente gegen das Ruhe-EKG sind organisatorische Aspekte. In den USA gibt es nicht genügend Sportärzte für eine flächendeckende Versorgung. Auch juristische Aspekte spielen eine Rolle bei möglichen Fehldiagnosen. Neben der bisherigen niedrigen Sensitivität, Spezifität und Vorhersagewert des EKG gilt das Fehlen einer prospektiven Studie zur Senkung der Mortalität durch ein Ruhe-EKG als wichtiges Gegenargument. Demgegenüber können viele potentiell gefährdende Erkrankungen wie Kardiomyopathien oder elektrische Erkrankungen des Reizleitungssystems im EKG erkannt werden.
- › **Neue Studien** sowie die Einführung verbesserter, zuverlässiger EKG-Kriterien bei Sportlern haben aber die Validität (Vorhersagewert) des EKG beim Sportler erheblich verbessert (u.a. Seattle Kriterien). Falsch positive und falsch negative Befunde nehmen deutlich ab. Durch eine computerunterstützte Analyse im Vergleich zur rein visuellen Befundung werden die Ergebnisse weiter verbessert. Neuere EKG Geräte verfügen zudem über eine spezielle Auswertesoftware für das EKG eines Sportlers. Die Abwägung zahlreicher Pro- und Contra-Aspekte zum Ruhe-EKG des Sportlers ergibt einen hohen prädiktiven Wert des EKG, dieser übersteigt den der Anamnese und klinischen Untersuchung. Die EKG-Aufzeichnung sollte fester Bestandteil einer sportärztlichen Untersuchung sein.
- › **Zu fordern** ist aber eine qualifizierte sportkardiologische Fortbildung und Sportler-EKG Fortbildung für Untersucher und möglichst die Verwendung einer speziellen EKG-Analyse-Software im EKG-Gerät.

## SCHLÜSSELWÖRTER:

EKG, Sportler, Vorsorgeuntersuchung, PC-EKG Analyse, Sportkardiologie

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1. PRACTICE FOR CARDIOLOGY, SPORTS MEDICINE, Remscheid, Germany
2. KAROLINSKA UNIVERSITY HOSPITAL STOCKHOLM, Swedish School of Sport and Health Sciences, Stockholm, Sweden
3. ROYAL COLLEGE OF SURGEONS IN IRELAND, Dublin, Ireland
4. UNIVERSITY WIEN, Zentrum für Sportwissenschaft, Abt. Sport- und Leistungsphysiologie, Wien, Austria
5. PRIVATE PRACTICE, Hasselt, Belgium



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## KORRESPONDENZADRESSE:

Herbert Löllgen, MD, Prof., FACC, FFIMS  
Practice for Cardiology, Sports Medicine  
Bernesgasse 32b  
42897 Remscheid  
✉: loellgen@dgsp.de

It is the task of the sports physician to protect the health of exercising persons and to prevent any complication during activity (either) including both cardiovascular or/ and traumatological. Do no harm is the goal.

In addition to positive effects of regular PA, more vigorous activity, such as sports, may increase the risk of sudden cardiac death (SCD), in individuals with underlying cardiovascular disease. Preparticipation examination (PPE) is the major tool to prevent negative events, by identifying individuals with increased risk, due to underlying cardiac disease. Thus, the PPE complements adequate safety at sporting arenas, by medical action plans including defibrillators, to treat SCD in athletes and leisure time athletes, as well (2, 15, 20, 27, 38).

### Goals of PPE are Primarily to Protect Health of Athletes

- to make sports activity of children and adolescents safe, and to do the same for all adults engaging in leisure time activities (12, 13, 25, 27),
- to recognise very early possible risks, signs and symptoms, of underlying cardiovascular disease (inherited or acquired) associated with higher risk of SCD in sports. The aim is to treat or correct this abnormality before starting with sports activities, if this is possible, otherwise treat and give individual advice on proper sports eligibility (24, 25, 27).
- to analyze if there are inborn diseases with possible hazards such as channelopathies or cardiomyopathies (12, 30, 35, 43).
- after PPE to recommend how to perform sports and activities for prevention, rehabilitation and therapy, especially for exercise prescription for health (14).

### History

Preparticipation examination and history taking are the same in European countries as in the USA (3, 27, 32, 34), and other countries, according to best clinical practice. The self-describing sheet for history should contain the medical history, family history with an emphasis on premature sudden cardiac events in the family, and a history of the previous sports activities. In addition, the sports physician should ask for possible congenital cardiac diseases (if they are known), e.g. Marfan's syndrome, and for effort-related symptoms like dyspnoe, chest pain, dizziness, syncope and palpitations. The documentation should ideally be uniform and standardised in all European countries (sheet to be prepared by EFSMA). Congenital diseases with higher risks are, for example all cardiomyopathies (CMP), esp. hypertrophic CMP, but also hypertension and electrical diseases such as channelopathies or WPW-syndrome (30, 35, 43, 44, 46).

### Physical examination

Physical examination should consider sign and symptoms of Marfan's Syndrome (e.g. basketball players) and thorax inspection. Cardiac auscultation has to be done in the supine and standing position to better hear a possible systolic murmur due to HOCM or mitral valve insufficiency or -prolapse. Blood pressure measurements are performed in the sitting position and peripheral pulses (carotids, femoral and radial) should be checked (Coarctation of the aorta), followed by lung auscultation and abdominal palpitation. Check also for lymphnodes and possible tumor of testes in young males. All findings have to be documented in a uniform standardized sheet. (to be prepared by EFSMA). There is a need for such a standardized sheet (31, 33, 38, 47).

History and physical examination may often have false positive findings, also compared to the ECG at rest (14.5 vs. 2.8 %) (22, 45), thus leading to further testing, if not combined with the ECG.

While having a low specificity, history and clinical examination are classical examinations of each doctor and belong to the mandatory medical armamentarium (good clinical practice, GCP). Unfortunately, clinical exam will be done in only 47% by physicians, with slightly higher numbers in Germany, but not satisfactory (26). Importantly, the history and clinical findings should always be complemented by a 12-lead resting-ECG to increase the yield of the screening (3, 4, 45).

### ECG at Rest

ECG and more detailed examinations are routinely performed in USA in elite or professional athletes and cardiac screening is considered very important by the AHA for ethical and public health reasons. However, there is a longstanding controversy on the significance of an ECG as part of PPE for all competitive athletes: ECG is not routinely recommended in US screening for children and high school athletes, while it is routinely recorded within PPE in most European countries. Also, ECG is recommended by most sports medicine federations in Europe (4, 6, 9, 11, 13, 25, 29, 33).

Arguments pro and contra have often been discussed and published, and is summarized below. This statement from EFSMA informs on current aspects and pro and cons.

### Pros and Cons with Regard to ECG at Rest During PPE

#### Scientific Evidence

**Contra:** One of the main arguments against (ECG in) PPE at all, is that evidence is lacking based on prospective randomised studies with hard endpoints (32, 38).

**Pro:** However, lack of evidence is not evidence of lack of effect. This is an argument against screening at all, not against screening with the ECG (30, 39, 37).

#### Sensitivity and Specificity of ECG-Screening

**Contra:** Sensitivity and specificity are low, so false positive and false negative findings are too frequent (24, 32, 38, 42).

**Pro:** Sensitivity and specificity of history and clinical examination are much lower, with high false positives in young athletes, and less reliable than the ECG at rest, (2, 3, 11, 22, 42, 45). Sensitivity and specificity have remarkably increased using the ESC-, and Seattle-Criteria and lately the „refined“ criteria (16, 17, 18, 19, 20, 37, 41). Further improvement is to be expected from the current Seattle conference on athletes ECG (2015). Automatic evaluation of athlete's ECG by a computer program with ECG device based on the Seattle criteria is now commercially available, and have made the interpretation more reliable than by visual alone (6).

#### ECG Interpretation Visual Versus PC ECG Device

**Contra:** ECG Interpretation by a physician using visual analysis alone is less reliable than machine read analysis.

**Pro:** Interpretation of ECG is by far more reliable by PC ECG device (6). Furthermore, US studies have shown that non-cardiologists are able to perform almost as good as cardiologists, using a simple "cook-book" sheet, summarizing the recommendations on "ECG interpretation in athletes" (12, 13, 16, 17, 18, 19, 20, 40).

### Psychological Aspects of Possible False Positive and Negative ECG Interpretations

**Contra:** Positive findings increase anxiety levels based on false positive results

**Pro:** Current findings do not support this, on the contrary, athletes feel more assured and has less psychological distress (1, 5, 6).

**Contra:** Correct positive and potentially endangering findings may frighten the athlete

**Pro:** There are many preventive and therapeutic measures to prevent lethal events for the athlete and in some cases for his family (e.g. ablation of cardiac structures (WPW), AED in the arena, or AICD implantation) (9, 26, 27, 29).

### Methodological and Logistic Aspects of ECG Screening

**Contra:** Screening is not possible due to large areas of the USA (including full states) and a paucity of sports physicians and lack of infrastructure (24, 32, 38).

**Pro:** Telemetric (or telephonic transmission) services may overcome this hurdle. The American Heart Association already recommends cardiac screening for all athletes, as necessary and ethical, but only by phys examination and personal history. So, the physician is already seeing the patient, and the addition of an ECG would be little time-consuming (45). The knowledge of the sports physician may have to be increased by education in ECG interpretation, and this is addressed by international courses, such as web-learnings (see Br J Sports Med, 2013). However, screening without ECG require similar level of professional competence, already today.

### Financial Aspects of ECG Recording

**Contra:** ECG is expensive and will not be covered by insurance companies. However, costs for ECG depends on the hospital ranking in the US and is much more expensive than in Europe (70-100 US \$ versus 30 to 40 Euros). (Besides, this is less than one tank full of gasoline or a pair of good running shoes). The great cost of cardiac screening is the physician and the room where to perform the screening. Screening with history and physical only will result in many symptoms, that needs to be evaluated, most certainly first by an ECG. Adding an ECG from the start would not add substantially to the costs, possibly even save some further investigations to history and physical alone (although not studied). The only way to make screening more cheap, is to not do it at all (5, 8, 9).

### Impacts of Positive and Negative ECG Findings on Athletes and their Family Members

**Pro:** Some positive ECG findings may advice against vigorous or competitive Sports. Thus life can be saved by early diagnosis (15, 33). In spite of this, positive finding on ECG, leisure time sports may be possible in most cases. Subjects with implanted devices such as pacemaker or AICD can participate in sports and moderate exercise, with the exception of contact and competitive sports (24).

**Pro:** In children and adolescents an ECG should be recorded during PPE once or twice before starting with sports, especially in competitive sports. This is less expensive than screening for congenital diseases in the infant. Admittedly, the interpretation of an ECG in children needs special knowledge and may also be done by special computer program in the ECG device. Here,

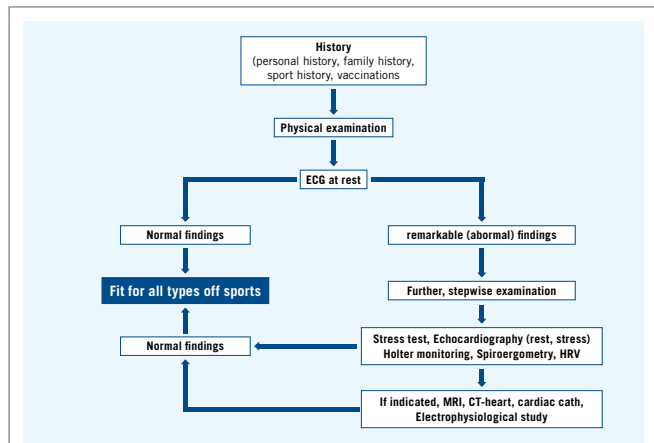


Figure 1

Flow chart of pre-participation examination as recommended by EFSMA (European Fed Sports Med. Associations). Abbreviations: MRI: Magnetic resonance imaging; HRV: Heart rate variability).

detailed recommendations of pediatric sports cardiologist should be followed (45).

**Pro:** Correct positive EKG-findings can save life in the children and/or in his family.

### Summary

To summarize, most arguments listed above argue in favour of ECG as part of the PPE.

PPE without the ECG has low sensitivity and will also likely have a very low specificity (too many vague symptoms). In addition, the ECG is very sensitive in cardiac screening, and the specificity is increasing constantly, as more evidence increase the interpretation of ECG recommendations. The only available prospective study of screening with the ECG is positive, while no studies on screening without ECG has shown any effects. These conclusion have recently been confirmed by a meta-analysis (fifteen papers) showing that ECG in athletes "is 5 times more sensitive than history, 10 times more sensitive then physical exam, has higher positive" and "lower negative likelihood ratio" with a "lower false positive rate" (24). For these reasons, the ECG is recommended and regularly included in the PPE in European countries (12, 13, 25).

### ECG in children and adolescents

One remaining problem is, that the ECG in children and adolescents (8-18 ys.) is rarely done during PPE, though the risk of sudden cardiac events due to genetic mutations is present, sometimes sudden death is the first documentation of a genetic variant (30, 35, 43, 44). For example, the sudden drowning death or near drowning in children is triggered in 30% by an unknown long QT-syndrome (43, 44). In addition, all these sudden deaths in childhood must be examined by molecular autopsy as a standard. Therefore, V.Vetter (45) demands ECG documentation in all neonates, children and youths. For the moment, European sports physicians recommend ECG at rest once in the youth and mandatory before high intensity sports or in competitive young athletes.

### Some more questions on PPE

Documentation of history and physical examination should ideally be performed in a standardised manner all over Europe. ➤

There should be a uniform and identical sheet, suitably adapted for electronic documentation, and preferably by an electronic card.

In all European countries and sports medicine federations, there should be experts in sports cardiology for counselling in case of borderline or abnormal finding in athlete's ECG (initiative of EFSMA). Considering carefully the Seattle and refined ECG criteria, this should be accepted as the standard examination. A new updated version of these criteria should be coming already in 2016.

### Recommendations for PPE in Europe

- Standardised history and clinical examination with „e-documentation“
- ECG at rest with 12 leads, computerized evaluation with athlete's ECG definitions if possible.

Additional education of sports physicians in athlete's ECG interpretation, possibly in combination with education in Exercise prescription for health. The first step is using the existing web-e-education (Brit J. Sport Med 2013 or ECG course by EFSMA). Every sports physician involved in sports ECG evaluation should have passed this e-ECG course. Further references are listed below (40).

### Time Schedule

ECG at rest once from 12 ys. on (45), before starting intensive sports or competitive sports, in all cases in the elderly, ECG is mandatory in all leisure time athletes (female and male). Beyond the age of 35 ys., physicians should follow the European recommendations (8, 9, 10), for pragmatic self assessment and

further screening of risk patients, with stress testing. In case of abnormal findings, such as symptoms and signs and abnormal ECG, further examinations are recommended as shown in Fig.1.

Exercise testing (incl. ECG) is recommended in patients with diabetes (in males > 40 ys, females > 50 ys.) and in asymptomatic subjects before vigorous sports (males > 45 ys., females > 55 ys., Guidelines EAPCR (8). At the same time, physical capacity should be measured by exercise testing for risk estimation and evaluation of future risk. For details see the FYSS-Book (10), the official EFSMA physical activity-prescription reference book.

Again, a standardized procedure for all competitive athletes, is strongly recommended, documentation has to be performed. Irrespective from these recommendations, the very top elite athletes may be required to undergo a more detailed examination (IOC, FIFA, FISO) including exercise testing, echocardiography and more as indicated according to cardiology guidelines. However, the scientific evidence for screening with echocardiography is still weak.

### Short Advice and Counselling for Physical Activity

As an advice to all physicians, every physician at every contact with a patient should ask about the physical activity or exercise deficiency syndrome (EDS) as a mandatory part of history (as a fifth vital sign) besides other risk factors. This is most important for exercise prescription for health in inactive or sedentary subjects and patients.

### Conflict of Interest

All authors report no conflict of interest with regard to this paper

### References

- (1) ASIF IM, SCHMIEG J, SMITH T, JOHNSON S, RAO AL, HARMON KG, DREZNER JA, SALERNO JC. The psychological impact of cardiovascular screening: The athlete's perspective. Br J Sports Med. 2014; 48: 1162-1166. doi:10.1136/bjsports-2014-093500
- (2) ASIF IM, RAO AL, DREZNER JA. Sudden cardiac death in young athletes: What is the role of screening? Curr Opin Cardiol. 2013; 28: 55-62. doi:10.1097/HCO.0b013e32835b0ab9
- (3) ASIF IM, DREZNER JA. Detecting occult cardiac disease in athletes: History that makes a difference. Br J Sports Med. 2013; 47: 669-674. doi:10.1136/bjsports-2013-092494
- (4) BAGGISH AL. A decade of athletes ECG criteria: Where we've come and where we're going. J Electrocardiogr. 2015; 48: 324-328. doi:10.1016/j.electrocard.2015.02.002
- (5) BERGE HM, STEINE K, ANDERSEN TE, SOLBERG EE, GJESDAL K. Measurement methods is important for interpretation of athlete's ECG. Br J Sports Med. 2014; 48: 567-568. doi:10.1136/bjsports-2014-093494.22
- (6) BERGE HM, STEINE K, ANDERSEN TE, SOLBERG EE, GJESDAL K. Visual or computer-based measurements: important for interpretation of athletes' ECG. Br J Sports Med. 2014; 48: 761-767. doi:10.1136/bjsports-2014-093412
- (7) BILLE K, FIGUEIRAS D, SCHAMASCH P, KAPPENBERGER L, BRENNER JI, MEIJBOOM FJ, MEIJBOOM EJ. Sudden cardiac death in athletes: The lausanne recommendations. Eur J Cardiovasc Prev Rehabil. 2006; 13: 859-875. doi:10.1097/01.hjr.0000238397.50341.4a
- (8) BÖRJESSON M, URHAUSEN A, KOUIDI E, DUGMORE D, SHARMA S, HALLE M, HEIDBUCHEL, BJÖRNSTAD HH, GIELEN S, MEZZANI A, CORRADO D, PELLICCIA A, VANHEES L. Cardiovascular evaluation of middle-aged/senior individuals engaged in leisure-time sport activities: position stand from the sections of exercise physiology and sports cardiology of the European Association of Cardiovascular Prevention and Rehabilitation. Eur J Cardiovasc Prev Rehabil. 2011; 18: 446-458. doi: 10.1097/HJR.0b013e32833bo969
- (9) BÖRJESSON M, DELLBORG M. Is there evidence for mandating electrocardiogram as part of the pre-participation examination? Clin J Sport Med. 2011; 21: 13-17. doi:10.1097/JSM.0b013e318204a7b4
- (10) BÖRJESSON M, HELLENIUS ML, JANSSON E, KARLSSON J, LEIJON M, STÄHLE A, SUNDBERG CJ, TAUBE J. Physical activity in the prevention and treatment of disease. Swedish National Institute, Stockholm, 2010 (new edition in 2015)
- (11) BROSNAN M, LA GERCHE A, KALMAN J, LO W, FALLON K, MACISAAC A, PRIOR D. The Seattle Criteria increase the specificity of preparticipation ECG screening among elite athletes. Br J Sports Med. 2014; 48: 1144-1150. doi:10.1136/bjsports-2013-092420
- (12) CORRADO D, PELLICCIA A, BJÖRNSTAD HH, VANHEES L, BIFFI A, BORJESSON M, PANHUYZEN-GOEDKOOP N, DELIGIANNIS A, SOLBERG E, DUGMORE D, MELLWIG KP, ASSANELID, DELISE P, VAN-BUUREN F, ANASTASAKIS A, HEIDBUCHEL H, HOFFMANN E, FAGARD R, PRIORI SG, BASSO C, ARBUSTINI E, BLOMSTROM-LUNDQVIST C, MCKENNA W, THIENE G. Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol. Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. Eur Heart J. 2005; 26: 516-524. doi:10.1093/eurheartj/ehi108
- (13) CORRADO D, PELLICCIA A, HEIDBUCHEL H, SHARMA S, LINK M, BASSO C, BIFFI A, BUJA G, DELISE P, GUSSAC I, ANASTASAKIS A, BORJESSON M, BJÖRNSTAD HH, CARRE F, DELIGIANNIS A, DUGMORE D, FAGARD R, HOOGSTEEN J, MELLWIG KP, PANHUYZEN-GOEDKOOP N, SOLBERG E, VANHEES L, DREZNER J, ESTES NA 3RD, ILCETO S, MARON BJ, PEIDRO R, SCHWARTZ PJ, STEIN R, THIENE G, ZEPPELLI P, MCKENNA WJ. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. Eur Heart J. 2010; 31: 243-259. doi:10.1093/eurheartj/ehp473
- (14) CUMMISKEY J. The green prescription: Exercise for health. 2013 RCSI House, St. Stephen's Green, Dublin 2
- (15) DOUGLAS PS. Saving Athletes' Lives A Reason to Find Common Ground? J Am Coll Cardiol. 2008; 52: 1997-1999. doi:10.1016/j.jacc.2008.07.069
- (16) DREZNER J, BERGER S, CAMPBELL R. Current Controversies in the Cardiovascular Screening of Athletes. Current Sports Medicine Reports. 2010; 9: 86-92. doi:10.1249/JSR.0b013e3181d573d6

- (17) DREZNER JA, ACKERMAN MJ, ANDERSON J, ASHLEY E, ASPLUND CA, BAGGISH AL, BÖRJESSON M, CANNON BC, CORRADO D, DIFIORI JP, FISCHBACH P, FROELICHER V, HARMON KG, HEIDBUCHEL H, MAREK J, OWENS DS, PAUL S, PELLICCIA A, PRUTKIN JM, SALERNO JC, SCHMIED CM, SHARMA S, STEIN R, VETTER VL, WILSON MG. Electrocardiographic interpretation in athletes: the 'Seattle criteria'. *Br J Sports Med.* 2013; 47: 122-124. doi:10.1136/bjsports-2012-092067
- (18) DREZNER JA, FISCHBACH P, FROELICHER V, MAREK J, PELLICCIA A, PRUTKIN JM, SCHMIED CM, SHARMA S, WILSON MG, ACKERMAN MJ, ANDERSON J, ASHLEY E, ASPLUND CA, BAGGISH AL, BÖRJESSON M, CANNON BC, CORRADO D, DIFIORI JP, HARMON KG, HEIDBUCHEL H, OWENS DS, PAUL S, SALERNO JC, STEIN R, VETTER VL. Normal electrocardiographic findings: recognising physiological adaptations in athletes. *Br J Sports Med.* 2013; 47: 125-136. doi:10.1136/bjsports-2012-092068
- (19) DREZNER JA, ASHLEY E, BAGGISH AL, BÖRJESSON M, CORRADO D, OWENS DS, PATEL A, PELLICCIA A, VETTER VL, ACKERMAN MJ, ANDERSON J, ASPLUND CA, CANNON BC, DIFIORI J, FISCHBACH P, FROELICHER V, HARMON KG, HEIDBUCHEL H, MAREK J, PAUL S, PRUTKIN JM, SALERNO JC, SCHMIED CM, SHARMA S, STEIN R, WILSON M. Abnormal electrocardiographic findings in athletes: recognising changes suggestive of cardiomyopathy. *Br J Sports Med.* 2013; 47: 137-152. doi:10.1136/bjsports-2012-092069
- (20) DREZNER JA, ACKERMAN MJ, CANNON BC, CORRADO D, HEIDBUCHEL H, PRUTKIN JM, SALERNO JC, ANDERSON J, ASHLEY E, ASPLUND CA, BAGGISH AL, BÖRJESSON M, DIFIORI JP, FISCHBACH P, FROELICHER V, HARMON KG, MAREK J, OWENS DS, PAUL S, PELLICCIA A, SCHMIED CM, SHARMA S, STEIN R, VETTER VL, WILSON MG. Abnormal electrocardiographic findings in athletes: recognising changes suggestive of primary electrical disease. *Br J Sports Med.* 2013; 47: 153-167. doi:10.1136/bjsports-2012-092070
- (21) BAGGISH AL, HUTTER AM JR, WANG F, YARED K, WEINER RB, KUPPERMAN E, PICARD MH, WOOD MJ. Cardiovascular screening in college athletes with and without electrocardiography: a cross-sectional study. *Ann Intern Med.* 2010; 152: 269-275. doi:10.7326/0003-4819-152-5-201003020-00004.
- (22) FUDGE J, HARMON KG, OWENS DS, PRUTKIN JM, SALERNO JC, ASIF IM, HARUTA A, PELTO H, RAO AL, TORESDAHL BG, DREZNER JA. Cardiovascular screening in adolescents and young adults: a prospective study comparing the Pre-participation Physical Evaluation Monograph 4th Edition and ECG *Br J Sports Med.* 2014; 48: 1172-1178.
- (23) HARMON KG, DREZNER JA, OWENS D, PRUTKIN JM, MALESZEWSKI JJ, LOPEZ-ANDERSON M, ACKERMAN MJ, ASIF IM, KLOSSNER D. Pathogenesis of sudden cardiac death in national collegiate athletic association athletes. *Circ Arrhythm Electrophysiol.* 2014; 7: 198-204. doi:10.1161/CIRCEP.113.001376
- (24) HARMON K G, ZIGMAN M, DREZNER JA. The effectiveness of screening history, physical exam, and ECG to detect potentially lethal cardiac disorders in athletes: A systematic review/meta-analysis. *Journal of Electrocardiology.* 2015; 48: 329-338. doi: 10.1016/j.jelectrocard.2015.02.001
- (25) JENOURE PJ. The preparticipation physical examination in Europe: All around the pre-participation examination. *Eur Fed Sports Med Federations.* www.efsm.net. Accessed March 19, 2013.
- (26) LAMPERT R, OLSHANSKY B, HEIDBUCHEL H, LAWLES C, SAARE E, ACKERMAN M, CALKINS H, ESTES NA, MARK S, LIN MS, MARON BJ, MARCUS F, SCHEINMAN M, WILKOF BL, ZIPES DP, BERUL CI, CHENG A, LAW I, LOOMIS M, BARTH C, BRANDT C, DZIURA J, LI F, CANNON C. Safety of Sports for Athletes With Implantable Cardioverter-Defibrillators. Results of a Prospective Multinational Registry *Circulation.* 2013; 127: 2021-2030.
- (27) LAWLESS C. Protecting the heart of the American athletes. *J Am Coll Cardiol.* 2014; 64: 2146-2171. doi:10.1016/j.jacc.2014.08.027
- (28) LEYK D, RUETHER, WUNDERLICH M, SIEVERT AP, ERLEY OM, LÖLLGEN H. Utilization and implementation of sports medical screening examination – Survey of more than 10000 long distance runners. *Dtsch Arztebl int.* 2008; 105: 609-614.
- (29) LÖLLGEN H, LEYK D, HANSEL J. The preparticipation examination for leisure time physical activity. *Dtsch Arztebl Int.* 2010; 107: 742-749.
- (30) LÖLLGEN H, LÖLLGEN R. Genetics, genetic testing and sports: Aspects from sports cardiology. *Genomics. Soc Policy.* 2012; 8: 32-47.
- (31) MADSEN NL, DREZNER JA, SALERNO JC. Sudden cardiac death screening in adolescent athletes: an evaluation of compliance with national guidelines. *Br J Sports Med.* 2012; 0: 1-6. doi:10.1136/bjsports-2012-091670
- (32) MARON BJ, FRIEDMAN RA, KLIGFIELD P, LEVINE BD, VISKIN S, CHAITMAN BR, OKIN PM, SAUL JP, SALBERG L, VAN HARE GF, SOLIMAN EZ, CHEN J, MATHERNE GP, BOLLING SF, MITTEN MJ, CAPLAN A, BALADY GJ, THOMPSON PD. Assessment of the 12-lead electrocardiogram as a screening test for detection of cardiovascular disease in healthy general populations of young people (12-25 years of age): A scientific statement from the American Heart Association and the American College of Cardiology. *J Am Coll Cardiol.* 2014; 64: 1479-1514. doi:10.1016/j.jacc.2014.05.006
- (33) PELLICCIA A. The preparticipation cardiovascular screening of competitive athletes: is it time to change the customary clinical practice? *Eur Heart J.* 2007; 28: 2703-2705. doi:10.1093/eurheartj/ehm455
- (34) PESCATELLO LS. ACSM Guidelines for exercise testing and prescription. 9th ed., Wolters, Kluwer Baltimore, 2014.
- (35) PRIORI SG, WILDE AA, HORIE M, CHO Y, BEHR ER, BERULC, BLOM N, BRUGADA J, CHIANG CE. HRS/EHRA/APHRs Expert Consensus Statement on the Diagnosis and Management of Patients with Inherited Primary Arrhythmia Syndromes. *Heart Rhythm.* 2013; 10: 1932-63. doi: 10.1016/j.hrthm.2013.05.014
- (36) RIDING NR, SHEIKH N, ADAMUZ C, WATT V, FAROOP A, WHYTE GP, GEORGE KP, DREZNER JA, SHARMA S, WILSON MG. Comparison of three current sets of electrocardiographic interpretation criteria for use in screening athletes. *Heart.* 2014; 0: 1-7. doi:10.1136/heartjnl-2014-306437
- (37) RIDING NR, SALAH O, SHARMA S, CARRE F, GEORGE KP, FAROQ A, HAMILTON B, CHALABI H, WHYTE GP, WILSON MG. Ecg and morphologic adaptations in arabic athletes: Are the european society of cardiology's recommendations for the interpretation of the 12-lead ECG appropriate for this ethnicity? *Br J Sports Med.* 2014; 48: 1138-1143. doi:10.1136/bjsports-2012-091871
- (38) ROBERTS WO, LÖLLGEN H, MATHESON GO, ROYALTY AB, MEEUWISSE WH, LEVINE B, HUTCHINSON MR, COLEMAN N, BENJAMIN HJ, SPATARO A, DEBRUYNE A, BACHL N, PIGOZZI F. Advancing the preparticipation physical evaluation: An ACSM and FIMS joint consensus statement. *Clin J Sport Med.* 2014; 24: 442-447. doi:10.1097/JSM.0000000000000168
- (39) SACKETT DL, ROSENBERG WMC, GRAY MJA, HAINES RB, RICHARDSON WS. Evidence, what it is and what it is not. *Brit J Med.* 1996.
- (40) SHARMA S, GHANI S, PAPADAKIS M. ESC criteria for ECG interpretation in athletes: better but not perfect. *Heart.* 2011; 97: 1540-1541. doi:10.1136/heartjnl-2011-300400
- (41) SHEIKH N, PAPADAKIS M, GHANI S, ZAIDI A, GATI S, ADAMI P, CARRÉ F, SCHNELL F, AVILA P, WILSON M, MCKENNA W, SHARMA S. Comparison of electrocardiographic criteria for the detection of cardiac abnormalities in elite black and white athletes. *Circulation.* 2014; 129: 1637-1649. doi:10.1161/CIRCULATIONAHA.113.006179
- (42) STEINVIL A, CHUNDADZE T, ZELTSER D, ROGOWSKI O, HALKIN A, GALILY Y, PERLUK H, VISKIN S. Mandatory electrocardiographic screening of athletes to reduce their risk for sudden death proven fact or wishful thinking? *J Am Coll Cardiol.* 2011; 57: 1291-1296. doi:10.1016/j.jacc.2010.10.037
- (43) TESTER DJ, ACKERMAN MJ. The role of molecular autopsy in unexplained sudden cardiac death. *Curr Opin Cardiol.* 2006; 21: 166-172. doi:10.1097/01.hco.0000221576.33501.83
- (44) TESTER DJ, ACKERMANN MJ. Postmortem long QT syndrome genetic testing for sudden unexplained death in the youth. *J Am Coll Cardiol.* 2007; 49: 240-246. doi:10.1016/j.jacc.2006.10.010
- (45) VETTER VL. Should electrocardiographic (ECG) screening of all infants children, and teenagers be performed? Electrocardiographic screening of all infants, children, and teenagers should be performed. *Circulation.* 2014; 130: 688-697. doi: 10.1161/CIRCULATIONAHA.114.009737
- (46) WILSON MG, BASAVARAJIAH S, WHYTE GP, COX S, LOOSEMORE M, SHARMA S. Efficacy of personal symptom and family history questionnaires when screening for inherited cardiac pathologies: The role of electrocardiography. *Br J Sports Med.* 2008; 42: 207-211. doi:10.1136/bjsm.2007.039420
- (47) WINGFIELD K, MATHESON GO, MEEUWISSE WH. Pre-participation evaluation: an evidence-based review. *Clin J Sport Med.* 2004; 14: 109-122. doi:10.1097/00042752-200405000-00002