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Cardiovascular Stress in Football Referees

Kardiovaskulärer Stress bei Fußball-Schiedsrichtern

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Summary

- ▶ **Problem:** As opposed to athletes, the cardiovascular strain of referees during a competition is neither systematically explored nor included in their cardiovascular screening programs.
- ▶ **Methods:** Twenty-one referees from the two upper Luxembourgish football divisions were monitored during and after a match with an ambulatory Holter electrocardiogram. The results were compared to a sports cardiological check-up including a maximal incremental test on the treadmill.
- ▶ **Results:** During the match, the referees evolved in average 17%, 32%, 34% and 17% in the "regenerative" (<80% of the HR of individual anaerobic threshold, IAT), "extensive" (80 - 87.5% IAT), "intensive" (87.6 - 102.5% IAT) and "high intensive" (>102.5% IAT) zones. During the match, the mean (154 ± 11 bpm, mean \pm SD) and maximal HR (180 ± 10 bpm) were only slightly lower than at the IAT (161 ± 9 bpm) and the end of the treadmill test (183 ± 11 bpm), respectively. ECG only revealed minor arrhythmias both during Holter monitoring and ergometry on the treadmill, but a higher incidence of premature beats during the 1.5h of the match than during the 15.5h off-match period. One referee showing significant ST segment depressions during the match suffered from a sudden cardiac exercise-associated event two years later.
- ▶ **Conclusion:** Football referees experience significant cardiovascular strain. A systematic endurance training is indispensable for football referees. Regular health monitoring, including a maximal exercise test on a treadmill ergometer, should be recommended not only for athletes but also for football referees.

Zusammenfassung

- ▶ **Fragestellung:** Im Gegensatz zu den Sportlern wurde bei Schiedsrichtern die kardiovaskuläre Beanspruchung während eines Spiels bisher weder systematisch untersucht noch in kardiovaskulären Screening-Programmen berücksichtigt.
- ▶ **Methoden:** Einundzwanzig Schiedsrichter aus den beiden oberen luxemburgischen Fußballligen wurden während und nach einem Spiel mit einem ambulanten Langzeit-EKG überwacht. Die Ergebnisse wurden mit denen eines sportkardiologischen Check-up einschließlich eines maximalen Stufentests auf dem Laufband verglichen.
- ▶ **Ergebnisse:** Während des Spiels befanden sich die Schiedsrichter im Durchschnitt zu 17%, 32%, 34% und 17% in den Bereichen „regenerativ“ (definiert als <80% der Herzfrequenz an der individuellen anaeroben Schwelle, IAS), „extensiv“ (80 - 87,5% IAS), „intensiv“ (87,6 - 102,5% IAS) und „hochintensiv“ (>102,5% IAS). Die mittlere (154 ± 11 /min, Mittelwert \pm SD) und die maximale Herzfrequenz (180 ± 10 /min) lagen während des Spiels nur geringfügig niedriger als an der IAS (161 ± 9 /min) bzw. am Ende des Laufbandtests (183 ± 11 /min). Das EKG zeigte sowohl im Langzeit-EKG als auch auf dem Laufband insgesamt nur geringgradige Arrhythmien, aber eine höhere Inzidenz von Extrasystolen während den 90 min des Spiels im Vergleich zu den 15,5 Stunden außerhalb des Spiels. Ein Schiedsrichter, der während des Spiels signifikante ST-Strecken-Senkungen aufwies, erlitt zwei Jahre später ein plötzliches kardiales Ereignis im Training.
- ▶ **Schlussfolgerung:** Fußballschiedsrichter sind einer erheblichen kardiovaskulären Beanspruchung ausgesetzt. Ein systematisches Ausdauertraining ist für Schiedsrichter unverzichtbar. Eine regelmäßige Gesundheitsüberwachung, einschließlich eines maximalen Belastungstests auf einem Laufband, sollte nicht nur für die Spieler, sondern auch für Fußballschiedsrichter empfohlen werden.

KEY WORDS:

Sudden Death, Cardiovascular Risk, Cardiovascular Strain, Soccer

SCHLÜSSELWÖRTER:

Plötzlicher Herztod, Kardiovaskuläres Risiko, kardiovaskuläre Beanspruchung, Fußball

Introduction

For nearly twenty years, sudden death during physical activity has become a concern of high priority in the field of sports medicine. In professional athletes as in football, these deaths were highly publicized in popular media and led to major discussions and regulations. Besides these cases of well-known athletes, there is a much higher number of less prominent unknown athletes of all ages suffering the same

fate. A Danish working group published data on the frequency of sudden cardiac death (SCD) among young people under the age of thirty-five years during sports activities and in general (29). This study reported a rate of SCD in young people of 2.8 per 100 000 person-years and about 11% of the SCDs occurred in the age group until 35 years during sports activity. Following these alarming events, research has



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been launched all over the world and sudden death prevention programs have been initiated (16). In Italy, a systematic program to detect the risk of competitive athletes, through systematic annual clinical examinations including an electrocardiogram (ECG) at rest has shown to result in a dramatic reduction in sudden death among athletes (7). The rationale for a systematic implementation of cardiac screening as well as its content is however still debated (15).

In the wake of several tragic incidents during football matches before the European Championships 2008, the European Football Association (UEFA) established a mandatory annual cardiovascular screening program at rest for all players of the participating teams.

Concerning international referees, the International Federation of Football Associations, FIFA only requires a medical certificate and for referees over the age of 45 on a case-by-case basis additional specific medical examinations and fitness testing. Among the aggravating factors for suffering a cardiac incident during sports, besides the physical intensity of the exercise, mental stress also plays an important

role. Cardiac complications such as myocardial infarction could be demonstrated during natural disasters, like earthquakes (23), but also during the World Soccer Championships in 2006, where German spectators, watching games of their own national team on television, had a two times higher risk to suffer a cardiovascular event (28). In rugby, one study showed that referees have a relatively greater cardiac risk (1 referee died per 3000 -hours) than athletes (1 per 50000 hours) due to their higher age, their cardiovascular risk profile and their often-poorer physical condition. The on field mental stress may furthermore be another aggravating factor. To the author's knowledge, no study has however been published on the specific cardiovascular strain of football referees. There are only a few studies dealing with orthopedic problems and muscular injuries (1) or describing the physical abilities in tests and the distances covered during a match (3-5, 8, 25-27). Therefore, this study has the following two objectives:

1. To study the cardiovascular health, including risk factors, and the running endurance physiological performance of referees in the first national football division in Luxembourg.
2. To evaluate cardiovascular stress, in terms of physical and psychic constraints, during a football match and the influence of endurance on cardiovascular reactions.

Material and Methods

The study was approved by the Medical Faculty of the University of Strasbourg, France and the University of Luxembourg. All 23 referees operating in the 2 upper football divisions of Luxembourg, including 9 "FIFA" and 14 "non-FIFA" referees, were informed about the study via the national football federation. Twenty-one participants gave their written informed consent to participate in the study.

During the first part of the study, from August to September, participants underwent a sports medical examination. The anamnesis and clinical examination as well as a venous blood analysis were conducted by a physician experienced in sports cardiology. The risk of sustaining cardiovascular events was assessed according to the Systematic Coronary Risk Evalua-

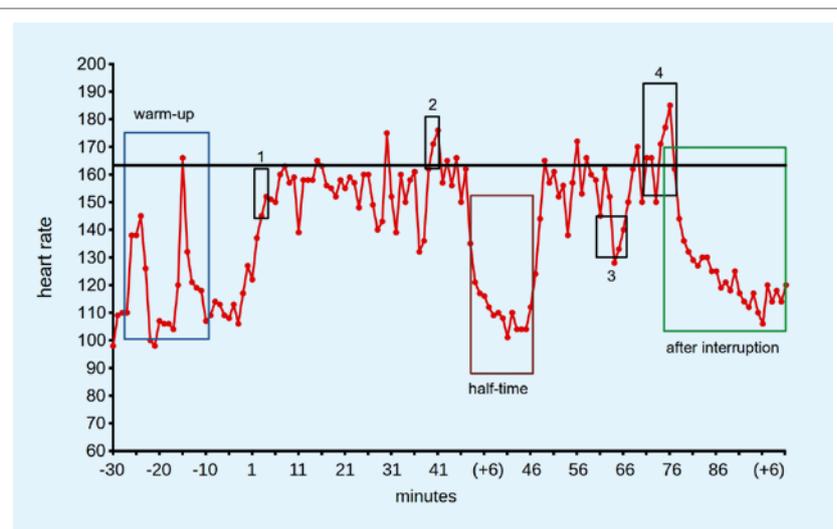


Figure 1

Example of a 145-minute observation period during the match (0 to 76 min in X-axis) with the highest number of stressful situations. 1 = yellow cart; 2 = yellow/red cart; 3 = yellow cart; 4 = yellow cart after contesting annulation of goal discussion - aggression on referee assistant and coach - match aborted. The black horizontal line shows the heart rate at the individual anaerobic threshold during the treadmill test.

tion (SCORE) based on gender, age, total cholesterol, systolic blood pressure and smoking status (2). Blood pressure was measured on both arms after 5 minutes in a supine position. The body mass index was determined with the results of measuring height and weight. Then, a 12-lead electrocardiogram (ECG) at rest and during a treadmill ergometer test (slope of +0.5 % and starting at 2.0 m/s, increasing every 3 min by 0.5 m/s until maximal volitional exhaustion) with capillary blood lactic measurements during exercise and the first 10 minutes after exercise to determine the individual anaerobic lactate threshold (IAT - 21) were performed. Blood pressure was taken manually on the left arm according to Riva-Rocci at the 2d and 3d stage during exercise as well 5 minutes after the end of the exercise. A high blood pressure during exercise was defined according to (21).

In the second examination-period from September to May, the referees received a 3-lead ECG Holter before, during and after an official match. The ECG holter was placed either at the referee's home or at the locker room a few hours before the match. Nine different stressful situations were pre-defined by an UEFA assistant referee (start of the match delayed due to any inconvenience, recalls or expulsions of a coach, penalties, yellow cards for a player who has committed an infringement of the game rules, red cards for a player who has committed a rule violation, stoppage of the match due to an assault on the refereeing body, match interruption due to an object throw / an invasion by spectators or animals / bad weather, post-match protest and serious injuries requiring substitution) and notified during each match by the same referee, together with the exact timing. By synchronizing the match referee clock with the Holter ECG time marker, an exact time assignment could be made between ECG events and the stressful situations. Each documented stressful situation was compared to the events of the Holter ECG and the HR was analyzed 30 seconds before, during and 30 seconds after. After the match, ECG Holter devices were worn until the next morning, allowing a total of 17-hour recording. The ECG recordings were evaluated by a physician experienced in sports cardiology. A detailed analysis of the HR was made during the 145 minutes of >

Table 1

Repertition of the different intensities during the 21 matches according to the mean times spent within the different heart rate zones related to the individual anaerobic threshold (IAT; measured on treadmill).

REGENERATIVE	MODERATE	INTENSIVE	HIGH INTENSIVE
< 80% IAT	80-87.5% IAT	87.5-102.5% IAT	> 102.5% IAT
17%	32%	34%	17%

the critical phase period surrounding/covering the match. The HR was recorded every 30 seconds during this time. The intensity of effort was determined by attributing the HR during the match to one of the following 4 categories: “regenerative” = < 80 % of the HR measured at the IAT on the treadmill; “moderate” = 80 – 87.5 % of the HR measured at the IAT on the treadmill; “intensive” = 87.6 – 102.5 % of the HR measured at the IAT on the treadmill “high intensive” = > 102.5 % of the HR measured at the IAT on the treadmill.

Statistical Analysis

The data were analyzed statistically and the basic parameters means and SD were reported. The differences and correlations between the 2 variables were explored by the Student’s t-test and linear regressions using the software “Statistical Package for the Social Sciences” (SPSS). The p-value was considered statistically significant when it was less than or equal to 5 % (0.05).

Results

Twenty-one (91 %) of the male referees agreed to participate in the study (age 36±8 years – range 21-50; height 179±6 cm, weight 84±10 kg; BMI 26±2 kg/m²). Seventeen referees showed at least one cardiovascular risk factor, and 2 referees had even 4 risk factors. Three subjects reported a myocardial infarction of the father at age below 55 years, 3 had a blood pressure at rest of above 140/90 mmHg, 2 were smokers or stopped less than 3 years before, 6 had a LDL cholesterol above 1.20 g/l, 2 a HDL cholesterol less than 0.40 g/l, 14 were overweight, 1 obese and none had diabetes. All subjects were at low SCORE risk of sustaining cardiovascular events within the next 10 years (2). The maximal performance on the treadmill was 15.8 ± 1.2 km/h at a maximal HR of 183 ± 11 beats per minute (bpm), the IAT as a marker of running endurance was 12.5 ± 1 km/h at an HR of 161 ± 9 bpm. Three referees showed an elevated blood pressure profile during and after exercise (2d stage, HR 148 ± 12 bpm: 172 ± 25 / 81 ± 9 mmHg; 5 min after exercise: 131 ± 17 / 81 ± 8 mmHg), two of whom with an elevated and one with a high-normal blood pressure at rest.

Twenty-one matches, one per referee, were investigated, 13 matches in the 1st and 8 in the 2nd division of the Luxembourg football league. The average duration of the match was 94 ± 4 min. Figure 1 shows an example of HR recording during and off-match. During the match, the mean HR was 154 ± 11 bpm, the maximum HR 180 ± 10 bpm. The average distribution of the intensity of effort is available in Table 1. There was a very weak inverse relationship ($p \leq 0.05$) between running endurance (IAT) and the maximum HR increase during the match, however influenced by the small number of subjects and some outliers.

A total of 94 stress situations were notified during 19 of 21 games: 0x start of the match delayed due to any inconvenience, 2x recalls or expulsions of a coach, 7x penalties, 76x yellow cards

for a player who has committed an infringement of the game rules, 5x red cards for a player who has committed a rule violation, 1x stoppage of the match due to an assault on the refereeing body, 0x match interruption due to an object throw / an invasion by spectators or animals / bad weather, 1x post-match protest and 2x serious injuries requiring substitution. There were no situations of stress in the other two games. Sixty-three goals were scored, with an average of 3 goals per match. The stress situations were accompanied by a significant increase ($p < 0.01$) in the HR of 16 ± 10 bpm. Figure 1 shows the HR during the match with the most stress situations for one referee as well his HR at the IAT on the treadmill.

The resting ECG revealed no pathological findings: Three referees showed an incomplete right bundle branch block, 1 an atrio-ventricular block of first degree (PQ interval 224 ms, normalizing during exercise), and 1 a deviated left axis with left anterior hemiblock. The ECG events in the ambulatory Holter monitoring during and outside the matches, as well as during the treadmill ergometry are shown in Table 2 (see supplemental material online). During the treadmill ergometry, only 5 referees demonstrated minor arrhythmias. During the game, almost all referees had isolated premature ventricular (PVC) and/or supraventricular contractions (PSVC). Related to time, ventricular arrhythmias were more frequent during the 1.5 h of the match itself compared with the approximately 15.5h off-match period. There was no clear relationship between the occurrence of the arrhythmias during the Holter monitoring during or outside the matches and the arrhythmias seen during the treadmill stress tests.

In one referee (number 14 in Table 2 (see supplemental material online); Figure 2) an asymptomatic ST-segment depression was found during the first 30 minutes of the match during two periods of elevated HR (160 respectively 176 bpm; maximum HR 184 bpm during the match and 186 bpm at the ergometric test; at the IAT of the treadmill test 164 bpm). During the treadmill ergometry, there were no significant ST-segment changes. This 47 year old referee presented an overweight with a BMI of 27.7 kg/m², an elevated blood pressure at 140/90 mmHg and a treated hypercholesterolemia. In the follow-up, a myocardial scintigraphy during maximal cycling ergometry had been asked without showing significant abnormalities. However, two years later, he suffered a sudden cardiac event during training.

Discussion

Football referees experience a considerable cardiovascular strain during matches. To the best of our knowledge, this is the first study to this day, which analyses the cardiac response in football referees during a football game and compares the results with a maximal exercise test in the ergometric lab.

The distance covered during a football match by an international field referee has been measured to be 11.200 ± 1050 m (8), which is quite similar to that of the players. It results that running endurance plays a crucial role in the physiological profile of a soccer referee (3). According to the few international studies carried out in England and Italy, the anaerobic threshold in professional football referees is between 11 and 14 km/h (5, 27). Referees should aim at an IAT of not lower than 90% of the level of the field players of the same level. By comparing with the German leagues (20) and according to our tests on the national level (unpublished results), running endurance (IAT) of a football referee could be considered as “good” if it is > 13 km/h, as “sufficient” if 12.5 - 13 km/h and as “insufficient” if < 12.5 km/h. In our study, on average, the IAT was just sufficient with

12.5 km/h, while 9 of the 21 referees had an insufficient running endurance.

During the match, the mean HR (154 bpm) was only slightly below the mean HR of the IAT (161 bpm) and corresponded to 84 % of the maximum HR of the treadmill ergometer test (mean value 183 bpm). This is in accordance with another study of the Italian group, reporting that a referee reaches 85 to 90 % of the maximum HR during a match (9). On average, during the match period, the referees were at 83 % in an intensity zone below their individual anaerobic threshold, while 17 % of the time, the intensity of the match was in a predominantly anaerobic zone, known to go along with progressive lactic accumulation over time.

The ECG recordings in our study revealed only minor arrhythmias during the treadmill ergometry as well as during the Holter monitoring. However, a higher number of premature ventricular and supraventricular extrasystoles were observed during the match compared to the 10-times longer off-match period. No clear relationship could be observed between the occurrence of the arrhythmias during the Holter monitoring during or outside the matches and the arrhythmias seen during the treadmill stress tests. The case of the one referee with significant ST-segment depression during the match, but not during maximal treadmill test despite reaching the same maximal HR and with an unsuspecting myocardial scintigraphy, raises questions because he suffered from a sudden cardiac exercise-associated event two years later. It may be speculated, that at this time still latent coronary abnormalities i.e. spasms could have been induced by the specific stress exposition of the match, exceeding the testing situations in the ergometric and cardiac lab, despite maximal volitional effort have been achieved.

Regarding the cardiovascular stress, the age and the cardiovascular risk profile of the tested referees, regular monitoring should be recommended for football referees. The average age of the referees tested was 36 years and the vast majority (17 of 21) had at least one cardiovascular risk factor. According to the Euro Score (2), all subjects had a low risk of presenting a cardiovascular event in 10 years. The treadmill test revealed an elevated blood pressure response to exercise in 3 subjects including one with a high-normal value at rest, which has been described as at risk for a new-onset of hypertension (21). In the medical check-up for the eligibility of subjects engaged in more intense sports activities, a maximal effort test including ECG and blood pressure measurements is recommended in case of a significant cardiovascular risk profile, especially > 35-40 years (11, 13, 14, 15).

In Italy, a (constant load) bicycle stress test is even part of the nation-wide mandatory yearly screening program of all competitive athletes (30). For elite and professional athletes all over the world, they are usually a mandatory part of the annual medical examinations. Despite their higher age and risk profile, referees usually do not benefit from an annual cardiovascular check-up including an exercise test. There is still a debate on the role of stress testing to reveal significant cardiac pathology in younger and/or asymptomatic subjects.

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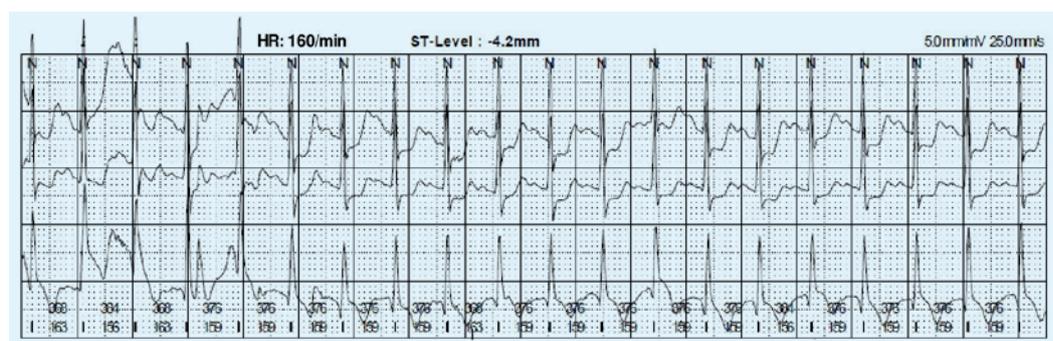


Figure 2

ST segment depression during the match detected at Holter ECG in one referee.

In this population with low pre-test probability, the exercise ECG has shown a low positive predictive validity and increases the costs by subsequent evaluations of false-positive findings concerning the detection of coronary artery disease (9, 12, 15, 17, 18, 24). The reported low sensitivity may be influenced by a tendency of stopping exercise tests at a submaximal level because of the reaching of some target heart rates, which is not recommended and limits the sensitivity (9, 12, 13, 30). Treadmill tests, as performed in the present study, are reported to have a higher ability for the detection of significant coronary artery disease than tests on cycle ergometer (10). Besides clinical indications in many cardiac and pulmonary diseases (6), a recent review, places exercise testing as a first-line work-up in the algorithm for the evaluation of athletes with premature ventricular beats for the revelation of underlying structural especially myocardial or electrical disease and risk stratifying (30). There are other indications for exercise tests in athletes, such as the evaluation and of blood pressure with prediction for new-onset hypertension (21) and metabolic and pulmonary response, the utility of a baseline status useful for the future assessment of a possible cardiac complication, the psychological assurance especially of beginners as well as providing objective performance diagnosis and individual training recommendations.

A critical point of our study is that it is not possible to completely differentiate physical stress from psychic stress during the match. The exact distance performed during a football match could not be calculated due to the lack of highly specialized and expensive video material, but this would probably not change the conclusions of the study. The physical performance of referees in a football match, also characterized by repetitive sprinting activities, and does not depend only on running endurance measured by IAT. Other direct measures of the metabolic stress during the match, for example, lactate or stress hormone concentrations, were not performed.

In conclusion, the main finding of our study is that football referees experience significant cardiovascular strain during football matches: mean HR was at 84 % of maximal HR tested in treadmill ergometer test. The intensity zone was above their individual anaerobic threshold during 17 % of the time, stressful situations resulted in a significant increase of the HR, and an increased number of ventricular and supraventricular arrhythmias was observed compared to off-match period. Regarding the cardiovascular stress, the age and the cardiovascular risk profile of the tested referees, regular monitoring (annually), including a test of maximum effort, for example on a treadmill ergometer, should be recommended for football referees. ■

Conflict of Interest

The authors have no conflict of interest.

References

- (1) **BIZZINI M, JUNGE A, BAHR R, DVORAK J.** Injuries of football referees: a representative survey of Swiss referees officiating at all levels of play. *Scand J Med Sci Sports.* 2011; 21: 42-47. doi:10.1111/j.1600-0838.2009.01003.x
- (2) **EUROPEAN ASSOCIATION OF PREVENTIVE CARDIOLOGY.** 2021. <http://www.heartscore.org> [September 14th, 2021].
- (3) **CASTAGNA C, ABT G, D'OTTAVIO S.** Activity profile of international-level soccer referees during competitive matches. *J Strength Cond Res.* 2004; 18: 486-490.
- (4) **CASTAGNA C, ABT G, D'OTTAVIO S.** Physiological aspects of soccer refereeing performance and training. *Sports Med.* 2007; 37: 625-646. doi:10.2165/00007256-200737070-00006
- (5) **CASTAGNA C, ABT G, D'OTTAVIO S.** Relation between fitness tests and match performance in elite Italian soccer referees. *J Strength Cond Res.* 2002; 16: 231-235.
- (6) **COHEN-SOLAL ACF.** Practical guide to cardiopulmonary exercise testing. Issy-les-Moulineaux: Elsevier Masson; 2012.
- (7) **CORRADO D, BASSO C, PAVEI A, MICHIELI P, SCHIAVON M, THIENE G.** Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. *JAMA.* 2006; 296: 1593-1601. doi:10.1001/jama.296.13.1593
- (8) **DI SALVO V, CARMONT MR, MAFFULLI N.** Football officials activities during matches: a comparison of activity of referees and linesmen in European, Premiership and Championship matches. *Muscles Ligaments Tendons J.* 2012; 1: 106-111.
- (9) **FLETCHER GF, ADES PA, KLIGFIELD P, ARENA R, BALADY GJ, BITTNER VA, COKE LA, FLEG JL, FORMAN DE, GERBER TC, GULATI M, MADAN K, RHODES J, THOMPSON PD, WILLIAMS MA; AMERICAN HEART ASSOCIATION EXERCISE, CARDIAC REHABILITATION, AND PREVENTION COMMITTEE OF THE COUNCIL ON CLINICAL CARDIOLOGY, COUNCIL ON NUTRITION, PHYSICAL ACTIVITY AND METABOLISM, COUNCIL ON CARDIOVASCULAR AND STROKE NURSING, AND COUNCIL ON EPIDEMIOLOGY AND PREVENTION.** Exercise standards for testing and training: a scientific statement from the American Heart Association. *Circulation.* 2013; 128: 873-934. doi:10.1161/CIR.0b013e31829b5b44
- (10) **HAMBRECHT RP, SCHULER GC, MUTH T, GRUNZE MF, MARBURGER CT, NIEBAUER J, METHFESSEL SM, KÜBLER W.** Greater diagnostic sensitivity of treadmill versus cycle exercise testing of asymptomatic men with coronary artery disease. *Am J Cardiol.* 1992; 70: 141-146. doi:10.1016/0002-9149(92)91265-6
- (11) **HARMON KG, DREZNER JA, WISLON MG, SHARMA S.** Incidence of sudden cardiac death in athletes: a state-of-the-art review. *Br J Sports Med.* 2014; 48: 1185-1192. doi:10.1136/bjsports-2014-093872
- (12) **KINDERMANN W.** Ergometrie-Empfehlungen für die Praxis. *Dtsch Z Sportmed.* 1987; 38: 244-268.
- (13) **KINDERMANN W, DICKHUTH HH, NIESS A, RÖCKER K, URHAUSEN A.** Plötzlicher Herztod beim Sport und kardiovaskuläres Screening, in: *Sportkardiologie, 2e edition, Steinkopff Darmstadt; 2007.*
- (14) **MAYER F, BONAVENTURA K, CASSEL M, MUELLER S, WEBER J, SCHARHAG-ROSENBERGER F, CARLSOHN A, BAUR H, SCHARHAG J.** Medical results of pre-participation examination in adolescent athletes. *Br J Sports Med.* 2012; 46: 524-530. doi:10.1136/bjsports-2011-090966
- (15) **MONT L, PELLICCIA A, SHARMA S, BIFFI A, BORJESSON M, BRUGADA TERRADELLAS J, CARRÉ F, GUASCH E, HEIDBUCHEL H, LA GERCHE A, LAMPERT R, MCKENNA W, PAPADAKIS M, PRIORI SG, SCANAVACCA M, THOMPSON P, STICHERLING C, VISKIN S, WILSON M, CORRADO D; REVIEWERS, LIP GY, GORENEK B, BLOMSTRÖM LUNDQVIST C, MERKELY B, HINDRICKS G, HERNÁNDEZ-MADRID A, LANE D, BORIANI G, NARASIMHAN C, MARQUEZ MF, HAINES D, MACKALL J, MANUEL MARQUES-VIDAL P, CORRA U, HALLE M, TIBERI M, NIEBAUER J, PIEPOLI M.** Pre-participation cardiovascular evaluation for athletic participants to prevent sudden death: Position paper from the EHRA and the EACPR, branches of the ESC. Endorsed by APhRS, HRS, and SOLAECE. *Eur J Prev Cardiol.* 2017; 24: 41-69. doi:10.1177/2047487316676042
- (16) **MYERBURG RJ, SPOONER PM.** Opportunities for sudden death prevention: directions for new clinical and basic research. *Cardiovasc Res.* 2001; 50: 177-185. doi:10.1016/S0008-6363(01)00253-X
- (17) **PIGOZZI F, SPATARO A, ALABISO A, PARISI A, RIZZO M, FAGNANI F, DI SALVO V, MASSAZZA G, MAFFULLI N.** Role of exercise stress test in master athletes. *Br J Sports Med.* 2005; 39: 527-531. doi:10.1136/bjsm.2004.014340
- (18) **PILOTE L, PASHKOW F, THOMAS JD, SNADER CE, HARVEY SA, MARWICK TH, LAUER MS.** Clinical yield and cost of exercise treadmill testing to screen for coronary artery disease in asymptomatic adults. *Am J Cardiol.* 1998; 81: 219-224. doi:10.1016/S0002-9149(97)00871-0
- (19) **RIDING N, PIELES G.** Should cardiac screening be compulsory in athletes? *Aspetar Sports Med J.* 2019; 8: 204-208.
- (20) **SCHWESIG R, SCHULZE S, REINHARDT L, LAUDNER KG, DELANK KS, HERMASSI S.** Differences in Player Position Running Velocity at Lactate Thresholds Among Male Professional German Soccer Players. *Front Physiol.* 2019; 10: 886. doi:10.3389/fphys.2019.00886
- (21) **SINGH JP, LARSON MG, MANOLIO TA, O'DONNELL CJ, LAUER M, EVANS JC, LEVY D.** Blood pressure response during treadmill testing as risk factor for new onset of hypertension. *Circulation.* 1999; 99: 1831-1836. doi:10.1161/01.CIR.99.14.1831
- (22) **STEGMANN H, KINDERMANN W, SCHNABEL A.** Lactate kinetics and individual anaerobic threshold. *Int J Sports Med.* 1981; 2: 160-165. doi:10.1055/s-2008-1034604
- (23) **STEPTOE A.** The impact of natural disasters on myocardial infarction. *Heart.* 2009; 95: 1972-1973. doi:10.1136/hrt.2009.178616
- (24) **VAN DE SANDE DA, BREUER MA, KEMPS HM.** Utility of exercise electrocardiography in pre-participation screening in asymptomatic athletes: A Systematic Review. *Sports Med.* 2016; 46: 1155-1164. doi:10.1007/s40279-016-0501-5
- (25) **WESTON M, CASTAGNA C, IMPELLIZZERI FM, RAMPININI E, BREIVIK S.** Ageing and physical match performance in English Premier League soccer referees. *J Sci Med Sport.* 2010; 13: 96-100. doi:10.1016/j.jsams.2008.07.009
- (26) **WESTON M, DRUST B, ATKINSON G, GREGSON W.** Variability of soccer referees' match performances. *Int J Sports Med.* 2011; 32: 190-194. doi:10.1055/s-0030-1269843
- (27) **WESTON M, GREGSON W, CASTAGNA C, BREIVIK S, IMPELLIZZERI FM, LOVELL RJ.** Changes in a top-level soccer referee's training, match activities, and physiology over an 8-year period: a case study. *Int J Sports Physiol Perform.* 2011; 6: 281-286. doi:10.1123/ijspp.6.2.281
- (28) **WILBERT-LAMPEN U, LEISTNER D, GREVEN S, POHL T, SPER S, VÖLKER C, GÜTHLIN D, PLASSE A, KNEZ A, KÜCHENHOFF H, STEINBECK G.** Cardiovascular events during World Cup soccer. *N Engl J Med.* 2008; 358: 475-483. doi:10.1056/NEJMoa0707427
- (29) **WINKEL BG, HOLST AG, THEILADE J, KRISTENSEN IB, THOMSEN JL, OTTESEN GL, BUNDGAARD H, SVENDSEN JH, HAUNSØ S, Tfelt-HANSEN J.** Nationwide study of sudden cardiac death in persons aged 1-35 years. *Eur Heart J.* 2011; 32: 983-990. doi:10.1093/eurheartj/ehq428
- (30) **ZORZI A, VESSELLA T, DE LAZZARI M, CIPRIANI A, MENEGON V, SARTO G, SPAGNOL R, MERLO L, PEGORARO C, MARRA MP, CORRADO D, SARTO P.** Screening young athletes for diseases at risk of sudden cardiac death: role of stress testing for ventricular arrhythmias. *Eur J Prev Cardiol.* 2020; 27: 311-320. doi:10.1177/2047487319890973