The young athlete's heart

Bessem, Bram

CHAPTER 2

THE LAUSANNE RECOMMENDATIONS;

A DUTCH EXPERIENCE

Bram Bessem, Floor P. Groot and Wybe Nieuwland

Br. J. Sports Med. 2009;43;708-715

ABSTRACT

Objective: This study presents the results of 28 months of pre-participation cardiovascular screening using the Lausanne recommendations which include a personal and family history, physical examination, and electrocardiogram (ECG). Results are compared to those found by Corrado et al.

Design: From January 2006 until April 2008 the data of the Lausanne screenings carried out at the University Centre of Sports Medicine in Groningen were collected.

Participants: 825 cardiovascular screenings were performed of which 397 were excluded. Exclusion criteria were an age under 12 or over 35 years of age, multiple screenings (only first was included) and known cardiovascular disease.

Main Outcome Measurements: Negative screening result, (false) positive screening result, medical consumption and number needed to screen.

Results: A total of 371 (87%) athletes had a negative screening result. Fifty-five athletes (13%) underwent additional (stage 2) testing and 7 athletes (1.6%) further (stage 3) testing. Only 27 athletes (6.3%) were referred for additional testing based only on abnormalities of their ECG. Forty-seven athletes (11%) had a false positive screening result. Ten athletes (2%) had a positive screening result, and 3 athletes (0.7%) were ultimately restricted from sports participation. Stage 2 medical consumption was 62%, 20% and 18% for respectively 1, 2 and 3 or more additional tests. Stage 3 medical consumption was 1.6%. The number of athletes needed to screen to find a single athlete with a potentially lethal cardiovascular disease was 143.

Conclusion: This study found that when the Lausanne recommendations are implemented in the Netherlands, the screening results resemble those found by Corrado et al. This study also shows that the number of athletes needed to screen to detect 1 athlete with a potentially lethal cardiovascular disease is within an acceptable range.

INTRODUCTION

In 2005 the Study Group on Sports Cardiology of the Working Group on Cardiac Rehabilitation and Exercise Physiology and the Working Group on Myocardial and Pericardial Diseases of the European Society of Cardiology proposed a common European protocol for the cardiovascular pre-participation screening of young competitive athletes for the prevention of sudden death; the Lausanne recommendations.[1] These recommendations where primarily based on 30years of experience with pre-participation screening by Corrado et al. in the Veneto region, Italy. The athletes were first screened at the age of 12, and screenings were repeated every two years until the athlete reached the age of 35. The screening consisted of taking the family history as well as the athlete's personal history, a physical examination and an electrocardiogram (ECG).[1-3]

These Lausanne recommendations have since been the source of much debate. Arguments that have been posted against the recommendations included the geographical differences between populations, the possibility of high rates of false positive results when adding an ECG and the fact that, besides Corrado's findings, there are few other data available on the screening outcome of the Lausanne recommendations.[4-12]

Since January 2006 we have implemented the Lausanne recommendations in the cardiovascular screening of athletes performed at the University Centre of Sports Medicine in Groningen, the Netherlands.

In this article we present the results of 28 months of screening using these recommendations and compare them with the results found in Italy by Corrado et al..[1-3] The screening results are defined as the percentage of false positive screening outcomes, the detected cardiovascular diseases and the medical consumption. Additionally we will present the number of athletes we needed to screen to detect a single athlete with a potentially lethal cardiovascular disease.

METHODS

Population

Between January 2006 and April 2008, 825 cardiovascular screenings were performed at the University Centre of Sports Medicine in Groningen. The data of these screenings were collected, 397 of which were excluded because participants were under 12 or over 35 years of age, because a participant had undergone multiple screenings (Lausanne) of which only the first one was included, or because participants were known to suffer from cardiovascular disease prior to the screening. A total of 428 screenings remained and were included in this study (Fig. 1).

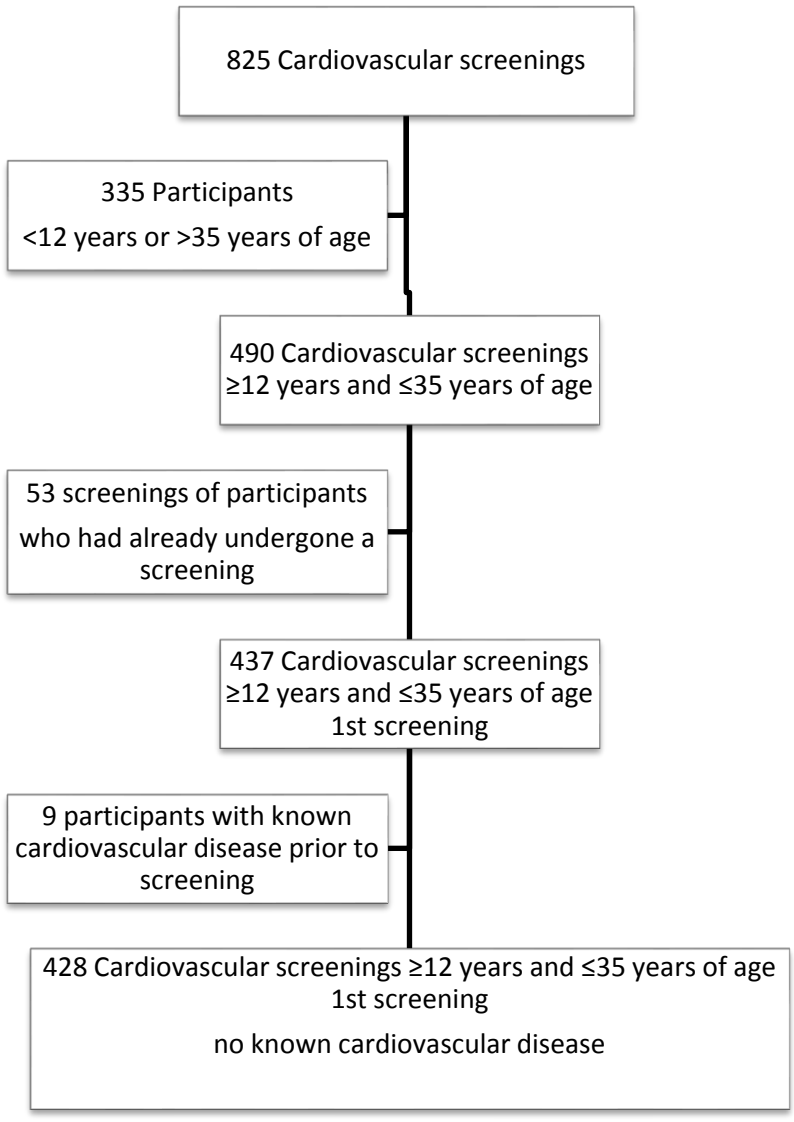

Figure 1. Overview of population included

Lausanne screening

From the 1st of January 2006 the Lausanne recommendations were implemented in the cardiovascular screening of athletes aged 12-35 years at the University Centre of Sports Medicine in Groningen, the Netherlands.

The cardiovascular screening was divided into three stages. The first stage consisted of the cardiovascular screening according to the Lausanne recommendations. The athletes with no abnormalities at this screening (negative screening outcome) were found eligible for sports participation. When the screening showed abnormalities participants underwent primary additional testing (stage 2). Based on the suspected type of cardiovascular disease these (stage 2) tests consisted of echocardiography, an exercise stress test, a signal averaged ECG (SA-ECG) and / or a 24-hour ECG monitoring. When these tests showed no abnormalities and there was no suspicion for a cardiovascular disease, the athletes were found eligible for sports participation (false positive screening outcome). When the tests showed abnormalities consistent with a type of cardiovascular disease, or when a type of cardiovascular disease was suspected, the athletes underwent secondary additional testing (stage 3). When after these tests a cardiovascular disease could be excluded the athletes were found eligible for sports participation (false positive screening outcome). When the additional test showed evidence for a cardiovascular disease the athletes were (temporarily) disqualified from sports participation (positive screening outcome) (Fig. 2).

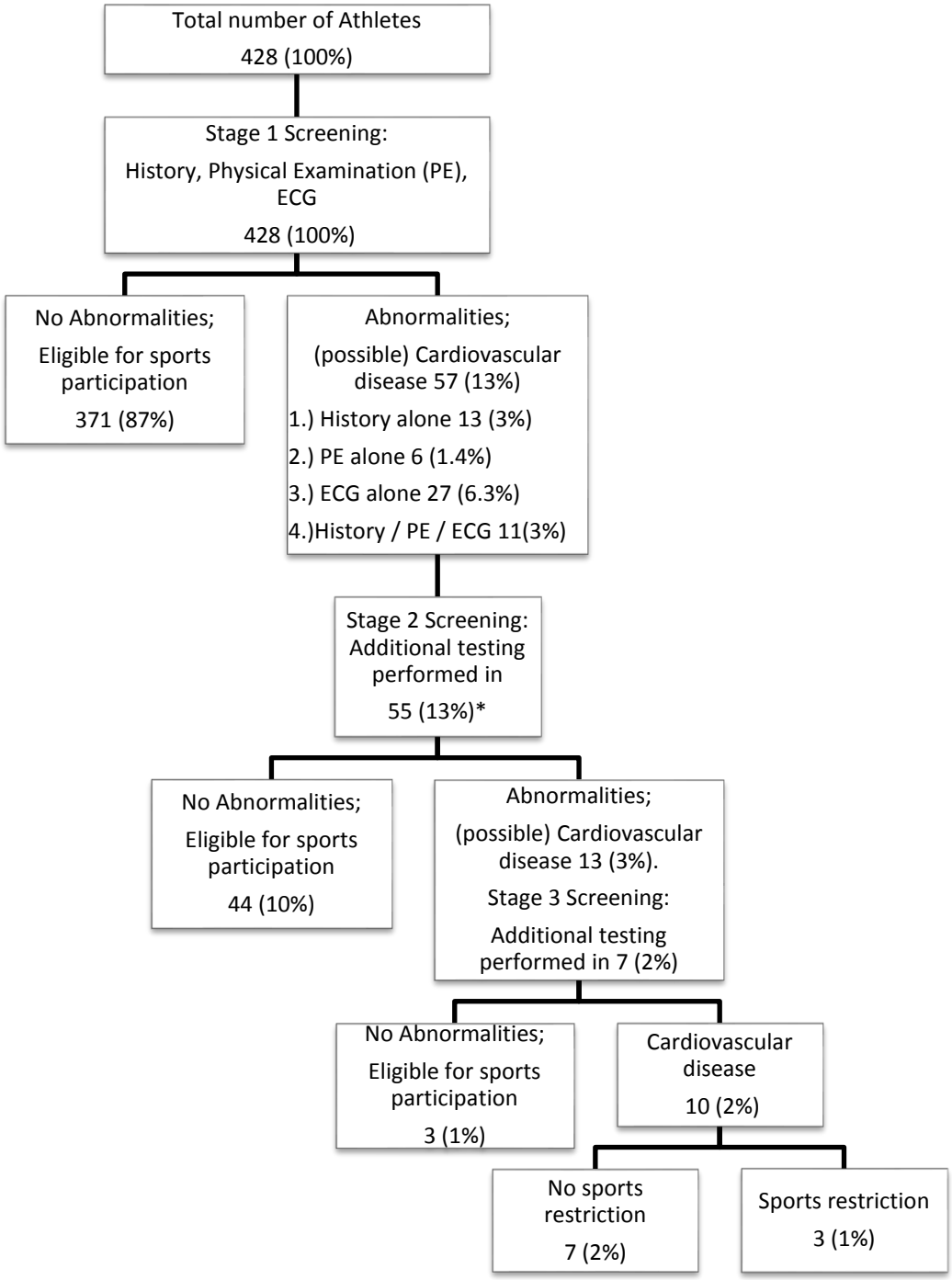

Fig. 2. The 3 stages of the Lausanne screening. Absolute numbers and percentages are both shown.

Data collection

Data were collected for all three stages.

The data collected for stage 1 consisted of a questionnaire containing the reason for screening, information about sports participation and the Lausanne questionnaire (personal history, family history, and cardiovascular symptoms). In addition, data were collected on the physical examination (according to the Lausanne recommendations) and the ECG.

When participants were referred for primary and secondary additional cardiovascular testing these data were also collected (stages 2&3). The reason for referral for additional testing was documented as well. Finally, the outcome of the screening was noted.

Statistical analysis

Statistical analysis was done using SPSS version 14.0.

RESULTS

Population

Between January 2006 and April 2008, screenings of 428 athletes were included. Of these 428 athletes 322 (75%) were male, and the average age at the time of screening was 22 years of age (range 12-35 years). 77% of these athletes underwent a mandatory screening because of their high level of sports participation and 7% underwent the screening because of cardiovascular symptoms. The athletes participated mostly in rowing (34%), soccer (21%) and cycling (19%) (Table 1).

Lausanne screening (stage 1)

Of all athletes, 371 (87%) had no abnormalities in their family or personal history as was shown by a questionnaire, nor did they have abnormalities at physical examination or in their ECG. They were therefore found eligible for sports participation. A total of 57 (13%) athletes showed abnormalities at the screening and therefore they had to undergo primary additional testing (stage 2). These abnormalities consisted of the following (see also Table 2):

Characteristics	Total (N=428)
Age – years	
• Average	22 (sd 5)
• Range	12 – 35
Sex –numbers (%)	
• Male	322 (75)
• Female	106 (25)
Reason for screening – numbers (%)	
• Mandatory	327 (77)
• Cardiovascular symptoms	32 (7)
• Other health issue(s)	69 (16)
Sport – numbers (%)	
• Rowing	146 (34)
• Soccer	91 (21)
• Cycling	81 (19)
• Running	25 (6)
• Ice-skating (speed)	20 (5)
• Other	65 (15)

Table 1. Population characteristics.

Family and personal history

Twenty-three athletes, who were referred, had abnormalities in their personal and family history. 13 of these 23 athletes were referred only because of abnormalities in their family and personal history. The other 10 athletes had abnormalities at physical examination and/or on their ECG. Most abnormalities consisted of a positive family history of sudden cardiac death (<50 years of age) and/or cardiovascular disease (13) or symptoms of palpitations (11) (Table 2).

Physical examination

The physical examination was abnormal in 11 of the 57 athletes. Three times a brachial blood pressure >140/90 mmHg on more than one reading was found and in eight cases the abnormality consisted of a heart murmur (Table 2).

Electrocardiogram

At the screening 36 athletes (8%) were found to have an abnormal ECG according to the Lausanne criteria. The most common ECG abnormalities included increased voltage (24%) and ST-segment depression or T-wave flattening or inversion in ≥2 leads (22%). A total of 13 ECG's showed an increased voltage. In 6 of these 13 cases the increased voltage was the only abnormality found at the screening (including Family and Personal History and Physical Examination). All ECG abnormalities that were found are listed in Table 3. In 27 cases (6.3%) athletes were referred for additional testing based only on abnormalities of their ECG (Table 2).

Lausanne Screening outcome	**Total (N=428)**
Negative (no abnormalities) – numbers (%)	371 (87)
Positive (abnormal) – numbers (%)	57 (13)
• Family and personal history – numbers (%)*	23 (5)
○ A positive family history of sudden cardiac death (<50 years of age)	13*
○ Palpitations	11*
○ Exertional chest pain / discomfort	6*
○ Dizziness and/or (near) syncope	4*
○ Dyspnoea and/or unexplained tiredness	4*
• Physical examination – numbers (%)	11 (3)
○ Heart murmur	8
○ Hypertension	3
• ECG – numbers (%)	36 (8)

Table 2. Outcome Lausanne Screening.

*The total of these numbers (38) is higher than 23 because a number of athletes had more than 1 abnormality in their family and personal history.

ECG abnormalities – numbers (%)	Total (N=55)*
P-Wave	
• Left atrial enlargement: negative portion of the P-wave in lead	1 (2)
• Right atrial enlargement: peaked p-wave in leads II and III or	-
QRS-complex	
• Frontal-plane QRS axis deviation: right ≥ +120º or left -30º to -	4 (7)
• Increased voltage: amplitude of R or S wave in a standard lead ≥2	13 (24) **
• Abnormal Q waves ≥0.04 s in duration or ≥25% of the height of	1 (2)
• Right or Left bundle-branch block with QRS duration ≥ 0.12 s	4 (7)
• R or R' wave in lead V1 ≥0.5 mV in amplitude and R:S ratio ≥1	5 (9)
ST-segment, T-waves and QT-interval	
• ST-segment depression or T-wave flattening or inversion in ≥2	12 (22)
• Prolongation of heart rate corrected QT-interval ≥0.44 s in men	2 (4)
Rhythm and conduction abnormalities	
• Premature ventricular beats or more severe ventricular	2 (4)
• Supraventricular tachycardia, atrial flutter, or atrial fibrillation	-
• Ventricular pre-excitation: short PR interval (≤0.12 s) with or	2 (4)
• Sinus bradycardia with resting heart rate ≤ 40 beats/min	3 (5)
• First-degree (PR ≥ 0.21 s, not shortening with hyperventilation),	3 (5)
Other	3(5)

Table 3. ECG abnormalities found at the screening according the Lausanne recommendations.

*A total of 36 athletes had an abnormal ECG. Together, these ECGs showed 55 abnormalities.

** In 6 of these 13 ECG's this was the only abnormality found at the screening (including History and Physical Examination).

Additional tests (stage 2)

A total of 57 (13%) athletes had abnormalities at the screening which was reason for primary additional testing (stage 2). Of these 57 athletes, one athlete had a brachial blood pressure >140/90 mmHg on more than one reading and was referred to his physician for treatment. No additional testing was performed. Another athlete was diagnosed with Wolff-Parkinson-White (WPW) Syndrome, based on the ECG (delta wave & PR < 120ms). The athlete was referred to a cardiologist for further treatment through electrophysiological testing and possible radiofrequency catheter ablation and was not referred for additional stage 2 testing.

The remaining 55 athletes had in total 90 additional tests (34, 11 and 10 athletes respectively 1, 2, or more additional tests). Mostly these tests were echocardiography (49; 54%). Exercise stress test and 24h ECG registration monitoring completed in 23 and 14 athletes, respectively (Table 4).

The 6 athletes, who's only abnormality was an increased voltage on their ECG, were all referred for echocardiography. In all 6 cases no abnormalities were found at echocardiography.

The results of the additional tests necessitated further evaluation and/or treatment in 11 athletes. Together with the 2 athletes with already established cardiovascular disease, 13 of the 57 (23%) athletes were suspected to suffer from cardiovascular disease after stage 2 testing. The individual characteristics of these 13 athletes are shown in Table 5.

Seven of these 13 athletes underwent stage 3 testing in order to confirm or dismiss their suspected cardiovascular disease.

A total of 44 athletes of the 55 athletes who underwent stage 2 testing showed no abnormalities in these tests and were found eligible for sports participation (false positive screening outcome).

Additional testing (stage 2)	Total (n=55)
Number of tests per athlete – numbers (%)	**(N=55)**
• 1 test	34 (62)
• 2 tests	11 (20)
• 3 or more tests	10 (18)
Tests done – numbers (%)	**(N=90)**
• Echocardiogram	49 (54)
• Exercise stress test	23 (26)
• 24-hr ECG registration	14 (16)
• SA-ECG	4 (4)
Abnormal test outcome – numbers (%)	
• Echocardiogram	5 / 49 (10)
• Exercise stress test	2 / 23 (9)
• 24-hr ECG registration	3 / 14 (21)
• SA-ECG *	2 / 4 (50)

Table 4. Stage 2 additional testing.

* SA- ECG = Signal Averaged ECG

Nr	Sex	Age	History	Physical examination	ECG	Echo cor	Exercise test	24hr ECG registration	SA-ECG	Additional tests	Diagnoses	Sport eligibility
1	♀	32	Normal	Normal	Pre-excitation, Delta wave	N.P.*	N.P.	N.P.	N.P.	EPT*, benign accessory tract right	WPW * syndrome	No restriction
2	♂	22	Normal	Normal	High voltage with T-top inversion	minor pulmonary valve insufficiency (PI)	N.P.	N.P.	N.P.	N.P.	Insufficient pulmonary valve (PI),	No restriction, echocardiogram in 1 year
3	♂	23	Exertional chest pain, palpitations and a positive family history of premature M.I. *	Normal	(inc) RBBB *	Dilated right ventricle	Normal	Normal	Normal	MRI, EBT-scan, Lung-perfusion scan and chest X-ray showed no abnormalities *	No cardio-vascular disease	No restriction
4	♂	21	Father with DCM and a positive family history of premature M.I. *	Normal	First degree AV-block	minor dilated left ventricle with minor decrease of function	N.P.	N.P.	N.P.	MRI showed no abnormalities	No cardio-vascular disease	No restriction
5	♂	15	Normal	Normal	Frontal plane axis deviation to the right (>120º), ST inversion V2-V4	Slight aneuris-matic trabeculised right ventricle	Normal	Normal	Normal	MRI showed no abnormalities	No cardio-vascular disease	No restriction
6	♂	21	Sudden cardiac death of mother at age 52, palpitations	Normal	Normal	Normal	Varying QTc time with T-top abnormalities	Varying QTc time (400-450ms)	Abnormal (2 criteria)	Cardiogenetic evaluation	(suspicion of) Congenital Long-QT syndrome	Treatment with B-blockage, temporary restriction
7	♂	19	Normal	Normal	Long QTc and T-wave flattening and inversion in two or more leads	Normal	T-wave inversion in more than two leads.	Prolonged QTc (average 460ms)	N.P.	Cardiogenetic evaluation	(suspicion of) Congenital Long-QT syndrome	Treatment with B-blockage, temporary restriction

Table 5. Overview of 13 athletes who underwent stage 3 additional testing and/or athletes who were diagnosed with cardiovascular disease

*N.P. = Not Performed, EPT = Electrophysiological Testing, WPW = Wolff-Parkinson-White, M.I. = Myocardial Infarction, RBBB = Right Bundle Branch Block, MRI = Magnetic Resonance Imaging, EBT = Electron Beam Tomography, DCM = Dilated Cardiomyopathy, AVNRT =Atrioventricular Nodal Re-entry Tachycardia, CMT = Circus Movement Tachycardia, ARVC = Arrhythmogenic Right Ventricular Cardiomyopathy

Nr	Sex	Age	History	Physical examination	ECG	Echo cor	Exercise test	24hr ECG registration	SA-ECG	Additional tests	Diagnoses	Sport eligibility
8	♂	24	Normal	Hypertension and a systolic heart murmur	High voltage with (inc) RBBB	Normal	N.P.*	N.P.	N.P.	N.P.	Hypertension	Treatment of hypertension by physician, no restrictions
9	♂	22	Brother with congenital cardiovascular abnormalities	Hypertension	Normal	Normal	N.P.	N.P.	N.P.	N.P.	Hypertension	Treatment of hypertension by physician, no restrictions
10	♂	22	Normal	Hypertension	Normal	N.P.	N.P.	N.P.	N.P.	N.P.	Hypertension	Treatment of hypertension by physician, no restrictions
11	♀	20	Palpitations, exertional chest pain, shortness of breath, and a positive family history of premature M.I.	Normal	Normal	Normal	Normal	Normal	N.P.	N.P.	(suspicion of) Benign AVNRT (CMT) *	No restrictions
12	♀	21	Palpitations, shortness of breath, dizziness	Normal	Normal	Normal	Normal	Normal	N.P.	N.P.	(suspicion of) Benign AVNRT (CMT)	No restrictions
13	♂	15	Normal	Normal	Premature ventricular beats and more severe ventricular arrhythmias	Signs of an apical localized ARVC *	Excessive ventricular arrhythmias	Excessive ventricular arrhythmias	Abnormal (3 criteria)	MRI will follow	(High suspicion of) ARVC	Disqualified for sport participation

Table 5. Continued.

*N.P. = Not Performed, EPT = Electrophysiological Testing, WPW = Wolff-Parkinson-White, M.I. = Myocardial Infarction, RBBB = Right Bundle Branch Block, MRI = Magnetic Resonance Imaging, EBT = Electron Beam Tomography, DCM = Dilated Cardiomyopathy, AVNRT =Atrioventricular Nodal Re-entry Tachycardia, CMT = Circus Movement Tachycardia, ARVC = Arrhythmogenic Right Ventricular Cardiomyopathy

Additional tests (stage3)

Additional stage 3 testing was indicated in only 7 athletes (1.6%). A total of 4 MRI's were made, one in combination with an electron beam tomography scan. The athlete who was diagnosed with WPW syndrome underwent electrophysiological testing with the possibility of radiofrequency catheter ablation. In two cases athletes were also referred to the department of cardiogenetics for genetic testing. Furthermore, one lung-perfusion scan and one chest X-ray were made.

In 4 of these 7 cases a cardiovascular diagnosis could be made. In 3 athletes the suspicion of cardiovascular disease could be cleared and they were found eligible for sports participation (false positive screening outcome) (Table 5).

Cardiovascular diagnoses and sport eligibility

Of the 428 athletes screened between January 2006 and April 2008, ten (2%) were diagnosed with a cardiovascular disease. Three athletes (0.7%) received a (temporary) sports restriction (Table 5).

Three athletes were diagnosed with hypertension and were referred to their physician for treatment. They received no sports restriction.

Two athletes were diagnosed with an atrioventricular nodal re-entry tachycardia (circus movement tachycardia). Even though the additional test did not show any abnormalities, their history was so specific that there was still a high suspicion for a benign supra-ventricular tachycardia. Because of the benign nature of the tachycardia and the minor disability the athletes perceived no treatment was indicated. The athletes received no sports restriction.

One athlete was diagnosed with WPW-syndrome. Electrophysiological testing showed a benign accessory inferolateral tract on the right. Because of the benign nature and the athlete's wishes, no radiofrequency catheter ablation was performed. The athlete received no sports restriction.

One athlete was diagnosed with a minor insufficient pulmonary valve on the echocardiography. The athlete received no sports restriction but was advised to repeat echocardiography after one year.

Two athletes were diagnosed with a congenital long-QT syndrome. They received treatment with β-blocking agents and they received a temporary sports restriction. They were also advised not to use any QT-prolonging medication.

One athlete was diagnosed with arrhythmogenic right ventricular cardiomyopathy (ARVC). The athlete received a complete sports restriction for all competitive sports. The work-up of this athlete was still in progress at the time the data were collected (Table 5).

The number of athletes needed to screen to find a single athlete with a cardiovascular disease for which a (temporary) sports restriction is warranted was 143.

DISCUSSION

The Lausanne recommendations proposed in 2005 by Corrado et al. are based largely on 30 years of experience in the Italian Veneto region.[1-3] Since then there has been much debate on whether these recommendations should be incorporated, and if so, in what form.[3,13-34] This study, although small in sample size, gives a first insight into the experience with the Lausanne recommendations in Groningen, the Netherlands.

Of the 428 athletes who were screened between January 2006 and April 2008, a total of 13% (55) was referred for additional testing because of abnormalities at the screening. This percentage is comparable to the percentage found by Corrado et al., who referred 9% of the competitive athletes for additional testing.[1-3]

In this study we found a false positive screening outcome of 11%. Again this percentage corresponds to the percentage found by Corrado et al., who had a false positive screening outcome of (7%).[1-3] Our slightly higher false positive rate may in part be related to the population screened, with 7% of our athletes being referred for screening because of cardiovascular symptoms.

When looking at the cardiovascular diseases (2%) and (temporary) sports restriction (0.7%), the percentages also seem to match well with Corrado et al. They found that 2% of the athletes that were screened had a cardiovascular disease, which was reason for sports restriction in all cases.[1-3]

When focusing on the medical consumption used for additional testing, the results of our study are comparable to the medical consumption needed by Corrado et al. We documented a consumption of 62%, 20% and 18% for 1, 2 and 3 or more additional tests in stage 2 respectively. Corrado et al. found a similar consumption (66%, 21% and 12% respectively).We documented a stage 3 consumption of 1.6%, which was comparable to Corrado et al., who found a consumption of 2%.[1-3]

This study shows that when looking at the Lausanne recommendations the Dutch population seems comparable to the Italian results in abnormal screening outcome, (false) positive screening outcome and medical consumption. Even though this study is based on a small sample, the similarities with Corrado et al. are striking.[1-3] Also the cardiovascular diseases that were found show more similarities with the Italian population than, for example, the population of the United States. We found one athlete with ARVC and two with a Long QT syndrome, while we found no hypertrophic cardiomyopathy (HCM). This is more in line with Corrado et al., who found that most sudden cardiac deaths where related to ARVC and diseases of the conduction system, than with Maron et al., who found that most sudden cardiac deaths in the United States were due to HCM.[1-3,35]

Part of the debate on the Lausanne recommendations has been the inclusion of an ECG and the proposed ECG criteria.[4-12,24-29,31-34,36-38] Concern for false-positive results and costly additional work-ups by inclusion of ECG is cited as a major obstacle to wide adoption of this protocol. [4,7,10-12,35]

In this study 6.3% of the athletes are referred for additional testing only because of an abnormal ECG. To us this seems an acceptable percentage.

When looking at the ECG criteria, the focus of the debate has been partly on the criteria of increased voltage (amplitude of R or S wave in a standard lead ≥2 mV, S wave in lead V1 or V2 ≥3 mV, or R wave in lead V5 or V6 ≥3 mV). Questions have been raised whether voltage criteria alone (in the absence of T wave inversion, ST depression, or pathologic Q waves) represent a significant finding suggestive of HCM or are just a part of athletic heart adaptations. Recent studies suggest that voltage criteria (for LVH) alone do not represent a pathologic finding.[38] In this study 6 athletes were referred for additional testing based only on an increased voltage on their ECG. In all 6 cases additional echocardiography showed no signs of HCM. If we would exclude these athletes, the number of athletes with a positive (stage 1) screening outcome would be 11.9% (51) and the number of athletes referred for additional (stage 2) testing based only on an abnormal ECG would be 4.9% (21). Also the total false positive screening outcome would decrease from 10.9% (47) to 9.6% (41).

When we look at the number of athletes needed to be screened to find a single athlete with a cardiovascular disease which warrants a (temporary) sports restriction, a total of 143 athletes seems acceptable. Although this does not provide evidence for the effectiveness of the Lausanne recommendations, it does show that the Lausanne recommendation are an effective screening tool to detect potentially lethal cardiovascular diseases.

The numbers found in this study are possibly a slight overestimate of the percentages one would see if conducting only mandatory screening in athletes according to the Lausanne recommendations. In this study 77% of the athletes were screened because it was mandatory, but 7% were screened because of cardiovascular symptoms. Also, the fact that we only included the first cardiovascular screening might result in a small overestimate of the percentage of stage 1 abnormal screening outcome.

The sports participation of our study population is not a good reflection of sports activities in the Netherlands, with soccer as leading sport by far, while rowing is only a minor sport, but in our population the most performed sport. This may have lead to a referral bias. This difference may be explained by the fact that in rowing and cycling a cardiovascular screening is mandatory for all competing athletes, whereas in soccer this is only the case for professional players.

This study shows the data of a small sample of competitive athletes in the Netherlands. One could therefore argue that conclusions should be drawn with caution. On the other hand, the outcome of this study shows remarkable similarities with the findings of Corrado et al..[1-3] Thus, although the sample size is small, we feel this study is representative for the Dutch situation.

CONCLUSION

This study shows us that when we implement the Lausanne recommendations in the Netherlands, the screening results resemble those found by Corrado et al. in Italy.[1-3] The screening results in this study were defined as the percentage false positive screening results, the detected cardiovascular diseases and the medical consumption.

This study demonstrates that the false positive screening outcome and additional testing required based on ECG abnormalities are acceptable.

Finally this study shows that the number of athletes needed to screen to detect a single athlete with a potentially lethal cardiovascular disease is 143.

REFERENCES

1. Corrado D, Pelliccia A, Bjornstad HH, et al. 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(5):516-524.

2. Corrado D, Basso C, Pavei A, et al. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. *JAMA*. 2006;296(13):1593-1601.

3. Corrado D, Basso C, Schiavon M, et al. Screening for hypertrophic cardiomyopathy in young athletes. *N Engl J Med*. 1998;339(6):364-369.

4. Chaitman BR. An electrocardiogram should not be included in routine preparticipation screening of young athletes. *Circulation*. 2007;116(22):2610-4; discussion 2615.

5. Maron BJ, Thompson PD, Ackerman MJ, et al. Recommendations and considerations related to preparticipation screening for cardiovascular abnormalities in competitive athletes: 2007 update: A scientific statement from the american heart association council on nutrition, physical activity, and metabolism: Endorsed by the american college of cardiology foundation. *Circulation*. 2007;115(12):1643-1455.

6. Ghosh J. Sudden cardiac death in athletes - what can be done? *Indian Pacing Electrophysiol J*. 2006;6(3):139-141.

7. Hamilton B, Jaques R, Budgett R. Observations on the "lausanne recommendations" on sudden cardiovascular death in sport. *Br J Sports Med*. 2007;41(2):e1.

8. Hernelahti M, Heinonen OJ, Karjalainen J, et al. Sudden cardiac death in young athletes: Time for a nordic approach in screening? *Scand J Med Sci Sports*. 2008;18(2):132-139.

9. Sen-Chowdhry S, McKenna WJ. Sudden cardiac death in the young: A strategy for prevention by targeted evaluation. *Cardiology*. 2006;105(4):196-206.

10. Shephard RJ. Mass ECG screening of young athletes. *Br J Sports Med*. 2008;42(9):707-708.

11. Thompson PD, Levine BD. Protecting athletes from sudden cardiac death. *JAMA*. 2006;296(13):1648-1650.

12. Chaitman BR, Fromer M. Should ECG be required in young athletes? *Lancet*. 2008;371(9623):1489-1490.

13. Balady GJ. Sudden cardiac death in young military recruits: Guarding the heart of a soldier. *Ann Intern Med*. 2004;141(11):882-884.

14. Corrado D, Basso C, Rizzoli G, et al. Does sports activity enhance the risk of sudden death in adolescents and young adults? *J Am Coll Cardiol*. 2003;42(11):1959-1963.

15. Fuller CM, McNulty CM, Spring DA, et al. Prospective screening of 5,615 high school athletes for risk of sudden cardiac death. *Med Sci Sports Exerc*. 1997;29(9):1131-1138.

16. Eckart RE, Scoville SL, Campbell CL, et al. Sudden death in young adults: A 25-year review of autopsies in military recruits. *Ann Intern Med*. 2004;141(11):829-834.

17. Maron BJ, Araujo CG, Thompson PD, et al. Recommendations for preparticipation screening and the assessment of cardiovascular disease in masters athletes: An advisory for healthcare professionals from the working groups of the world heart federation, the international federation of

sports medicine, and the american heart association committee on exercise, cardiac rehabilitation, and prevention. *Circulation*. 2001;103(2):327-334.

18. Maron BJ, Shirani J, Poliac LC, et al. Sudden death in young competitive athletes. clinical, demographic, and pathological profiles. *JAMA*. 1996;276(3):199-204.

19. Wingfield K, Matheson GO, Meeuwisse WH. Preparticipation evaluation: An evidence-based review. *Clin J Sport Med*. 2004;14(3):109-122.

20. Maron BJ, Gohman TE, Aeppli D. Prevalence of sudden cardiac death during competitive sports activities in minnesota high school athletes. *J Am Coll Cardiol*. 1998;32(7):1881-1884.

21. Maron BJ. Sudden death in young athletes. *N Engl J Med*. 2003;349(11):1064-1075.

22. Pfister GC, Puffer JC, Maron BJ. Preparticipation cardiovascular screening for US collegiate student-athletes. *JAMA*. 2000;283(12):1597-1599.

23. Semsarian C, Maron BJ. Sudden cardiac death in the young. *Med J Aust*. 2002;176(4):148-149.

24. Bille K, Figueiras D, Schamasch P, et al. Sudden cardiac death in athletes: The lausanne recommendations. *Eur J Cardiovasc Prev Rehabil*. 2006;13(6):859-875.

25. Corrado D, McKenna WJ. Appropriate interpretation of the athlete's electrocardiogram saves lives as well as money. *Eur Heart J*. 2007;28(16):1920-1922.

26. Panhuyzen-Goedkoop NM, Verheugt FW. Sudden cardiac death due to hypertrophic cardiomyopathy can be reduced by pre-participation cardiovascular screening in young athletes. *Eur Heart J*. 2006;27(18):2152-2153.

27. Bjornstad H, Corrado D, Pelliccia A. Prevention of sudden death in young athletes: A milestone in the history of sports cardiology. *Eur J Cardiovasc Prev Rehabil*. 2006;13(6):857-858.

28. Corrado D, Migliore F, Basso C, et al. Exercise and the risk of sudden cardiac death. *Herz*. 2006;31(6):553-558.

29. Myerburg RJ, Vetter VL. Electrocardiograms should be included in preparticipation screening of athletes. *Circulation*. 2007;116(22):2616-26; discussion 2626.

30. Pelliccia A, Culasso F, Di Paolo FM, et al. Prevalence of abnormal electrocardiograms in a large, unselected population undergoing pre-participation cardiovascular screening. *Eur Heart J*. 2007;28(16):2006-2010.

31. Pelliccia A, Di Paolo FM, Quattrini FM, et al. Outcomes in athletes with marked ECG repolarization abnormalities. *N Engl J Med*. 2008;358(2):152-161.

32. Ma JZ, Dai J, Sun B, et al. Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death in china. *J Sci Med Sport*. 2007;10(4):227-233.

33. Wilson MG, Basavarajaiah S, Whyte GP, et al. Efficacy of personal symptom and family history questionnaires when screening for inherited cardiac pathologies: The role of electrocardiography. *Br J Sports Med*. 2008;42(3):207-211.

34. Pelliccia A, Di Paolo FM, Corrado D, et al. Evidence for efficacy of the italian national pre-participation screening programme for identification of hypertrophic cardiomyopathy in competitive athletes. *Eur Heart J*. 2006;27(18):2196-2200.

35. Maron BJ, Thompson PD, Ackerman MJ, et al. Recommendations and considerations related to preparticipation screening for cardiovascular abnormalities in competitive athletes: 2007 update: A scientific statement from the american heart association council on nutrition, physical activity, and metabolism: Endorsed by the american college of cardiology foundation. *Circulation*. 2007;115(12):1643-1455.

36. Pelliccia A, Culasso F, Di Paolo FM, et al. Prevalence of abnormal electrocardiograms in a large, unselected population undergoing pre-participation cardiovascular screening. *Eur Heart J*. 2007;28(16):2006-2010.

37. Tanaka Y, Yoshinaga M, Anan R, et al. Usefulness and cost effectiveness of cardiovascular screening of young adolescents. *Med Sci Sports Exerc*. 2006;38(1):2-6.

38. Melacini,Paola, Cianfrocca,Cinzia, Calore,Chiara, et al. Abstract 3390: Marginal overlap between electrocardiographic abnormalities in patients with hypertrophic cardiomyopathy and trained athletes: Implications for preparticipation screening. Circulation 2007;116:765.