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ORIGINAL ARTICLE

BEAT-IT: A de-novo cardiac screening programme in Maltese adolescents

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ABSTRACT

AIMS Sudden cardiac death (SCD) in young individuals is often unexpected, provoking substantial emotional stress for family and friends of the deceased. Cardiac screening may identify individuals who harbour disorders linked to SCD. The feasibility and diagnostic yield of a nationwide cardiac screening programme in adolescents has never been explored.

METHODS All individuals eligible for cardiac screening (students aged 15 years) were systematically invited to enrol. Students were provided with a health questionnaire. ECGs were acquired at school. A physician led consultation was carried out on site. Participants with an abnormal screen were then referred for secondary evaluation to the nation's tertiary centre. Feasibility criteria included a) participation rate >60%, b) adherence to secondary evaluation >80%, and c) cost per individual screened equating to <€100. The diagnostic yield was also evaluated.

RESULTS At the end of enrolment, 2708 students gave consent (mean 15 years, 50.4% male), equating to 67.9% of the eligible cohort. Overall, 109 participants (4.0%) were referred for further evaluation. An abnormal electrocardiogram (ECG) was the most common reason for referral (3.7%). Fifteen individuals (0.6%) were diagnosed with a cardiac condition. Nine (0.3%) had a condition linked to SCD (n = 1 Long-QT syndrome, n = 1 Hypertrophic Cardiomyopathy, n = 5 Wolff-Parkinson White, n = 2 coronary anomalies). The yield was similar in athletes and non-athletes (p = 0.324). The cost per cardiac individual screened equated to €51.15.

CONCLUSION A nationwide systematic cardiac screening programme for adolescent athletes and non-athletes is feasible and cost-efficient, provided that responsible centres have the appropriate infrastructure.

1. INTRODUCTION

Sudden cardiac death (SCD) in young and athletic (<35 years) individuals provokes profound emotional stress for the victim's family, friends, and wider society. The public health burden in terms of life-years lost is greater than all individual cancers and most other leading causes of death.[1] Absence of systematic registries makes it difficult to accurately ascertain the incidence rate. Estimates are dependent on study design and population included and vary between 0.5 to 32 deaths per 100,000 person-years.[2,3]

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Lay Summary

A nationwide cardiac screening programme using a health questionnaire and ECG is feasible and cheap, with a similar pick-up rate in athletes and non-athletes.

- 0.3% of individuals screened were diagnosed with conditions linked to sudden cardiac death
- The total cost of screening equated to €51.15 per individual

Sudden cardiac arrest is often the first presentation of genetic or congenital disorders of the heart. Up to 80% of cases are without any warning symptoms or family history,[4,5], which invariably raises the role of prevention. Widely accepted preventive strategies include cardiac evaluation of symptomatic individuals and individuals with a family history of an inherited cardiac condition, and emergency response planning in sporting venues and the wider community. The role of cardiac screening remains a cause of intense debate. ECG based cardiac screening is now endorsed by many sporting bodies. The ECG may identify several conditions predisposing to SCD, including ion-channel disorders, cardiomyopathies, and congenital accessory pathways.[6]

Although the focus is commonly on elite level competitive athletes, young people who are physically active or engage in recreational sport account for the great majority of these deaths. Indeed, more than 90% of exercise related SCDs take place in recreational athletes.[7,8] Moreover, up to 40% of competitive athletes who succumb to SCD do not die during physical activity,[9] and the role of exercise in triggering malignant arrhythmias has been questioned in some of the inherited cardiac conditions, such as hypertrophic cardiomyopathy (HCM). Consequently, the ethics of limiting cardiac screening to competitive athletes have been questioned and there are calls for population based cardiac screening, irrespective of athletic activity.[10,11]

The aim of the BEAT-IT study was to evaluate the feasibility and diagnostic yield of a de novo national cardiac screening programme for adolescents, irrespective of athletic activity.

2. METHODS

2.1. STUDY DESIGN. This is a prospective cross-sectional study performed at the Maltese islands under the auspice of the Department of Cardiology at Mater Dei Hospital (MDH), a tertiary institution that caters for the entire population, estimated at 475,700. All students attending Form 5 classes (aged 15 years) in the 2017/2018 academic year were invited to undergo cardiac screening. Recruitment packs were distributed to all eligible students. Subjects who gave consent were asked to complete a health questionnaire at home. An electrocardiogram (ECG) and physician lead consultation were carried out in all the schools between September 2017 and May 2018. Participants were referred to MDH for secondary evaluation when deemed appropriate.

The study conforms to the principles stated in the Declaration of Helsinki and was approved by the University of Malta Research Ethics Committee. Approval was also obtained from both the national and MDH data protection offices. Written informed consent for screening was obtained from each student. A parent or legal guardian also signed the consent form in students ≤16 years.

2.2. EXAMINATION PROTOCOL. The evaluation included a health questionnaire (demographics, symptoms, family history and athletic ability - refer to Appendix I) and ECG. Sedentary individuals were defined as those participating in organised physical activity <4 hours a week. Individuals participating in organised physical activity for >4 hours a week were considered recreational athletes. A competitive athlete was defined as an individual who participated in a team or individual sport (club or national level), requiring systematic training and regular participation in competitions.[12]

Experienced physicians carried out consultations in schools. The attending physician was responsible for reviewing the health questionnaire and on-site ECG. The decision to refer an individual for secondary evaluation was left at the discretion of the attending physician, who was responsible for informing the participant and his legal guardians of the outcome of the screening. All ECGs were evaluated by two experienced physicians, including the first author who is an experienced cardiologist with expertise in cardiac screening of adolescent athletes and non-athletes. Borderline or pathological ECGs were discussed in a forum composed of dedicated MDH cardiologists with expertise in cardiomyopathy, channelopathy, sports cardiology, and electrophysiology. Participants referred for further investigations were evaluated at MDH.

2.3. TWELVE LEAD ELECTROCARDIOGRAM. A resting 12-lead ECG was performed in all participants in the supine position during shallow respiration using Philips PageWriter TC50 cardiograph machines (Philips, Bothell, Washington). The ECG was printed out as a hard copy (25 mm/s, 1 mV/cm) and acquired digitally. Heart rate (HR) at rest, PR interval, QRS duration, QT interval, T wave axis, and QRS axis were calculated.

The screened cohort consisted of young individuals, with a substantial proportion engaging in competitive sport. ECGs were interpreted using the 2017 International Criteria as these resembled our cohort most closely, similar to studies reported by other groups.[11,13] This was readapted for specific ECG findings. Asymptomatic individuals with isolated T-wave inversion in leads V_1 to V_3 were referred for echocardiography and reassured if this came back normal. They were also advised rescreening a year later, as per the international criteria.[13] Individuals with a Type 2/3 Brugada pattern on ECG were referred for a high-precordial ECG with leads V_1 and V_2 placed in the second and third intercostal space, Isolated T-wave inversion in any two of the three inferior leads was considered as abnormal.

Any negative deflection exceeding 1 mm was classified as T-wave inversion. These were categorised as anterior (V_1-V_2 & V_1-V_3), extended anterior (V_1-V_4), inferior (II/aVF, III/aVF & II/III/aVF), and lateral (V_5-V_6 and/or I/aVL). A repeat ECG for subjects with anterior and extended T-wave inversion was performed to ensure good lead positioning.

Subjects were asked to perform mild aerobic activity if the heart rate was <50 beats/minute (bpm). A repeat ECG after additional resting time was also performed in cases when the heart rate >90 bpm. The QT was corrected for heart rate using the Fridericia formula in cases with a persistently high heart rate.

2.4. SECONDARY EVALUATION PROTOCOL. All referred individuals had an echocardiogram performed. Further investigations were dictated by clinical suspicion. Participants with isolated anterior T-wave inversion in the absence of symptoms with a negative family history and normal echocardiography were invited for a repeat ECG in one year. Subjects with T-wave inversion in other territories also underwent 24-hour Holter monitoring, exercise testing and cardiac magnetic resonance (CMR) imaging. Those with a prolonged QT interval underwent a postural ECG, exercise test and 24-hour Holter monitoring. Patients with ventricular pre-excitation pattern on ECG underwent 24-hour Holter monitoring and were risk stratified with an exercise test. Patients were referred for an electrophysiological study a) if they experienced symptoms, b) in the absence of an abrupt cessation of antegrade conduction down the pathway during an exercise test or c) if the individual screened was a competitive athlete. Patients with ventricular ectopy (≥2 ventricular ectopics on ECG [14] were subjected to echocardiography, exercise testing and 24-hour Holter monitoring. Clinically significant ventricular ectopy was defined as an ectopic burden of more than 10%. Patients were referred for cardiac magnetic resonance imaging (CMR) if any of the following were present a) ventricular ectopy not suppressed with exercise, b) evidence of complex arrhythmias and b) left ventricular dysfunction on echocardiography. Computer tomography (CT) coronary angiography was performed in subjects with exertional chest pain and normal echocardiography. Those diagnosed with an anomalous coronary artery were subjected to a stress echocardiogram. Pharmacological provocation with Ajmaline testing was not offered to any patient suspected of having Brugada Syndrome as no one was older than 16 years. It would however be considered at a later stage to help confirm or refute the diagnosis when clinically relevant. Family screening was also offered in cases where probands had a suspected or confirmed inherited cardiac disorder.

2.5. DIAGNOSING INDIVIDUALS WITH CARDIAC PATHOLOGIES LINKED TO SUDDEN CARDIAC DEATH. The diagnosis of a cardiac disorder was made in accordance with internationally recognised guidelines. Definitions were altered in specific situations. A juvenile ECG pattern was diagnosed in cases with anterior T-wave inversion in leads V_1-V_3/V_4 in the absence of symptoms, a negative family history and normal echocardiography. The diagnosis of HCM was based on a maximal wall thickness (MWT) more than two standard deviations greater than the predicted mean (z-score >2) when adjusted for age and body surface area (BSA).[15-17] Subjects with a borderline MWT were also diagnosed with HCM when co-existing with other features, including (a) abnormal ECG suggestive of HCM, (b) pattern of left ventricular hypertrophy (LVH), (c) late gadolinium enhancement on CMR, (d) a likely or definite pathogenic gene mutation, (e) presence of other phenotypic features such as ventricular arrhythmias or blunted blood pressure response at peak exercise, (f) relative apical hypertrophy and apical cavity obliteration in cases of apical HCM, and (g) known or newly diagnosed first degree family members with HCM.[18] The diagnosis of dilated cardiomyopathy (DCM) was considered if the left ventricular (LV) end-diastolic volume exceeded 80 mL/m^2 in males and 71 mL/m^2 mm in females and a reduced ejection fraction (<52% in males and <54% in females), independent of athletic ability.[19] A Wolff-Parkinson-White ECG pattern was based on the presence of a short PR and slurred upstroke to the QRS complex, independent of QRS duration. The diagnosis of long-QT syndrome (LQTS) was based on a corrected QT (QTc) interval of ≥500 msecs on two or more occasions. A Schwartz score of ≥3.5 in subjects with a borderline prolonged QTc of 470-500 msecs was also diagnostic.

The presence of a probable or definite pathogenic variant in a gene linked to LQTS also helped confirm the diagnosis. Coronary artery anomalies including anomalous origin, coronary bridging and coronary fistula were diagnosed based on CT coronary angiogram findings. The diagnosis of LVNC was based on a ratio of non-compacted to compacted myocardium ≥2.3 in end-diastole in combination with other clinical and imaging features, a) family history of LVNC, b) ejection fraction <50%, c) dilated left ventricle, d) late gadolinium enhancement, e) complex ventricular arrhythmias, and f) the presence of myocardium thinning and non-ischaemic RWMAs. The diagnosis of Brugada syndrome, arrhythmogenic cardiomyopathy, valvular heart disease and congenital heart disease was based on published criteria.

2.6. ASSESSING FEASIBILITY. Participation is a key indicator of a screening programme's acceptance and effectiveness. The screening programme was deemed feasible if a) participation rate exceeded 60% of the eligible cohort, b) adherence to secondary evaluation exceeded 80% of all referred participants, and c) provided costs per individual screened were less than 100 euros. The standards set for participation rate mirrors a compliance rate exceeding 50% in the locally observed breast cancer screening programme.[20] An 80% attendance for secondary evaluation was deemed appropriate by the investigators. The acceptable cost per screened individual was pre-determined based on cost analysis published by other groups.

2.7. STATISTICAL ANALYSIS. Statistical computations were performed with SPSS V.23 (IBM, Armonk, New York, USA). Normal distribution of all continuous variables was examined using the Shapiro-Wilk. Data is presented as the mean ± SD and data ranges. Categorical variables are reported as frequencies and percentages. When appropriate, continuous variables were analysed with Student's test and categorical variables with Chi Squared ($\chi 2$) test. A p value of <0.05 was considered statistically significant.

2.8. COST ANALYSIS. The cost of consultations and evaluations were calculated based on standard Mater Dei Hospital costings for the year 2018. Cardiac genetic testing was performed in a foreign institution (Health in Code S.L., A Coruna, Spain). Costs were incurred in euros €.

3. RESULTS

3.1. STUDY POPULATION. All students (n = 3991) enrolled in Form 5 classes across the Maltese archipelago were invited, and 2708 students (67.9%) provided consent to participate (Table 1). Most students were white Caucasian (95.8%). Genders were equally presented. Almost 40% were considered athletes.

TABLE 1 Baseline Characteristics

Demographic	Frequency (%)
Age	
Mean	15
Median	15
Range	14-17
Gender	
Female	1325 (49.6)
Male	1347 (50.4)
Ethnicity	
White (Maltese)	2486 (93.0)
White (European)	74 (2.8)
White (South African)	1 (0.0)
Black (African)	18 (0.7)
Asian	10 (0.4)
Mixed	73 (2.7)
Other	10 (0.7)
Recreational Athletes	186 (6.9)
Competitive Athletes	
Club (Semi-Professional)	543 (20.3)
Club (Professional)	203 (7.6)
National	110 (4.1)
Sporting Discipline	
Football	426 (40.9)
Dancing	130 (12.5)
Basketball	65 (6.2)
Swimming	56 (5.4)
Handball	40 (3.8)
Other	325 (31.2)
Sport Category	
Skill	171 (16.4)
Power	46 (4.4)
Mixed	649 (62.3)
Endurance	106 (10.2)
Not recorded	70 (6.7)
Weekly training hours	
<2	113 (10.8)
2-5	239 (22.9)
5-10	482 (46.3)
>10	208 (20.0)

3.2. FIRST EVALUATION. 109 (4.0%) adolescents were referred for further evaluation. An abnormal ECG was the main reason for referral (n = 99, 3.7%). A small proportion (n = 21) were referred because of symptoms (abnormal ECG n = 13 [0.5%]) or a relevant family history (n = 10) (abnormal ECG n = 8 [0.3%]). Five subjects with an abnormal ECG were not referred for evaluation as they were being followed up by a cardiologist for a suspected or confirmed cardiac phenotype (n = 1 HCM, n = 4 surgically corrected congenital heart disease).

TABLE 2 Outcome of secondary evaluations

Outcome	Frequency (n)	Referrals (%)	Study cohort (%)
Discharged	28	25.7	1.0
Surveillance	20	18.3	0.7
Repeat screen in 1 year	42	38.5	1.6
Cardiac Condition	15	13.8	0.6

3.3. SECONDARY EVALUATION. The outcome of secondary evaluations was classified into four subgroups (Table 2). Six (0.2%) withdrew consent for follow up evaluations. Close to 25% of the participants were reassured and discharged following preliminary tests (n = 27, 24.8%). Those with a suspicion of a juvenile ECG pattern were advised to repeat their ECG in one year. A proportion were referred for surveillance in the absence of a clinical phenotype at baseline. Fifteen (0.6%) individuals were diagnosed with a cardiac condition (Figs. 1 and 2). These include 9 (0.3%) diagnosed with a condition linked to SCD including long QT syndrome (LQTS) (n = 1, 0.04%), HCM (n = 1, 0.04%), Wolff Parkinson White (n = 5, 0.18%), and coronary anomalies (n = 2, 0.07%).

Only a minority (n = 2, 13.3%) of those diagnosed with heart disease had symptoms. The majority of those diagnosed with heart disease (86.7%) and those labelled with a high-risk cardiac disorder linked to SCD (88.9%) had an abnormal ECG (Table 3).

3.4. ATHLETE VERSUS NON-ATHLETES. Overall, 5.0% of athletes were referred for secondary evaluation versus 3.8% of non-athletes (p = 0.134). Following all second line tests, 0.8% of athletes versus 0.4% of non-athletes were given a cardiac diagnosis (p = 0.381) with 5 (0.5%) athletes being diagnosed with a cardiac phenotype linked to SCD versus 4 (0.2%) non-athletes (p = 0.324). Using the latest international recommendations for ECG interpretation,[13] non-athletes shared the same likelihood for referral for secondary evaluation and for being labelled with a cardiac diagnosis compared to athletes.

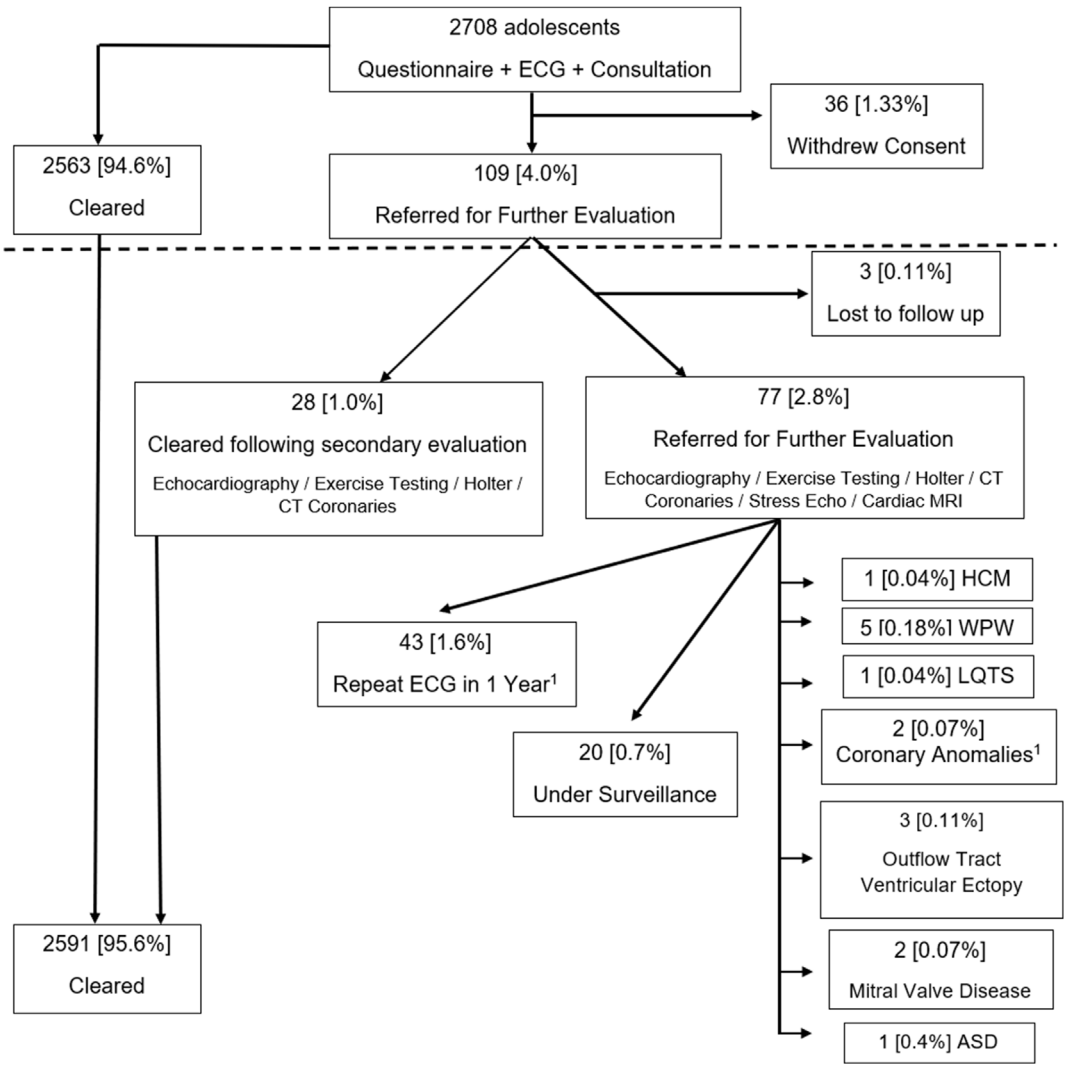
3.5. TREATMENT AND SPORTS ELIGIBILITY. All 15 subjects with a cardiovascular diagnosis were offered lifestyle advice and warned about red-flag symptoms. All are under surveillance. One athlete with WPW was referred for catheter ablation. The athlete with LQTS was commenced on beta-blocker therapy and implanted with an implantable loop recorder. Genetic testing confirmed a likely pathogenic mutation in KCNQ1. Following a shared decision approach, the athlete was disqualified from competitive sport as per current guidelines.[21] Cascade family screening in those probands suspected of having an inherited cardiac disorder was recommended.

3.6. COST. The cost of screening participants with a questionnaire and ECG equated to €39.66 per individual. The total cost incurred at the end of enrolment for the entire cohort came at €107,399.28. The cost incurred for all second line investigations equated to a further €27,662.95 (Table 4). Administrative costs totalled €3,447.72. The total cost of the screening programme was €138,509.95, equating to €51.15 per individual screened. The cost per cardiac disorder identified was €9,234.00, increasing to €15,390.00 per cardiac diagnosis linked to SCD.

3.7. DISCUSSION. This study demonstrated the feasibility of a systematic national cardiovascular screening programme in adolescent individuals. All adolescents attending a specific academic year in all Maltese secondary schools had the unique opportunity of undergoing cardiac screening, as opposed to an opportunistic sampling method which is the case in other cohorts.[11] The modus operandi employed in this programme could easily be upscaled to other countries, as has been reported in another nationwide screening programme locally.[22] Centres offering such a service should undoubtedly have the necessary infrastructure in place and should boast experts in this field. Enrolment (67.9%), adherence to follow up testing (96.3%) and cost per individual screening (€ 51.15) surpassed all initial expectations. The cost per individual screened is similar to what other groups have reported,[11,23] though this is heavily dependent on healthcare costs in different areas of the globe.[23-26] Adherence with follow up evaluations is difficult to evaluate in larger countries due to patients potentially being followed up in different tertiary centres. The presence of one tertiary centre on the island allows us to report this important factor with confidence. The absence of a denominator (total number of individuals eligible for screening) is also a major limiting factor in other similar studies, another positive finding which we can happily report. The investigators are now confident that nationwide screening programmes are feasible.

Methodical cardiac screening in a young population (under 35 years) has been reported in the United Kingdom and Japan.[11,24] Uniform systematic school screening in adolescents on a national level has however never been reported in the literature. More human resources and logistic harmonisation would undoubtedly be needed to make it work. Referral

FIGURE 1 Clinical yield for the BEAT-IT screening programme ([1]One participant having a coronary anomaly and Anterior T wave inversion)



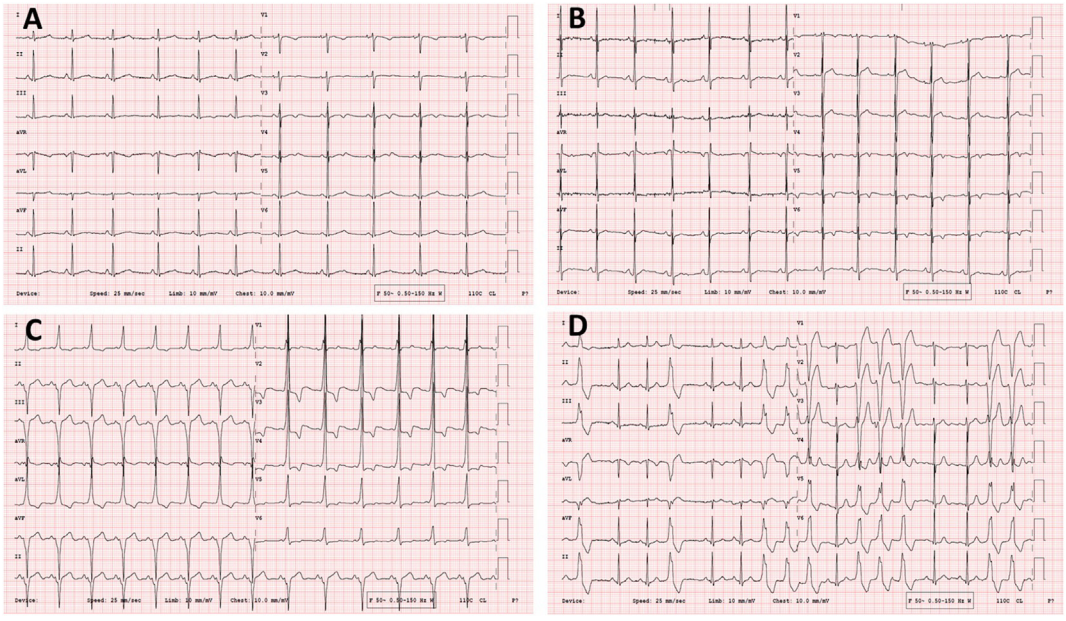
centres would need to be equipped with several services. A large team of individuals that would include inherited cardiac disease specialists, cardiac imagers, electrophysiologists, cardiac geneticists and sport cardiologists is also advisable to make such a programme feasible.

In this study, 2708 adolescents were screened with a questionnaire and ECG, 4.0% were referred for secondary evaluation. A minority were diagnosed with heart disease (0.6%). A small proportion were labelled with a phenotype linked to SCD (0.3%). The clinical yield is comparable to what has been previously reported in cardiac screening programmes in athletes and non-athletes.[3,11,25-30]

As reported in previous screening programmes, most of the individuals diagnosed with a condition linked to SCD were identified by ECG (88.9%),[3,31] highlighting the vital importance of ECG in any screening protocol for athletes and non-athletes. For this reason, most sporting bodies now recommend ECG screening in their protocols.

Presentation and clinical course of most inherited cardiac conditions is profoundly heterogenous. Age-related penetrance notably in cardiomyopathies is well known, often manifesting later in life. Channelopathies and cardiomyopathies are the leading cause of morbidity in the second decade of life.[32] ECG manifestations may present years before a definite

FIGURE 2 **Pathological ECG patterns (2A: Long QT syndrome in a 15 year old Caucasian female competitive swimmer, 2B: T wave inversion in V4-V6 in a non-athletic Caucasian 14 year old male who with a structurally normal heart and is under surveillance, 2C: Frequent outflow tract ventricular ectopy in a 15 year old non-athletic Caucasian female with a structurally normal heart, 2D: Wolff Parkinson White in a 15 year old Caucasian male football player)**



clinical phenotype.[33] This may lead to a lower clinical yield if subjects are screened in adolescence. An additional 21 (0.8%) subjects in the cohort harbour a pathological ECG in the absence of a clinical phenotype. The diagnostic yield of the screening programme is potentially an underestimate as a clinical phenotype may become apparent during follow up. Follow up evaluations have in fact been shown to increase the diagnostic yield of a screening programme.[30]

Should screening be limited to elite athletes? Cardiac screening in competitive athletes is currently endorsed by most sporting bodies, despite very little positive long-term outcome data.[29] Athletes who harbour heart disease were previously thought to carry a higher risk of SCD compared to non-athletes, simply because they engaged in competitive sport. Emerging data however may not substantiate previous claims. Several arguments are worth mentioning:

a) The number of non-competitive athletes is far greater the elite athletic individuals. The prevalence of SCD is in turn higher in this group[7,34]
b) Athletes who succumb to SCD often occurs during normal daily life and not during exercise.[32,35]

TABLE 3 **Summary of cardiac conditions detected according to the screening method 4**

		Abnormal Result		
Condition	Frequency	History	ECG	History & ECG
Hypertrophic Cardiomyopathy	1	0	1	0
Long QT syndrome	1	0	1	0
Wolff Parkinson White	5	0	5	0
Coronary Anomalies	2	1	0	1
Mitral Valve Prolapse	2	0	2	0
Atrial Septal Defect	1	1	0	0
Outflow Tract Ventricular Ectopy	3	0	3	0

TABLE 4 **Cost for Secondary Evaluation**

Investigation	Cost (€)	Frequency (n, %)	Total Cost (€)
Outpatient Review	35.00	23 (0.85)	805.00
High lead ECG	4.66	13 (0.48)	60.58
Echocardiogram	116.50	99 (3.66)	11,533.50
Ambulatory ECG Monitoring	116.50	40 (1.48)	4,660.00
Exercise Test	116.50	25 (0.92)	2,912.50
CT Coronary Angiogram	116.50	6 (0.22)	699.00
Cardiac Magnetic Resonance Imaging	210.00	13 (0.48)	2,730.00
Stress Echocardiogram	116.50	2 (0.07)	233.00
Electrophysiological study	2329.37	1 (0.04)	2,329.37
Cardiac Gene Panel	850.00	2 (0.07)	1,700.00

There is strong evidence supporting exercise as an important disease modifier in arrhythmogenic cardiomyopathy.[36] The data is far less convincing for other conditions like HCM or LQTS.

c) The incidence of SCD in athletes may be lower than the general population.[37]

All these arguments raise a very important ethical dilemma, should systematic cardiac screening also include young non-athletic individuals? This is an important public health issue, why should young individuals be arbitrarily excluded from potentially life-saving clinical screening? After all, the diagnostic rate in screening programmes is similar for athletes and non-athletes. A national systematic screening programme is certainly feasible as has been demonstrated in this study, provided that the necessary infrastructure is available. The experiences shared by other academic groups certainly confirm that large-scale cardiac screening programmes that include a health questionnaire and resting 12-lead ECG are able to identify young individuals (<35 years) who harbour cardiac disorders linked to SCD.[3,11,31,38] Long term data to support such initiatives remain inconclusive and elusive, making it harder to justify the investment into such initiatives.[29,39] Recent evidence also supports the implementation of serial evaluations to help reduce the false negative rates of cardiac screening.[3,40] Long term follow up data will hopefully shed some light in the near future.

3.8. STUDY LIMITATIONS. The age bracket chosen for the study is well known to cause significant academic turmoil because of important exit exams prior to switching to sixth form, the American equivalent of high school. This may have discouraged students and parents from participating. As outlined in the study protocol, a younger cohort would have led to a higher false positive rate whilst selecting an older age bracket would not have made the study design feasible.

The results of this study may not be applicable to other countries with different health care system models. Such a comprehensive screening programme may also be an issue in larger countries. Cardiologists with expertise in inherited cardiac conditions, advanced cardiac imaging modalities and electrophysiological labs, to name just a few, may only be present in a handful of tertiary care centres. Costs of individual tests may also vary significantly. The cohort comprised predominantly (96%) of Caucasian adolescents. The results may not be applicable to non-Caucasian cohorts, a higher prevalence of ECG anomalies in Afro-Caribbean athletes has traditionally lead to a higher referral rate.[41] There was no interobserver variability analysis, potentially leading to bias. A thorough discussion with all investigators for all potential referrals was however carried out to try and mitigate this limitation.

The main purpose of the study was to assess feasibility and the baseline diagnostic yield of a systematic cardiac screening programme. No long-term follow-up data is available at present, as is the case with similar studies, making it harder to justify setting up a cardiac screening programme.

4. CONCLUSIONS

A nationwide systematic cardiac screening programme is feasible, inexpensive, with a good diagnostic yield (0.3%). The modus operandi can be replicated on a larger scale. The results also confirm that the diagnostic yields of athletes and non-athletes are similar, raising very important ethical issues of extending cardiac screening across the whole population.

AUTHOR CONTRIBUTIONS

MA, MB, TF, MS substantially contributed towards study conception and design. MA, SX, KY, RX, KS, JB, LB, JFS, WC, EA, AC, MF contributed towards data collection. MA contributed towards data analysis. MA, MS, RGX, VG and MP contributed towards manuscript writing and proof reading of the final submission.

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ETHICS APPROVAL

The study was approved by the University of Malta Research Ethics Committee (Protocol 34-2017) and the data protection office.

DECLARATION OF COMPETING INTEREST

The authors have no conflict of interest to declare.

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APPENDIX A. SUPPLEMENTARY DATA Supplementary data to this article can be found online at https://doi.org/10.1016/j.hjc.2023.09.012.