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CONSENSUS DOCUMENT
Sports cardiology

Cardiac evaluation in the armed forces. A statement of the European Association of Preventive Cardiology of the ESC

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Sudden cardiac death, although infrequent, is a well-documented reality in young, often asymptomatic individuals. The risk of cardiac events is markedly amplified during high intensity physical activity, a circumstance commonly encountered in military environments. In this setting, undetected cardiovascular disease can have profound operational, safety, and morale consequences, particularly during high-demand duties where physiological stress is substantial and immediate medical support may be limited. This statement provides a structured approach to cardiovascular screening across all branches of military service, with the aim of promoting consistency and uniformity.

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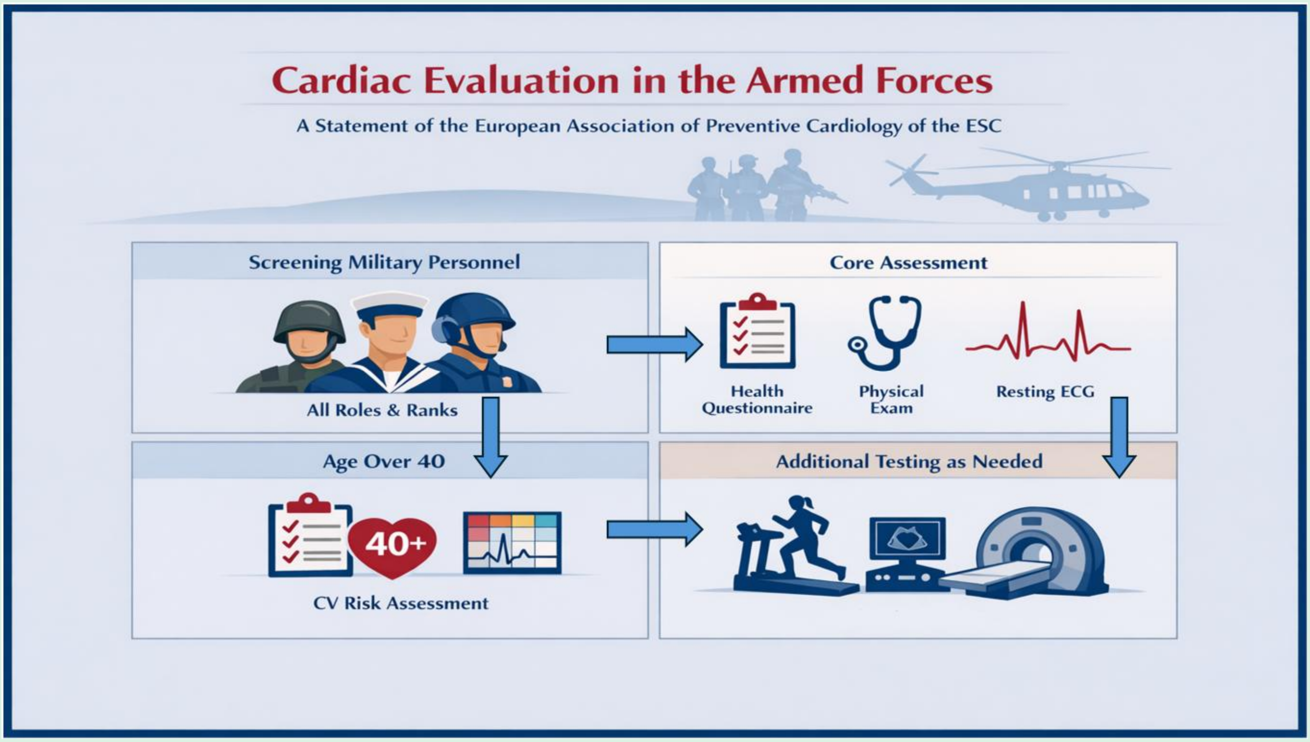
Graphical Abstract



Keywords Armed forces • Military • Cardiac screening • ECG • Sudden cardiac death

Introduction

Heart disease remains an important cause of morbidity and mortality worldwide. Military service members are predominantly young, fit, asymptomatic individuals. Sudden cardiac death or cardiac arrest (SCD/SCA) in this population is a well-documented reality, albeit uncommon occurrence,[1,2] as in young athletic cohorts.[3–5] Most sporting bodies have now endorsed cardiac screening in competitive athletes.[6–8] In a military context, undetected cardiovascular disease (CVD) can have profound operational, safety and morale consequences, especially during high-demand duties.[9] A similar prevalence of cardiovascular disorders in sedentary individuals, accompanied with the risk of SCD/SCA is now also well established in non-athletic young populations, with several groups acknowledging that ECG based cardiac screening programmes equally play a role in non-athletic cohorts.[10,11]

The purpose of this statement is to outline the key considerations and implications of a cardiac evaluation in all Armed Forces personnel. These recommendations should be implemented in all combatant and career-based occupations, in line with the growing evidence supporting cardiac screening in sedentary individuals.[10,11] We provide practical advice to support the development of cardiovascular screening approaches in service members, thereby helping medical professionals involved in safeguarding the health and occupational readiness of military personnel. In this unique clinical context, operational readiness often includes early identification of individuals at risk, whilst also promoting physical and mental well-being. This helps mitigate the occupational hazards that are fundamentally present in military duties. Specifically, the target population of this document is defined as asymptomatic Armed Forces personnel >16 years, including those engaged in high-risk duties military operations, without known cardiovascular conditions. This document aims to establish a common foundation for evidence-based screening practices, complementing existing guidelines on cardiovascular prevention and physical activity in athletes with CVD.[8,12,13]

Writing committee structure and selection process

The writing committee was constituted through formal nominations from national cardiovascular societies affiliated with the European Society of Cardiology (ESC), ensuring broad geographic and professional representation. Active engagement with military institutions was considered essential, particularly regarding cardiac screening practices, operational responsibilities, and the evaluation military personnel.

The group also included experts in cardiac screening of athletes, whose experience in large-scale screening programmes and interpretation of athlete-specific findings was considered essential. This structure ensured that the committee reflected both national perspectives and specialized expertise relevant to cardiovascular evaluation in physically demanding and high-performance environments.

Occupational and environmental hazards

Competitive athletes may occasionally encounter challenging environmental conditions. These are however typically

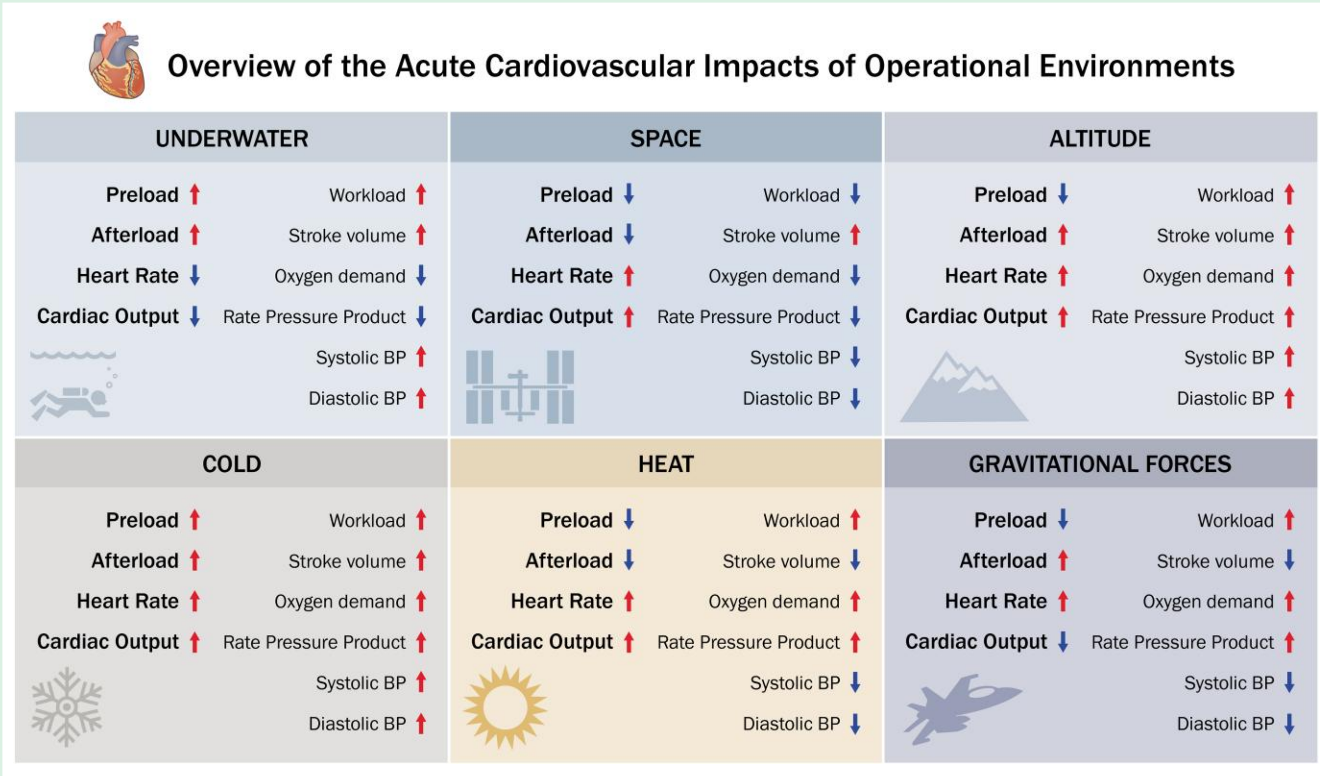


Figure 1 Acute cardiovascular impact of different operational environments.[14–21]

regulated events can be modified, delayed, or cancelled to ensure participant safety. In contrast, military personnel are duty-bound to perform in inhospitable environments, regardless of weather, terrain, or operational adversity. This fundamental difference in duty and exposure may result in a markedly broader and more sustained spectrum of cardiovascular and environmental stressors for military personnel, exposing these individuals to heightened acute physiological responses (*Figure 1*). Emergency action plans which allow the immediate rescue of a competitive athlete succumbing to heat stroke, for instance, are rarely available in a tactical environment. Factors that further amplify the cardiovascular strain of tactical duties performed in extreme heat, cold, altitude, or under water include the consequences of mission failure or serious injury to self or others. Service personnel with unrecognized CVD, whether inherited cardiac conditions or occult coronary artery disease (CAD), are particularly vulnerable when exposed to environmental extremes and the intense cardiovascular strain of high-strength, high-endurance exertion during life-threatening emergencies. This combination helps explain the disproportionately high rates of cardiovascular mortality observed in firefighters and other high hazard duty occupations.[22]

Prevalence and causes of SCD in military personnel

SCD in the military is a rare yet devastating event. The true incidence is not known. Much of the data are extrapolated from athletes where inherited cardiac conditions are the predominant cause of SCD in young (<35 years).[4,23,24] The incidence of SCD in athletes is approximately 1–2 per 100 000 athlete-years (<35 years).[4,25]

SCD in military personnel appears higher when compared with the incidence rates reported in athletic individuals. Much of the data on SCD in the military comes from the United States (US), including a large military study that showed a sudden death rate of 6.7 per 100 000 person-years for males and 1.4 for females.[26] Sudden death was attributed to a cardiac condition in 79% of cases.[26] A recently published study of 220 701 military personnel equally reported a high cardiac arrest rate of 10.8 per 100 000 person-years.[27] Similar rates of SCD were reported in US Air Force recruits from 1965 to 1985. Of the sudden deaths in this cohort 40% were attributed to a cardiac cause with the main aetiology being myocarditis followed by anomalous coronary arteries and hypertrophic cardiomyopathy (HCM).[28] Israeli data on SCD in military personnel over a 30-year period also found the leading cause of death to be cardiac (47%) with 20% of causes undetermined.[2]

The rates of SCD are equally high during recruit training. The incidence of SCD in military recruits has been reported as 8-11/100 000 per recruit-years.[1,29] In a 25-year review of non-traumatic deaths in US military recruits (1977–2001), most deaths (86%) occurred during exercise.[1] A definite cardiac aetiology was identified at post-mortem in 51% of cases. Within this group, the leading causes were anomalous coronary arteries (33%), myocarditis (20%), pre-mature CVD (16%), and HCM (13%).[1] The cause of a significant number of deaths was not determined (~35%).[1] The proportion of coronary artery anomalies in this study was significantly higher than in previous studies.[3,30]

Cardiac screening of military recruits

The World Health Organization (WHO) screening principles target important health threats that can be detected early with testing leading to effective treatment or risk mitigation.[31] Evidence in ESC guidelines support screening in athletes.[5,12] In contrast to the individual-centric focus of competitive sports, military medicine broadens screening to encompass risks to the unit, mission, service reputation, and the public. Most nations therefore have a military screening programmes for CVD that typically includes a history and physical examination with focused questions on symptoms and family history.[32] Experience when screening athletes suggests that the electrocardiogram (ECG) is 5 times more sensitive than the history, and is 10 times more sensitive than the physical examination.[33,34] This has led to several European nations adopting a resting 12-lead ECG as part of their screening protocol for athletes.[35]

In 2002, the US Department of Defence (USA) withdrew the requirement for resting 12-lead ECG in all applicants,[33,36] due to the false positive rate being unacceptably high (20–25%), accompanied with a very low (<0.3%) incidence of disqualifying conditions.[33,34] A resting 12-lead ECG may identify some disorders linked to SCA/SCD, including cardiomyopathy, ion-channel disorders or accessory pathways (*Table 1*).[37] Its diagnostic sensitivity is however highly variable, and some clinically affected individuals may inadvertently present with a normal ECG.[10,39–42] It is unable to identify conditions like coronary anomalies, catecholaminergic polymorphic VT, idiopathic VF, aortopathy, and valvular heart disease, which is why some organizations do not incorporate a resting ECG in their screening programmes. Implementation of artificial intelligence (AI),[43] iterative improvements in ECG interpretation, and consistent use of the International ECG criteria when screening athletes has decreased the false positive rate to 2–4% without decreasing specificity.[34] Contemporary ECG interpretation criteria have also led to a substantial reduction in the cost per athlete screened and the cost per diagnosis.[11,44–46] Inclusion of the ECG actually led to a 36% cost reduction per new diagnosis linked to SCD, when compared with a health questionnaire alone.[47] Most sporting bodies now mandate ECG acquisition during screening in athletes. The latest American Heart Association/American College of Cardiology (AHA/ACC) Scientific Statement upgraded screening ECGs for competitive athletes from not recommended to reasonable,[8] provided adequately trained clinicians are available. This is a significant milestone, given the longstanding reluctance of the US to incorporate a resting ECG when screening athletes.[8] Screening programmes in non-athletic populations have now also highlighted the validity of using ECG when screening young individuals.[11,47] A recommendation for ECG based screening in all Armed Forces personnel would therefore seem reasonable.

Echocardiography is certainly valuable as a second-line investigation in individuals with an abnormal preliminary screen. Recently published screening recommendations in adolescent athletes have however deemed it reasonable for athletes to undergo echocardiography at least once in their athletic career.[6,48] Extending this approach to military personnel is at best questionable. Adopting such an approach would incur considerable financial and logistic burden. It will inevitably divert resources away from patients with established disease.

Table 1 Cardiac disorders at risk of SCD potentially identified with a resting ECG[4,24,37,38]

ECG anomalies		Cardiac disorder
Likely/ possible	Unlikely	
✓		Cardiomyopathy (hypertrophic, non-dilated, dilated, arrhythmogenic)
✓		Long/short QT-syndrome
✓		Brugada syndrome
✓		Wolff Parkinson White syndrome
✓		Inflammatory myopericardial syndromes
✓		Congenital heart disease
	✓	Atherosclerotic coronary artery disease
	✓	Coronary anomalies
	✓	Catecholaminergic polymorphic ventricular tachycardia
	✓	Valvular heart disease
	✓	Aortopathy
	✓	Commotio cordis

Echocardiography has nevertheless been incorporated into screening algorithms for certain high-risk duty occupations,[49,50] despite poor evidence to support this approach. The diagnostic yield of echocardiography as a first-line screening modality was reported at 1.3–3.3% in two large aeromedical screening studies.[49,50] Most guidelines do not routinely recommend echocardiography as a first-line screening modality.[8,12,49,50]

A few nations use exercise ECG testing in recruit screening. It is reliable for predicting outcomes (prognosis), but the data in the medical literature do not support its use as a general screening tool.[51]

Screening personnel undertaking high hazard occupations

While sudden death in athletes is tragic, a military cardiovascular event carries the added risk of compromising the mission and endangering unit members. Most nations use more detailed screening for high hazardous military occupations (aircrew, divers, special forces, reconnaissance troops, etc.).[52] This usually includes ECG and may include exercise ECG (though there is considerable variation between nations and even between services within the same nation).[53] In many jurisdictions (with variable frequency, usually determined by age), periodical medical evaluation is undertaken with a health questionnaire, physical examination and resting ECG. Again, echocardiography is not performed routinely but reserved as a second-line investigation for abnormalities in the health questionnaire, family and personal history, physical examination or ECG.

Screening older military personnel (≥40 years)

Cardiovascular risk scores are used internationally to predict cardiovascular risk in middle aged and older patients. Examples include the SCORE2 (validated: 40–69 year olds) as recommended by the ESC;[54] and the AHA/ACC pooled cohort equation (validated: 40–79 year olds).[55] It should be noted that the application of population-based risk scoring to those younger than 40 may lead to unnecessary investigation and restrictions.[56] Exercise testing has played a key role in cardiovascular risk stratification for decades. Current guidelines consider it reasonable to perform exercise testing in asymptomatic individuals with high or very high cardiovascular risk who are not known to have atherosclerotic CVD.[8,12] The test however has limited sensitivity for detecting individuals with mild to moderate obstructive CAD. Which restricts its diagnostic utility in this subgroup.[57–59] Terminating exercise stress testing once the target heart rate is achieved, before the individual reaches the true physiological peak at exhaustion, also contributes to its poor sensitivity for detecting cardiovascular disease.[60] Addressing modifiable risk factors through lifestyle interventions and evidence-based preventive pharmacotherapy remains central, as these measures reduce overall cardiovascular risk in individuals with established atherosclerotic CVD. Coronary artery calcium score (CACS) has now emerged as a better predictor of coronary events in asymptomatic adults, independent of traditional risk factors. The ACC/AHA recommend that CACS 'should be' considered in adults aged 40–75 with an intermediate 10-year risk (7.5–20%).[61,62] However, in younger patients, there is a higher risk of false negatives. CACS does not detect non-calcified plaque disease, which (particularly in younger and fitter cohorts) may be the cause of occupationally significant disease.[63] A recent study of asymptomatic military aircrew (mean age 49) demonstrated the potential of computed tomography coronary angiography (CTCA), identifying aeromedically significant CAD (including non-calcified plaque) in 13% of participants.[64] High-risk plaque features were also observed in 21% of cases, one-fifth of these individuals not actually having significant CAD.[64] Unsurprisingly, 92% (n = 24/25) of participants with clinically relevant CAD had negative exercise testing (n = 1 ST segment depression) again highlighting its low sensitivity.[64] merging evidence increasingly suggests that CTCA, rather than CACS, offers a more reliable method for detecting occupationally significant CAD in younger individuals.[63,65]

Unsurprisingly, 96% (n = 24/25) of participants with clinically relevant CAD had negative exercise testing (n = 1/25 ST segment depression) again highlighting its low sensitivity

ECG interpretation in military personnel

Experience from cardiac screening programmes in athletes has shown that the ECG can effectively identify some individuals harbouring conditions associated with SCA/SCD. Extending a similar screening strategy to military personnel is therefore justifiable,[66,67] given the substantial physiological and psychological demands often required during military service and the increased risk of cardiac arrest as a result of these stressors.

Two major types of ECG changes may be distinguished:

Training-related changes are those associated with physiological adaptation of the heart. Training-related changes often take place in those engaging in >4 h of physical activity weekly, with more pronounced adaptation present in male endurance athletes. The extent of such ECG findings in military personnel is largely unknown, due to lack of studies.[66,68] In addition, the prevalence of exercise-induced changes, as described in athletes, will depend on the extent and intensity of exercise, in addition to physiological parameters such as body size, gender, and ethnicity.[37,69]

Borderline or pathological ECG patterns are those suggestive of a potential underlying cardiovascular disorder. The likely aetiology varies with age. In younger individuals, inherited cardiac conditions represent the predominant causes of exercise-related SCA/SCD[24,70]; although CAD has also been a reported as an important cause of sports related SCA/SCD in young adults.[71] CAD becomes increasingly prevalent in older individuals and is the most common cause of SCA/SCD above the age of 35. Ethnicity also influences the diagnostic yield of cardiovascular screening military populations. Studies demonstrate that different Asian populations exhibit susceptibility to different pathologies.[72,73] However, there are currently no studies evaluating the impact of Afro-Caribbean ethnicity on ECG findings within military screening programmes. In the absence of population-specific data, interpretation is generally extrapolated from the established evidence base in Black athletes, recognizing the higher prevalence of physiological and pathological ECG anomalies in this population.[34,69,74–76]

Guidelines on abnormal ECG findings in aircrew have been previously published.[77] International criteria for athletes are alternatively used by some Armed Forces.[37] Physiological ECG changes including sinus bradycardia, first-degree atrioventricular block, incomplete right bundle-branch block, and voltage criteria for left ventricular hypertrophy have to be evaluated in relation to the individual's exercise history, and body habitus. Additionally, older military personnel, with a long history of exposure to high-volume exercise may share the physiological adaptations, and associated ECG changes seen in master athletes.

Any physiological changes seen in military personnel must be distinguished from ECG-markers of underlying relevant CVD, associated with SCA/SCD. Major findings associated with inherited cardiac conditions (cardiomyopathies, long QT-syndrome, and Brugada syndrome) include: abnormal T-wave inversion (*Figures 2* and *3*), complete left bundle-branch block (LBBB), supraventricular and ventricular arrhythmias and prolonged QT-interval.[37]

Findings indicative of underlying CAD on resting ECG are not diagnostically helpful, and are of both low sensitivity and specificity. They include ST segment-depression, pathologic Q-waves and LBBB.[37] It should be acknowledged that with advancing age, underlying CAD is increasingly common but is typically not associated with abnormalities on the resting ECG. Atrial fibrillation is also more common with age, those with cardiovascular risk factors, in those engaging in chronic endurance exercise and with a long history of high-volume training. The ECG also plays an important role in those individuals harbouring a high CVD risk profile, identified using a validated risk score calculator, given that an exercise tolerance tests is non-diagnostic in individuals with certain underlying ECG abnormalities (e.g. LBBB). A decision for coronary anatomical imaging or a functional assessment to rule out ischaemia should be based on the predicted risk and the clinical profile.[12]

Current cardiovascular screening practices in military personnel: results of a European Association of Preventive Cardiology Survey

Data on screening practices in international armed forces has previously been unexplored. In preparation for the presented

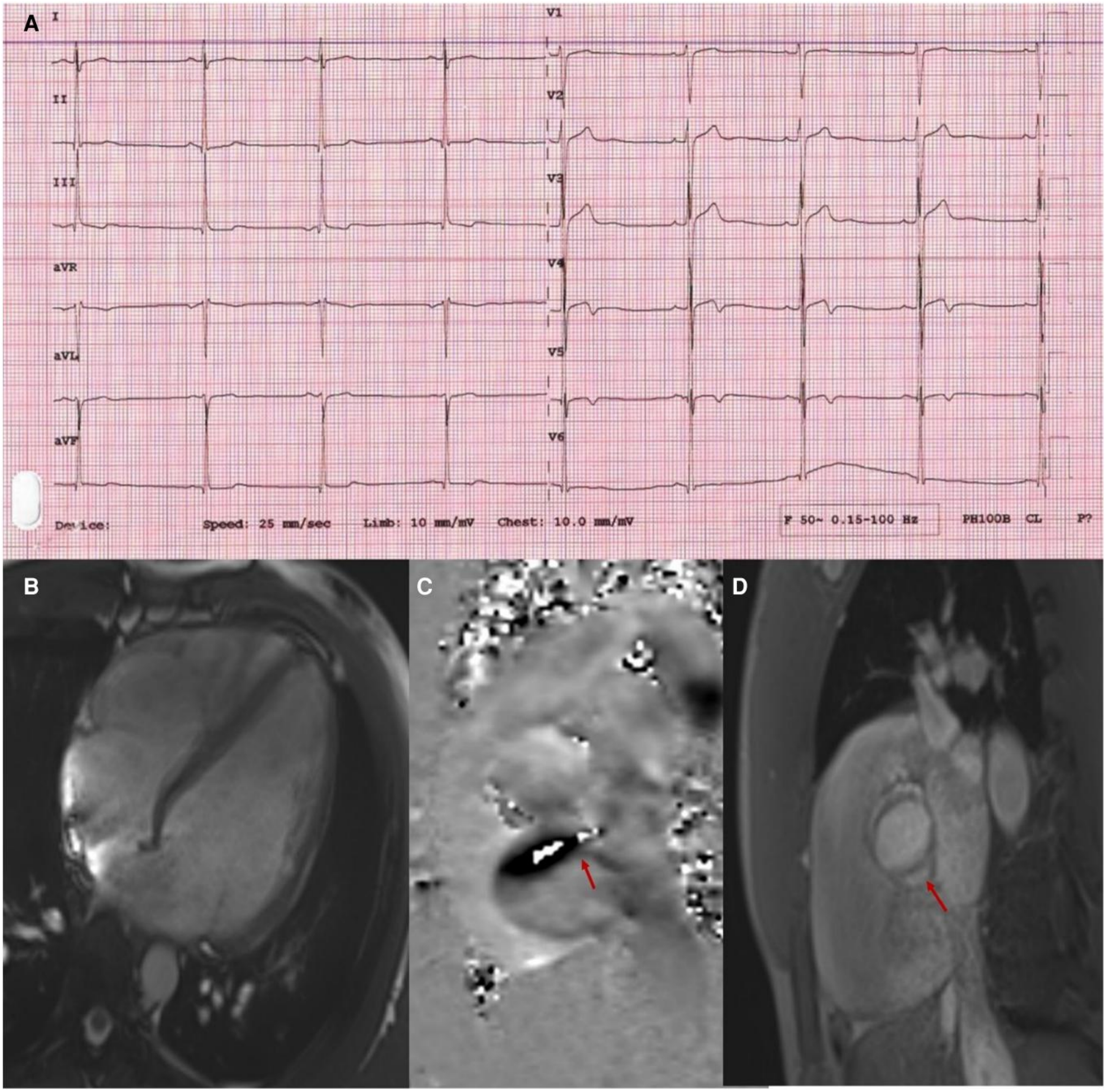


Figure 2 An asymptomatic white male athletic individual undergoes screening as a new recruit. The resting ECG was found to have lateral T-wave inversion (*A*). Cardiac magnetic resonance imaging later identified pathologically dilated ventricles (*B*), an atrial septal defect (*C*), and a bicuspid aortic valve (*D*) with mild-moderate regurgitation.

consensus statements, an online based electronic questionnaire including single- and multiple-choice questions that looked at cardiac screening practices in military entities was developed in 2024. This was distributed to national societies affiliated with the ESC and completed by June 2025. As we have recently reported,[53] the survey was completed by 17 physicians responsible for cardiovascular screening in the Armed Forces from 14 countries across 4 continents (*Figure 4*).

Pre-participation cardiovascular screening (PPCS) differed across all countries, without any significant differences when exploring screening practices between European and non-European services. Most services reported conducting PPCS in all their recruits (79%), often including a health questionnaire (100%), physical examination (91%), and a resting 12-lead ECG (91%). Despite the overwhelming evidence supporting ECG use in screening athletes,[8,12,37] an ECG based screening approach is still heavily underutilized in the military sector. In our survey, only 71.4% of the 14 participating nations (n = 7 European and n = 3 non-European) reported implementing ECG based screening in recruits.[53] Some countries who

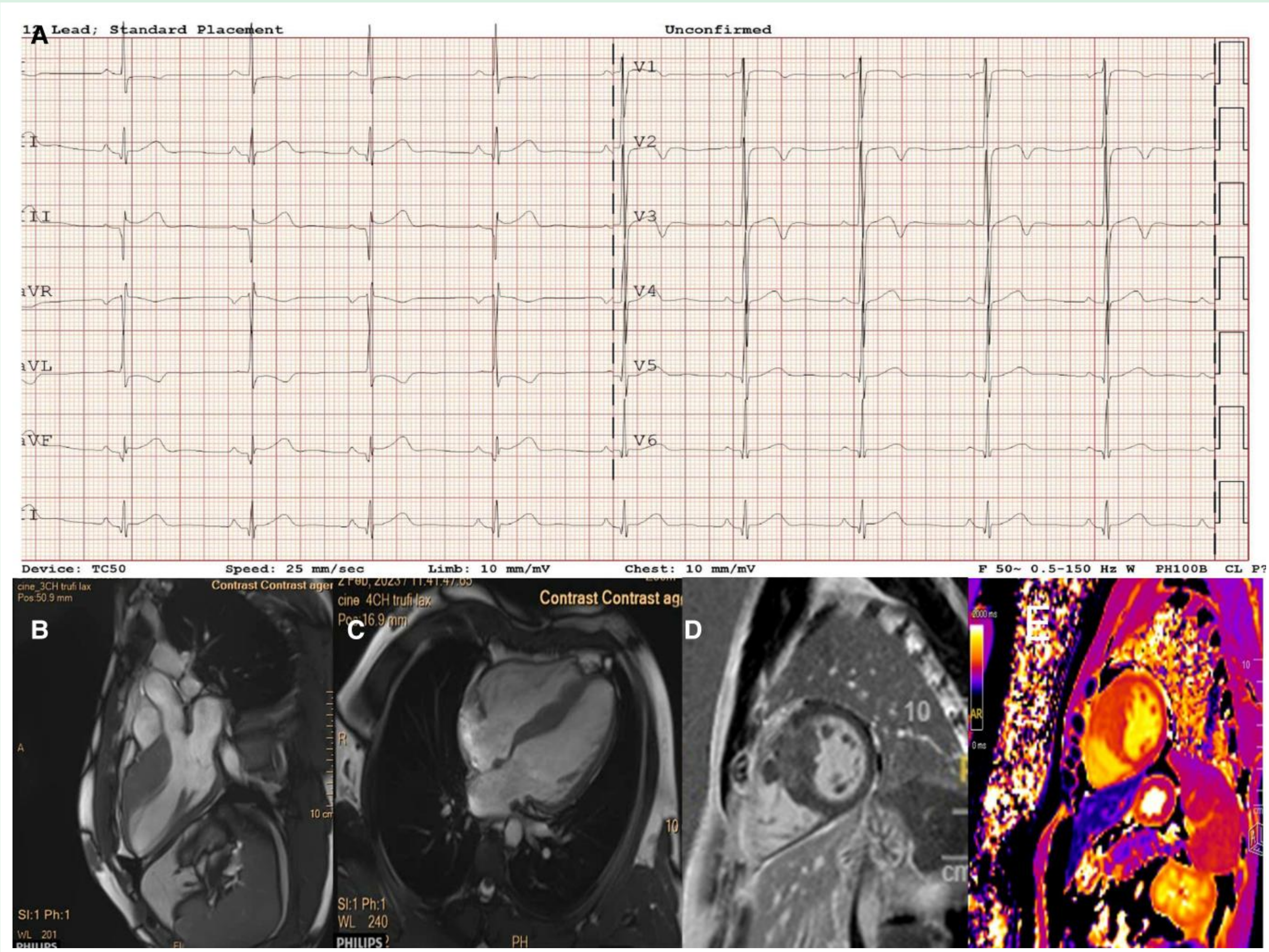


Figure 3 A 22 year old white male underwent cardiac screening at recruitment. A resting ECG was found to have anterior/lateral T-wave inversion (*A*). Cardiac magnetic resonance imaging later confirmed hypertrophic obstructive cardiomyopathy (*B* and *C*) with a high scar burden (*D* and *E*). Genetics was positive for a MYBPC3 pathogenic variant.

routinely screen their recruits (*n* = 11) also include an exercise test (18%) and echocardiogram (18%) in their screening protocol. A significant proportion also reported a different screening approach in older individuals (*n* = 6/14, 43%). A third (*n* = 5/14, 36%) reported changing their screening algorithm to specifically rule out CAD, using validated cardiovascular risk scores (*n* = 5/4, 36%), exercise testing (*n* = 6/14, 43%), and/or CTCA (*n* = 2/14, 14%).The individual's role in the Armed Forces influenced the screening strategy in half of the countries conducting PPCS. Reasons for disqualification, the role of a multi-disciplinary team and the logistical requirements for serial re-evaluation have also been reported in a separate manuscript.[53] The survey served to provide practical insights and contextual grounding, enabling the panel to assess whether the proposed recommendations are feasible and reasonable in real world settings.

Advice

Based on the existing literature and as a result of the present consensus, we propose that cardiovascular screening in military recruits play an essential part in the early detection of cardiac disease associated to SCA/SCD, with the ultimate aim to mitigate the risk of SCD and acute (non-fatal) cardiovascular events. It is worth acknowledging that the reported incidence of SCA/SCD in females appears lower (compared with males) in military cohorts, similar to data reported in female athletes.[78–80] Nevertheless, the current level of evidence would not justify a gender-specific screening strategy, similar to current recommendations in competitive athletes.

Members of the writing group voted anonymously on key advice statements using an online electronic survey with ≥75% agreement required for consensus. Questions which did not reach a consensus at the initial voting stage were rediscussed and reworded to enhance statement clarity. A second online electronic survey was then sent out with the revised statements.

Further detail regarding the explanation of evidence categories was added (*Table 2*). Key studies supporting each statement are provided in the relevant detailed sections in the manuscript. Eleven questions had to be answered with three choices, 'Advice', 'May be appropriate', and 'Area of uncertainty'. *Table 3* summarizes the consensus questions and the votes that reached consensus; Supplementary material online, *Table S1* lists consensus statements which did not receive ≥75% agreement.

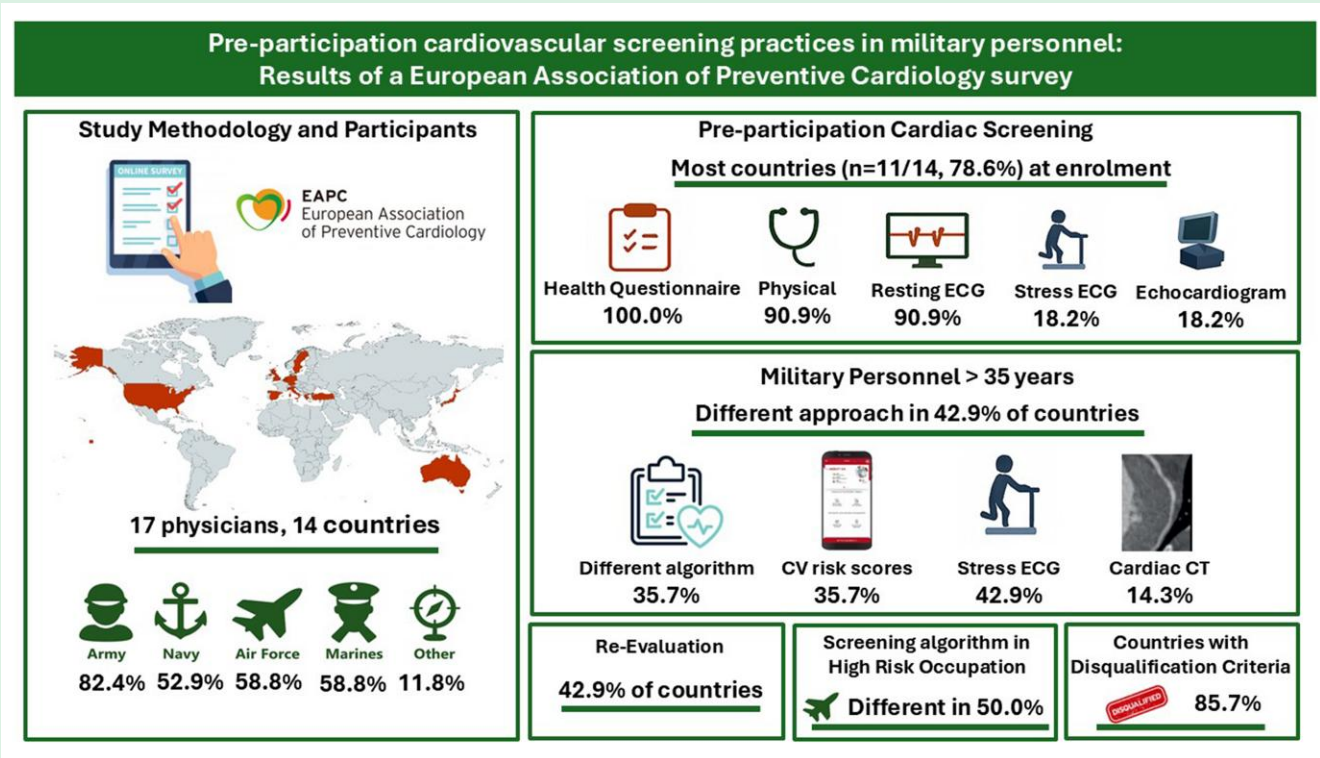


Figure 4 Survey results.

When a statement was based on robust evidence, it was designated 4 stars. When a statement was predominantly based on expert opinion, it was assigned 3 stars when all the authors agreed ('uniform consensus'). Statements were assigned 1 or 2 stars when ≥75% but not all authors were in agreement. The distinction between 1 star and 2 stars was based on 'some published evidence' or 'consensus opinion', respectively. Statements which did not reach consensus were not included in the key consensus statements (*Table 3*).

Key statements about cardiovascular screening for military recruits are provided in *Table 3*, indicating the strength of advice. A step-wise practical approach to screening is illustrated in *Figures 5* and *6*. Dissenting votes for statements that reached agreement and those that did not reach agreement are provided in Supplementary material online, *Table S1*.

For the purpose of this document, high hazard duty occupations are roles characterized by an increased cardiovascular response elicited during active engagement in challenging operational environmental conditions, including (but not limited to) extreme temperatures, altitude and gravitational forces (refer to *Figure 1*).

Table 2 The strength of advice based on the following definitions

Clinical advice, based on robust published evidence	****
Clinical advice, based on uniform consensus of the writing group	***
May be appropriate, based on published evidence	**
May be appropriate, based on consensus of the writing group	*
Area of uncertainty	?

Proposed infrastructure including human resources and facilities

All military personnel should undergo cardiac screening at recruitment, irrespective of their role with the entity. The screening algorithm should be uniform across the board, with no evidence supporting a modified approach in those undergoing high-risk duty occupations. Cardiac screening should be implemented at entry, preferably conducted by an experienced military physician.[81] They should be competent in completing a health questionnaire, conducting a physical examination, and also performing and interpreting a resting 12-lead ECG. A proposed screening algorithm to complement the reported consensus statement is shown in *Figures 5* and *6*. This, however, requires some experience in ECG interpretation, especially in younger individuals to avoid over or under-interpretation of ECG abnormalities.[37] Most abnormal ECG patterns identified at screening are physiological training-related variants. These anomalies should be regarded as normal variants, as outlined in the International Criteria for ECG in athletes,[37] albeit developed for athletes, not soldiers.[37] Serial re-evaluation in individuals with a normal initial screen would seem reasonable (*Figure 5*), particularly in light of emerging evidence suggesting that repeat assessment may enhance diagnostic yield.[82,83]

Table 3 Key statements

Topic	Explanation	Strength of advice
Screening advice	Cardiac screening may be appropriate in all asymptomatic new military recruits.	**
	Cardiac screening should be performed in all new military recruits engaging in specific high hazard duty occupations.	**
Screening algorithm	The screening algorithm for all new military recruits should include a health questionnaire (personal and family history), physical examination and a resting 12-lead ECG.	*
	Symptomatic individuals or those with an abnormal screening should undergo a comprehensive evaluation. This may include echocardiography, stress ECG and other exams as clinically appropriate.	**
	A multi-disciplinary approach when evaluating abnormal screening outcomes in military personnel is advised.	**
Screening considerations	A screening programmes should include the necessary infrastructure and resources which should have access to a multi-disciplinary team.	**
	Inclusion of a cardiologist with expertise in Military Occupational Medicine as part of the multi-disciplinary team may be appropriate.	**
Screening in older individuals (≥40 years)	In addition to the standard screening algorithm, older individuals (≥40 years) in the military should have a cardiovascular risk assessment using cardiac society endorsed validated cardiovascular risk calculators. Those with a high or very high cardiovascular risk profile should undergo further evaluation.	****
Frequency of screening	Periodic re-evaluation is warranted in individuals with abnormal screening results who nevertheless meet the military forces' entry criteria.	**

However, the optimal interval for re-screening remains undefined, and any proposed frequency should take into account local infrastructural and economic considerations. Referral for a more in depth evaluation is warranted in symptomatic individuals, in cases of an abnormal examination, personal and/or family history, or when the ECG is abnormal.[37,84] The frequency of re-evaluation should be adjudicated on a case-by-case basis.

A modified screening algorithm for young recruits in high-risk duty occupations remains an area of ongoing debate. At present, there is no evidence supporting a different approach in asymptomatic individuals with a normal family history and resting ECG, nor data indicating that these recruits carry a higher baseline risk. As outlined in a previous section, some organizations nevertheless adopt expanded protocols for those recruits engaging in a high-risk duty occupation.[49–53] Any decision to implement such an expanded approach should reflect local priorities and be balanced against available resources and clinical expertise.

For older individuals, access to a laboratory is required to rule out hyperlipidaemia (lipid profile) and hyperglycaemia (fasting blood glucose and HbA1c).[85] These results are key components in cardiovascular risk calculators.[13] Risk factor management with lifestyle modification and medical therapy, complimented with repeat testing inevitably helps improve cardiovascular outcomes.

For second- or third-line diagnostic tests, a multi-disciplinary team is required.[86–88] Inclusion of a cardiologist with expertise in military occupational medicine as part of the multi-disciplinary team may be appropriate. They should preferably have access to exercise ECG (or cardiopulmonary exercise testing), echocardiography, stress-echocardiography for functional testing, ECG monitoring, and ambulatory blood pressure monitoring. The multi-disciplinary team should ideally include a cardiac imaging specialist. CTCA may be required if suspecting anomalous coronary arteries. CTCA may also be used to confirm/exclude CAD and in high hazard employees this may include its use in asymptomatic individuals with an elevated CV risk. Cardiac magnetic resonance (CMR) may be required for tissue characterization (suspicion of cardiomyopathy or myocarditis), stress perfusion (ischaemia assessment), valvular heart disease (severity), or aortic dimensions.[89] Nuclear imaging (i.e. for myocardial perfusion imaging, positron emission tomography-computed tomography, single photon emission computed tomography) can be helpful.[77] Genetic testing also plays a complementary role in phenotyping and risk stratification of inherited cardiovascular disorders. For certain high hazard duty occupations including flying or diving, referral to an appropriately trained specialists in aerospace or diving medicine is mandatory.

Risk stratification of asymptomatic older individuals is certainly an area of uncertainty. As outlined in a previous section, CAD is an important driver of cardiovascular morbidity above the age of 35 years. Emerging evidence about the high prevalence of coronary calcification and CAD in master athletes has also paved the way for more elaborate phenotyping with CTCA.[56] The long-term clinical implications of ischaemia testing or coronary anatomy assessment of asymptomatic individuals in high or very high cardiovascular risk categories remains unclear, which is why the recent EAPC/ACC clinical consensus statement on the evaluation of Master Athletes does not commit to a uniform approach.[56] Similarly, the ideal approach in military personnel is unclear. We suggest a pragmatic approach towards risk stratification in this population (*Figure 6*), comprising of a history, physical examination, resting 12-lead ECG, and validated

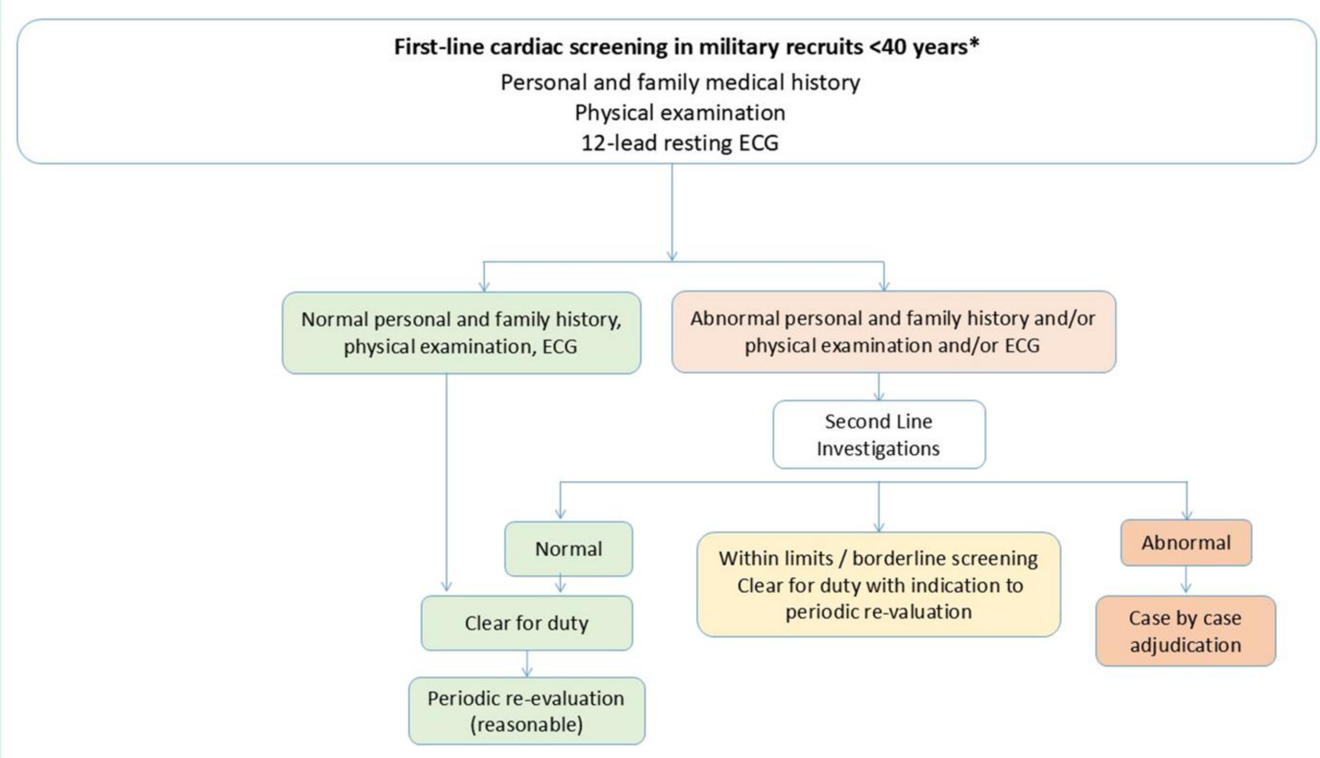


Figure 5 Proposed screening algorithm for military recruits <40 years, irrespective of military branch (*). Second-line investigations may include (but not limited to) echocardiography, exercise testing, ambulatory ECG monitoring, CTCA, cardiac magnetic resonance imaging, cardiac genetics (Legend: white boxes: evaluations, green boxes: normal results, red boxes: abnormal results, yellow boxes: cleared for duty but with indication for follow-up).

cardiovascular risk calculators. Notably, conventional risk calculators are validated primarily for individuals aged 40 years or older. The risk stratification algorithm should hence be individualized in those individuals in the 'grey zone' (≥35 and <40 years). Ultimately, the diagnostic pathway for all older service members demands an individualized approach tailored to the specific clinical scenario, level of concern, and available institutional resources.

Given that delayed access to defibrillation and advanced care is a recognized driver of cardiovascular mortality in tactical settings, it is reasonable to highlight that broader emergency preparedness, including access to automatic external defibrillators, first-responder training, and structured emergency action plans, may offer additional layers of protection.[90,91] While specific recommendations fall outside the scope of this document, acknowledging these elements provides a natural and actionable complement to screening-based strategies.

Barriers to adopting a uniform approach

The main barrier to adopting a uniform approach to screening for CV disease is the diversity of specializations within the Armed Forces. Whilst 200 years ago, Armed Forces could more or less be divided into infantry, artillery, cavalry, and navy, all acting on the battlefield or the ocean, personnel nowadays have very different tasks, including information technology, cyberwarfare, etc. This sub-specialization is also evident in the Air Force, with a marked difference when comparing fighter pilots, pilots of other manned aircraft, pilots, and operators of remotely piloted aircraft systems, personnel operating reconnaissance satellites in space, operating missiles, radar, or communication systems.

All of the different services and branches of the armed forces have their own physical challenges, and many have their own specialized medical personnel responsible for their specific evaluation. Defining the balance between clinical risk and operational readiness across diverse environments remains challenging. This is further complicated by the inherent tension between a traditional model centred on patient autonomy and a shared-decision-making framework. In military settings, the decision making circle necessarily expands to include not only the medical officer and the service member, but also the operational commander, whose considerations must reflect the exigencies of military operations. The risk of sudden incapacitation because of serious cardiac pathology (*Table 1*) or benign yet limiting symptoms changes in different situations and environments. Individuals with an abnormal screening outcome should be adjudicated on a case-by-case basis (*Figures 5* and *6*), factoring in personnel safety, operational requirements and knowledge gaps.

Beyond reducing the risk of SCD, regular physical assessments are often done to evaluate who is fit enough and best

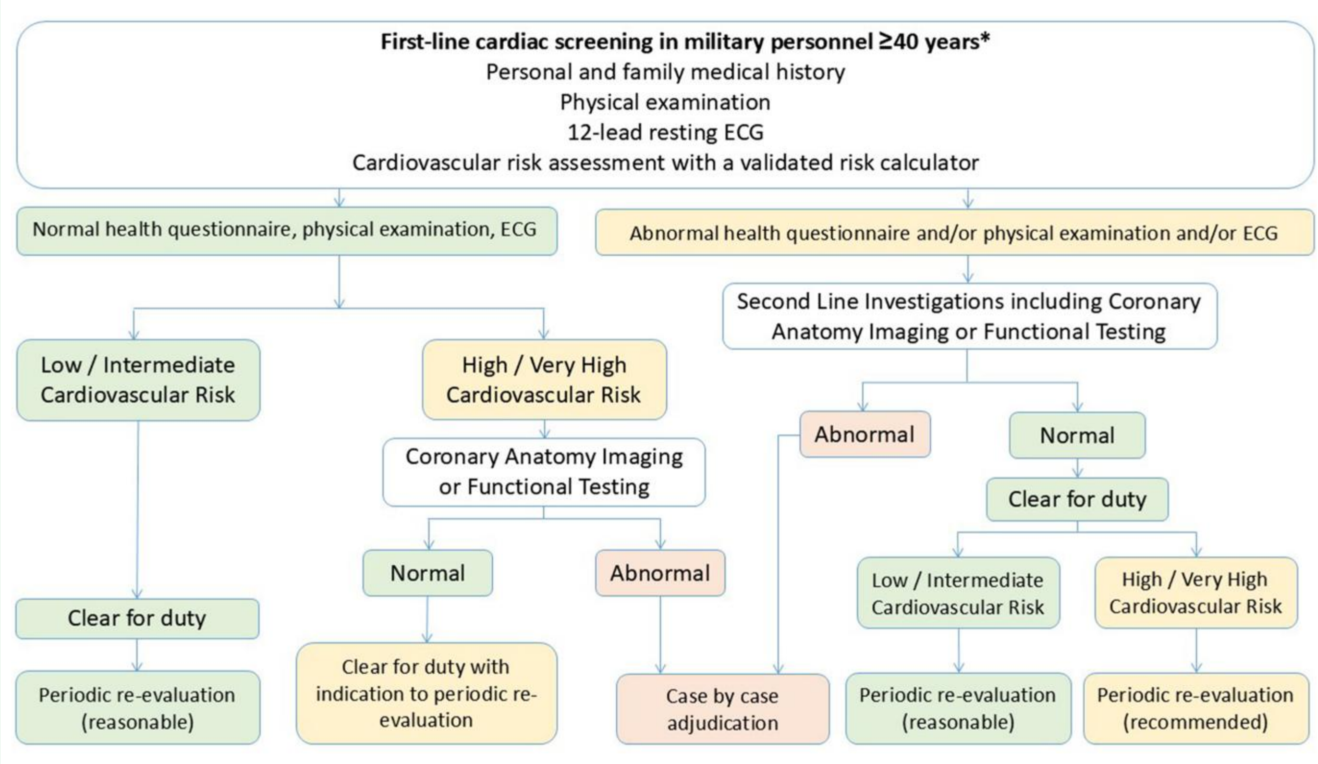


Figure 6 Proposed screening algorithm for military recruits <40 years, irrespective of military branch (*). Second-line investigations may include (but not limited to) echocardiography, exercise testing, ambulatory ECG monitoring, CTCA, cardiac magnetic resonance imaging, cardiac genetics, as clinically indicated (Legend: white boxes: evaluations, green boxes: normal results, red boxes: abnormal results, yellow boxes: cleared for duty but with indication for follow-up).

suited for military operations. As a result of varying force sizes, defence budget constraints and level of current conflict, different nations may have to take a very different approach to their service personnel in terms of anticipated period of service, or willingness to tolerate workforce attrition for medical reasons. In spite of these variable factors, modern service personnel remain subject to the physical and environmental stressors outlined above. The ongoing threats to cardiovascular health that these stressors present demand our attention, and require the presentation of a coherent international consensus on recruit screening, which protects the individual and the mission.

Economic feasibility and health inequality

A uniform cardiovascular screening model may not be feasible across nations with widely varying military health budgets. Factoring in financial considerations when adopting these screening recommendations is paramount,[6,48] although the cost of a baseline clinic assessment and a resting 12-lead ECG are generally modest. A tiered framework, defining optimal screening components while allowing a pragmatic focus on higher-risk groups, enables armed forces in lower-resource settings to implement a scalable approach without compromising core risk-mitigation principles. Priority groups that warrant focused evaluation include personnel in high-risk occupations, symptomatic individuals, and those with a family history of cardiovascular disease. At a minimum, screening should consist of an entry health questionnaire, physical examination, and resting ECG. Use of cardiovascular risk calculators in older individuals (>40 years) is also reasonable, provided these are validated for the population at risk. Any screening programme must also be supported by the necessary infrastructure for timely follow-up, evaluation, and management, ensuring that identified abnormalities can be appropriately addressed.

Knowledge gaps and future research

Data on the diagnostic yield of cardiac screening programmes have been reported in the general population, including athletes and non-athletes.[11,42,47,82,92] However, the yield of screening in military cohorts remains to be fully determined. Moreover, the evidence supporting ECG inclusive screening algorithms is derived almost exclusively from young, physically active populations. Its performance in older individuals (>40 years), including ageing military personnel, is far less certain. Standardized screening algorithms and a properly defined denominator for screened individuals may help address these knowledge gaps. The impact of screening on cardiovascular outcomes in the military context should also be explored in large studies.

Owing to a paucity of data, conditions that may require occupational restriction in the military are usually determined by expert consensus. Furthermore, military fitness test results are rarely included in the health record. This represents a failure to exploit prognostically significant data for risk prediction.[93] Capturing these data points, widespread implementation of military trauma registries (including disease and non-battle injury), and the creation of 'mirror cohorts' from huge clinical outcome datasets available in civilian medicine are all being explored to fill the existing evidence gaps.[94]

The potential for AI to analyse vast clinical datasets offers a potential paradigm shift in military medical screening. Instead of relying on diagnostic tests that are *qualitatively associated* with risk, AI offers quantitative prediction of clinical events: an accurate, unbiased diagnosis directly tied to outcomes. However, it is essential to appreciate that this approach is exquisitely vulnerable to the quality, and applicability of the data being analysed and that it risks potentially excluding those individuals who fall outside the normal distribution. The AI-ECG risk estimation algorithm has been validated to predict short- and long-term mortality risk from a single ECG.[26] Exploring an AI-ECG approach in military screening programmes is reasonable and should be evaluated in large longitudinal studies.

There are excellent data on the prognostic power of CACS in asymptomatic individuals.[56,95] There are currently three active studies exploring the prognostic significance of CTCA in asymptomatic groups (Netherlands: SUSPECT cohort, USA: Aging Warrior Study, Scotland: SCOT-HEART 2 Trial).[64,96] Other novel approaches such as the use of radiomic analysis of imaging data also hold potential promise in risk prediction.[50]

Conclusion

Cardiac screening in military personnel offers an excellent opportunity to identify individuals at risk of harbouring cardiovascular conditions linked to SCA/SCD. It also helps identify those individuals who need periodic re-evaluation due to cardiovascular disorders that are not linked to SCA/SCD, or in those with equivocal yet non-diagnostic findings at evaluation. Uncovering these anomalies has significant implications for the individual's health, operational readiness, and long-term cardiovascular risk. A previously high false positive rate when screening athletes with ECG has discouraged widespread implementation of ECG based screening programmes in military personnel. The improved sensitivity and specificity of the latest international criteria, has however rekindled the role of the ECG when screening athletic individuals.[8] The advice presented in this manuscript will hopefully streamline screening practices in military personnel, whilst encouraging ECG based screening algorithms. Future work should explore the diagnostic yield of screening programmes within the armed forces, and evaluate the long-term implications of such screening on cardiovascular outcomes.

Supplementary material

Supplementary material is available at *European Journal of Preventive Cardiology*.

Author contributions

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