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Why cardiovascular screening is not appropriate for the general population?

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Abstract: *In most cases, exercise is beneficial for cardiovascular disease, but sometimes exercise can trigger sudden death, and different factors influence the common causes of premature death. Although most cases of sudden death have a rapid onset, some of these deaths can be predicted in advance. For example, cardiovascular screening is clinically significant for preventing sudden cardiac death. There are many types of early screening, the most common being electrocardiography (ECG), ambulatory blood pressure, coronary angiography, computerized tomography (CT), PET-CT, and ECG general exercise testing. Some national and regional clubs have made cardiovascular screening a mandatory pre-competition test for athletes to reduce the likelihood of sudden death during competition. However, to date, cardiovascular screening has not been widely available in the general population worldwide, taking into account numerous factors. This article will discuss why cardiovascular screening is unsuitable for use in the general population in terms of low prevalence, differences in screening modalities corresponding to different pathogenesis, and the inaccuracy and high cost of differential cardiac screening methods.*

Keywords: *sudden death, sports, cardiovascular screening, general population*

1. Introduction

Regular exercise has been shown to reduce the risk of many diseases and reduce cardiovascular mortality. But people still die every year while playing sports. Sudden death while participating in sports causes irreparable damage to the individual and affects many parts of society, such as the victim's family, team members, and healthcare workers. The previous study (Weiner et al., 2012)[1] has shown that most sudden exercise-related deaths result from cardiovascular disease. At present, the common causes of sudden death are myocardial infarction, myocarditis, conduction abnormalities, etc. Different cardiovascular diseases are affected by various factors, such as age and gender.

Despite the tragic consequences of sudden death during exercise, cardiovascular screening has not been widely used for pre-exercise screening in the general population. Researchers differ on whether cardiovascular screening should be applied to the general population. However, the current consensus among the majority of the population is that cardiovascular screening is not cost-effective for sudden death during exercise and is not suitable for use in the population. This article will explore why cardiovascular screening is unsuitable for the general population. And whether there are ways to reduce sudden death in exercise in the general population in the future or make cardiovascular screening available in the general population.

2. Situation

SCD was defined as death occurring within 12 hours of apparent health. There are few cases of sudden death in sports, which are caused by cardiovascular disease. Some of these deaths could have been predicted in advance and prevented, sparking some scientific debate. Proponents of cardiovascular screening before exercise (Corrado et al., 2007)[2] argued that screening can prevent many cases of sudden death. Although exercise reduces coronary heart disease events, vigorous exercise is associated with a risk of sudden cardiac death and myocardial infarction, which typically occur in individuals with structural heart disease. In young people, abnormalities in cardiovascular disease are mainly genetic and congenital. But in adults, atherosclerosis is the leading cause of such events.

Thompson et al.(2007)[3] had pointed out that the pathological manifestations of sudden sports death

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vary with age. The most common manifestations in young people younger than 40 years old are hypertrophic cardiomyopathy, coronary artery abnormalities, aortic stenosis, and arrhythmias. Another condition among young people is myocarditis. The immediate cause of death under these pathological manifestations is ventricular arrhythmia. Coronary heart disease is the most common cause of sudden exercise death in the elderly compared with the young. As such cardiovascular diseases are characterized by occult onset, sudden onset, lack of warning, and high mortality and disability rates, it seems that early screening is of clinical significance. In the routine examination, the most common are electrocardiogram, dynamic electrocardiogram, dynamic blood pressure, coronary angiography, CT, cardiac magnetic resonance, ECT, and can also do PET-CT, electrocardiogram flat exercise test, and compound echocardiography. When necessary, arteriography also needs to be done. Most of these screenings are costly, and not all cardiovascular procedures can be predicted using the same screening methods. Therefore, this paper will analyze the reasons why cardiovascular screening is not suitable to be popularized in the general population based on the factors such as the extremely low incidence of sudden death during exercise, the population characteristics of sudden death during exercise, and the sensitivity and specificity of different cardiovascular screening methods.

3. Reasons

3.1 Reason 1——Low incidence rate

Many researchers believe that cardiovascular screening is not appropriate for the general population to prevent sudden death during exercise for various reasons. The first is that the incidence of sudden death is extremely low. Solberg et al. (2009)[4] have stated that although the relative risk of sudden death during exercise is 2.5-17 times higher than at rest, the absolute risk of sudden death during exercise remains low. Studies have measured the probability of sudden death during exercise in different populations. It turns out that the likelihood of sudden death is very low in athletes and even lower in non-athletes.

Corrado et al. (2003)[5] conducted a 21-year prospective cohort study of all young people in a particular region of Italy, including male and female athletes and non-athletes, involving a total population of 1.386,600 people, including 112,279 people competitive athletes. The researchers conducted gender analysis and pathological basis analysis of SD in the exercise and non-exercise population. According to the data, 2.3 out of 100,000 athletes and only 0.9 out of 100,000 non-athletes suffer from sudden death each year.

In addition, most published reports of the incidence of sudden cardiac death range from 1:8,000 to 1:200,000, suggesting that sudden cardiac death is uncommon in high school - and college-age competitive athletes (Maron et al.,2015)[6].

Although some countries and regions list pre-competition cardiovascular screening as a must-check item for athletes, with such low rates of sudden death, offering such screening to the general population would be costly in most areas and therefore not recommended.

3.2 Reason 2——Different pathological bases require other screening methods

In addition to its low incidence, another essential factor why cardiovascular screening is not recommended in the general population is that the exact causes and predisposing factors of sudden cardiac death are varied. An analysis of autopsy reports from athletes who died over 20 years found that sudden arrhythmogenic death syndrome (SADS) was the most common cause of death at 42 percent, followed by cardiac disease at 35 percent. The causes of death were also age-related and sex-related. The results showed that SADS was more common in younger people, accounting for 56% of those under 18, and declined with age. In people older than 35, the leading causes of death are idiopathic LHV/fibrosis and SADS. The choice of targeted screening remains a question. Some findings (Toh et al., 2017)[7] suggested that a strategy based solely on first-degree relative screening is of low diagnostic efficacy in SADS cases. The highest yield tests appear to be resting 12-lead ECG and ajmaline provocation.

Screening requirements for sudden cardiovascular death events are not the same on different pathological bases. General screening includes family history、symptoms、physicalexamination(PE)、ECG(electrocardiogram)、Echocardiogram and some others，like 24-hour Holter monitor、exercise test、cardiac magnetic resonance imaging(CMRI). The 12-lead ECG has been proven to provide a valuable diagnosis of sudden cardiac death due to arrhythmia (Brugada et al.,2010)[8]. For example, screening for catecholamine-sensitive pleomorphic ventricular tachycardia (CPVT) usually includes family history、symptoms、ECG and exercise tests. For QT syndrome, besides primary screening, like family history, symptoms, and ECG, a 24 hour Holter monitor can also be used to screen for short QT syndrome.

The screening method for long QT syndrome can be based on the screening for short QT syndrome with Ajmaline provocation.

Finocchiaro et al. (2016)[9] have pointed out that while SADS and coronary artery abnormalities mainly affect young athletes (≤ 35 years old), the myocardial disease is more likely to occur in the elderly population, and arrhythmogenic right ventricular cardiomyopathy(ARVC) and left ventricular fibrosis most strongly cause SCD during exercise. Cardiomyopathy, a group of cardiovascular diseases, based on ventricular morphology and function, is one of the leading causes of morbidity and mortality worldwide. Cardiomyopathy, mainly divided into hypertrophic (HCM), dilated (DCM), and restricted (RCM), is a chronic debilitating disease caused by biomechanical defects in myocardial contraction and may progress to heart failure (HF) (Yadav et al., 2019)[10]. The main screening methods for cardiomyopathy are routine electrocardiogram, echocardiography, coronary artery CTA, and myocardial biopsy, combined with clinical findings and family history. Here are three examples of cardiomyopathy, namely ARVC, DCM (Dilated Cardiomyopathy), and HCM (Hypertrophic cardiomyopathy). The standard screening methods for ARVC in the elderly include family history, symptoms, PE, ECG Echocardiogram, EP studies, and CMRI. However, EP studies are not used for HCM and DCM screening. Instead of the exercise test, HCM can also be screened by CMRI.

Therefore, there are many possibilities for exercise-induced sudden cardiac death, and each pathologic basis is screened differently. Consequently, it is crucial to select the most appropriate screening method. More common screening methods, such as family history, PE, and ECG, can be used in most cardiovascular diseases, so screening is not specific and cannot identify the cause. In order to confirm the diagnosis, other screening methods should be selected. It is true that electrocardiograms or echocardiograms can increase the chance of detecting cardiovascular abnormalities. Still, it was noted that such cardiovascular screening is not feasible and costly to provide on a continuous basis for most schools. Especially considering the frequency of sudden death (Glover, 1998)[11].

3.3 Reason 3——Inaccuracy & high cost

In addition to the extremely low incidence and many factors that make screening a problematic option, researchers believe there is another reason cardiovascular screening should not be used in the general population. This is the inherent inaccuracy and high cost of cardiovascular screening. Whether any screening can be popularized in a population involves its own efficiency and cost. In terms of efficiency, previous studies have linked the majority of sudden death during exercise to cardiovascular disease. This has raised concerns about cardiovascular screening before exercise. The selection of targeted screening methods can predict insidious diseases and lead to life-saving measures. Although pre-exercise screening has been used at some events, its overall efficacy in reducing sudden death during exercise is uncertain. A current focus is to add noninvasive testing (especially 12-lead electrocardiograms) to the history/family history and key physical examinations. It has been suggested that the accuracy of cardiovascular screening remains to be tested (Thompson & Levine, 2006)[12]. When evaluating the accuracy of cardiovascular screening, there are two fundamental indicators: positive and negative. Both positive and negative predictive values are used to assess the accuracy of a screening procedure. These two indicators define whether screening tests are reliable. The positive predictive value refers to the probability of abnormalities during screening and the actual presence of disease. In contrast, the negative predictive value refers to whether a negative screening result reflects the absence of disease.

Weiner et al.(2012) conducted a study of echocardiographic analysis of college athletes in the United States. The results found that both positive and negative predictive values of pre-exercise cardiovascular screening using only medical history and physical examination were less effective. However, when an electrocardiogram was added to screening, the negative predictive value decreased, but the rate of false-positive results increased. The addition of the ECG appears to improve screening but not the accuracy of the test because of the high false-positive rate. At the same time, other researchers (Steinvil et al., 2011)[13] demonstrated that mandatory ECG screening for athletes had not reduced sudden death rates in Israel.

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There are also human factors that affect the accuracy of the electrocardiogram. Currently, the American Heart Association supports the use of medical and family history and physical examination as pre-exercise cardiovascular screening programs (Maron et al., 2007)[14]. The European Society of Cardiology, the International Olympic Committee, the Federation Internationale Football Association, and several other countries have adopted more sophisticated screening methods, adding electrocardiograms and the standard medical history. However, an Italian study showed a 90 percent reduction in sudden death from exercise after a screening program that included an ECG. But the lack of doctors skilled enough to interpret ECG correctly remains a significant obstacle, raising concerns about the reasonability, false-positive rate, and cost-effectiveness of the screening program for the general population (Asif & Drezner, 2012)[15].

Regarding the cost-effectiveness of screening in isolation, the cost of adding ECG to screening programs has been a central argument against its routine use. Previous studies have not thoroughly analyzed the costs and benefits of ECG screening. WHEELER et al. (2010) attempted to establish a cost-effectiveness model for applying 12-lead ECG to pre-participation cardiovascular screening in young athletes. The authors obtained medical costs for the tests from the National Center for Health Statistics. A general physical exam and medical history cost $73, a 12-lead EKG costs $34, and additional screening options mentioned earlier, such as ultrasound EKG costs $253, cardiac MRI costs $1,100, and Holter Monitor costs $380. The trial, which estimated the cost of each type of screening, suggests that screening athletes using electrocardiograms alone may be the best option, which is less costly. It has been shown that screening by cardiovascular history and physical examination alone may not be cost-effective, mainly because of the poor sensitivity and specificity of the screening method. The problem is that the data are based on a single screening, not annual screening, as is currently advocated. Although the most cost-effective screening method is acceptable, due to the inaccuracy of screening, positive screening results are highly likely to be false-positive results, resulting in more secondary screening costs.

Furthermore, the authors suggest that extending screening to all students is not cost-effective in reducing the incidence of sudden sports death. Developing screening for younger age groups may be a more economical option for screening without screening and combining ECG with a medical history and physical examination. It is not hard to imagine that applying the same screening strategy to different risk groups would have different cost benefits. In general, men and professional athletes seem to be at high risk for sudden death during sports. In addition, the epidemiology of sudden death varies between regions and countries, and these differences can lead to low cost-effectiveness of cardiovascular screening in the general population.

Researchers in Japan have also analyzed the usefulness and cost-effectiveness of cardiovascular screening for adolescents compared with similar reports in the United States (TANAKA et al., 2006)[16]. During this time, Seventh graders in all schools at one location in Japan took part in a cardiovascular screening questionnaire and an electrocardiogram screening. A total of 37,807 students were screened at level 1 at the cost of $1.26 million. Secondary screening, which includes chest X-rays, echocardiography, and exercise stress electrocardiograms, was performed by 1,876 students at a total cost of $290,000. The study identified a total of nine victims, one of whom died. Based on Fuller's algorithm, the trial concluded that the annual cost of lives saved from the screening program was $8,800, far less than the $44,000 to $200,000 that Fuller has reported (FULLER, 2000) [17].

In contrast, Fuller's data analysis on the cost-effectiveness of cardiovascular screening in high school athletes showed that electrocardiograms were the most cost-effective cardiovascular screening available and were about twice as sensitive as medical history and physical examination. Compared with echocardiography, its cost is lower, about 4.5 times. A history of cardiovascular disease screening and physical examination is limited by their inability to detect the cause of sudden death. Most hypertrophic cardiomyopathy is asymptomatic and difficult to screen for on physical examination. Echocardiograms are limited by their high price, which is $350. Echocardiograms produce false positives when HSA screening is performed and therefore require further and more expensive screening, so the actual cost-effectiveness of echocardiograms may be lower than the experimental results suggest.

4. Evaluation

The United States and Japan trials were conducted among adolescents and young adults. Due to the low incidence and mortality of sudden cardiac death in this population, the study results may be

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inaccurate in calculating the cost-effectiveness, which does not apply to the general population. In addition, the study in the United States is conducted among athletes, who have a higher probability of sudden death in sports compared with the general population. Therefore, the cost-benefit value obtained will be higher if applied to the general population. In addition, due to age, gender, and other factors, the cost-effectiveness of different groups is different, so how to properly evaluate the cost-effectiveness still needs further study.

On the other hand, there is a common drawback of the current experiments, that is, the insufficient number of samples and the characteristics of participants in each study are similar. Future investigations should consider whether the participants need to be further expanded to include different groups. In addition, the follow-up screening was interrupted in the experiment. Although some students have abnormal screening results but are very positive for follow-up screening, many students still do not follow the recommended follow-up evaluation. The barriers may be demographic errors, family's lack of support, and lack of health insurance.

In fact, due to the low incidence of such sudden death, many countries conduct cardiovascular screening only in the competitive athlete population, with the cost of screening for athletes under 18 years of age being financed by the state. But Danish medical authorities do not screen young athletes for cardiovascular disease. They choose to use these resources elsewhere to reduce mortality and improve public health. Those policies could include releasing cardiac arrest transmitted defibrillators in public places. When the cost of controlling mortality is too high, it may be possible to improve the treatment of the disease and reduce mortality in the population.

5. Conclusion

At present, most researchers believe that cardiovascular screening should not be universal in the general population to prevent sudden death during exercise. The reasons are mainly about the incidence of disease and the characteristics of such screening. Firstly, the incidence and mortality of sudden sports death are very low. Secondly, the incidence of sudden sports death varies with age, sex, and occupation. Previous studies have shown that the frequency of sudden death in sports is much higher for athletes than for the general population, and men are more likely to have sudden death. And the common pathogenesis of young people is different from that of the elderly. Young people are more sudden death caused by arrhythmia, and older adults are more sudden death due to cardiomyopathy.

On the other hand, screening also has factors that make it difficult to generalize. There are many different cardiovascular screening programs, and different programs have different sensitivity and specificity. It is difficult to ensure appropriate screening programs when patients are asymptomatic. If multiple screening programs are performed to ensure that the pathologic mechanism is identified, this can waste cost. And there is still a shortage of doctors in the United States who can accurately interpret the meaning of electrocardiograms. The accuracy of screening also needs to be improved. There are further and more expensive screening costs when there are false positives in primary screening. Combined with these factors, current cardiovascular screening is not suitable for use in the general population due to its low cost-effectiveness. Future research could explore whether it is possible to introduce different cardiovascular screening programs in different people or reduce sudden death rates through national policy support in areas other than screening, such as first aid education or defibrillators. Future research could also explore improving techniques to make screening less costly or more accurate.

References

[1] Weiner, R. B., & Baggish, A. L. (2012). Accuracy of ECG-inclusive preparticipation screening in athletes: more work to be done. Expert Review of Cardiovascular Therapy, 10(6), 671–673. https://doi.org/10.1586/erc.12.60

[2] Corrado D, Thiene G. Protagonist: routine screening of all athletes prior to participation in competitive sports should be mandatory to prevent sudden cardiac death. Heart Rhythm 2007;4:520 – 524.

[3] Thompson, P. D., Franklin, B. A., Balady, G. J., Blair, S. N., Corrado, D., Estes, N. M., Fulton, J.

ISSN 2706-6819 Vol.4, Issue 7: 1-6, DOI: 10.25236/IJFM.2022.040701

E., Gordon, N. F., Haskell, W. L., Link, M. S., Maron, B. J., Mittleman, M. A., Pelliccia, A., Wenger, N. K., Willich, S. N., & Costa, F. (2007). Exercise and Acute Cardiovascular Events. Circulation, 115(17), 2358–2368. https://doi.org/ 10.1161/circulationaha.107.181485

[4] Solberg, E. E., Gjertsen, F., Haugstad, E., & Kolsrud, L. (2009). Sudden death in sports among young adults in Norway. European Journal of Cardiovascular Prevention & Rehabilitation, 17(3), 337–341. https://doi.org/10.1097/ hjr.0b013e328332f8f7

[5] Corrado, D., Basso, C., Rizzoli, G., Schiavon, M., & Thiene, G. (2003). Does sports activity enhance the risk of sudden death in adolescents and young adults? Journal of the American College of Cardiology, 42(11), 1959–1963. https://doi.org/10.1016/j.jacc.2003.03.002

[6] Maron, B. J., Winkel, B. G., & Tfelt-Hansen, J. (2015). Cardiovascular screening for young Athletes— Reply. JAMA : The Journal of the American Medical Association, 313(16), 1674-1674. https://doi.org/ 10.1001/jama.2015.3237

[7] Toh, T., Coyne, C., Stewart, K., Muir, A., & McCall, D. (2017). 33 The diagnostic yield of screening first- degree relatives in sudden arrhythmic death syndrome.Heart (British Cardiac Society),103(Suppl 6), A20. https://doi.org/10.1136/heartjnl-2017-ICS17.33

[8] Brugada, R., & SpringerLink (Online service). (2010). Clinical approach to sudden cardiac death syndromes. Springer.

[9] Finocchiaro, G., Papadakis, M., Robertus, J., Dhutia, H., Steriotis, A. K., Tome, M., Mellor, G., Merghani, A., Malhotra, A., Behr, E., Sharma, S., & Sheppard, M. N. (2016). Etiology of sudden death in sports: Insights from a United Kingdom regional registry. Journal of the American College of Cardiology, 67(18), 2108-2115. https://doi.org/10.1016/j.jacc.2016.02.062

[10] Yadav, S., Sitbon, Y. H., Kazmierczak, K., & Szczesna-Cordary, D. (2019). Hereditary heart disease: Pathophysiology, clinical presentation, and animal models of HCM, RCM, and DCM associated with mutations in cardiac myosin light chains. Pflügers Archiv, 471(5), 683-699. https:// doi.org/10.1007/ s00424-019-02257-4

[11] Glover, D. W. (1998). Profile of Preparticipation Cardiovascular Screening for High School Athletes. JAMA, 279(22), 1817. https://doi.org/10.1001/jama.279.22.1817

[12] Thompson, P. D., & Levine, B. D. (2006b). Protecting Athletes From Sudden Cardiac Death. JAMA, 296(13), 1648. https://doi.org/10.1001/jama.296.13.1648.

[13] Steinvil, A., Chundadze, T., Zeltser, D., Rogowski, O., Halkin, A., Galily, Y., Perluk, H., & Viskin, S. (2011). Mandatory Electrocardiographic Screening of Athletes to Reduce Their Risk for Sudden Death. Journal of the American College of Cardiology, 57(11), 1291–1296. https://doi.org/10.1016/ j.jacc.2010.10.037

[14] Maron, B. J., Thompson, P. D., Ackerman, M. J., Balady, G., Berger, S., Cohen, D., Dimeff, R., Douglas, P. S., Glover, D. W., Hutter, A. M., Krauss, M. D., Maron, M. S., Mitten, M. J., Roberts, W. O., & Puffer, J. C. (2007). Recommendations and Considerations Related to Preparticipation Screening for Cardiovascular Abnormalities in Competitive Athletes: 2007 Update. Circulation, 115(12), 1643–1655. https://doi.org/10.1161/ circulationaha.107.181423

[15] Asif, I. M., & Drezner, J. A. (2012). Sudden Cardiac Death and Preparticipation Screening: The Debate Continues—In Support of Electrocardiogram-Inclusive Preparticipation Screening. Progress in Cardiovascular Diseases, 54(5), 445–450. https://doi.org/10.1016/j.pcad.2012.01.001

[16] TANAKA, Y., YOSHINAGA, M., ANAN, R., TANAKA, Y., NOMURA, Y., OKU, S., NISHI, S., KAWANO, Y., TEI, C., & ARIMA, K. (2006). Usefulness and Cost Effectiveness of Cardiovascular Screening of Young Adolescents. Medicine & Science in Sports & Exercise, 38 (1), 2-6. https://doi.org/10.1249/01.mss. 0000183187.88000.53 from 1989 to 1997

[17] FULLER, C. M. (2000). Cost effectiveness analysis of screening of high school athletes for risk of sudden cardiac death. Medicine & Science in Sports & Exercise, 887-890. https://doi.org/10.1097 /00005768- 200005000-00002