Int J Cardiovasc Sci. 2023;36:e20220052

ORIGINAL ARTICLE

Electrocardiogram as Part of the Evaluation of Children and Adolescents Before Starting Physical Exercise

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Abstract

Background: Children and adolescents should be encouraged to participate in sports; however, physicians should screen for cardiac abnormalities that can lead to sudden death. The European Society of Cardiology, the Brazilian Society of Cardiology and the Brazilian Society of Sports Medicine indicate performing an electrocardiogram (ECG) in evaluating athletes, while the American Heart Association indicates complementary exams only when there is a personal or family history of cardiovascular diseases or changes in clinical examination.

Objectives: To evaluate the need for an ECG in evaluating children and adolescents before starting physical activities.

Methods: We recruited 983 children and adolescents who practiced physical activities for anthropometric assessment, clinical examination and conventional ECG at rest. Variables were analysed using the Goodman test with a significance level of 5%.

Results: Participants had a higher incidence of overweight, obesity and severe obesity compared to standard World Health Organization (WHO) values. The most common finding in clinical examination was heart murmur (18.5% of participants). Electrocardiographic changes were found in 3.3% of participants, including paroxysmal supraventricular tachycardia and pre-excitation syndrome, which may be responsible for sudden death, even in asymptomatic individuals with no personal or family history of heart disease and no abnormality on clinical examination.

Conclusions: ECG revealed arrhythmias that were not detected by clinical examination and may precede sudden death in individuals subjected to physical exertion, indicating its role in the assessment of children and adolescents before starting regular physical exercise .

Keywords: Physical Exercise; Children; Adolescents; Youth Sports; Electrocardiography/methods; Electrocardiography/prevention and control.

Introduction

The beneficial effects of physical exercise on physical, emotional and social development of children have been widely publicised,[1] as well as its important role in preventing chronic diseases in adults. In contrast, physical inactivity is an independent risk factor for cardiovascular diseases.[2-6]

Although the cardiovascular benefits of regular physical exercise are well established, participation in physical activities imposes a risk of sudden cardiac death, with a 2.8-fold increase in risk compared to sedentary individuals.[7] Sudden death, despite being a rare event, is highly relevant in public health, as it affects presumably healthy young people, and may be the first manifestation of heart disease and arrhythmia.[8,9]

In Italy in 1982, an evaluation program was implemented for 12 to 35-year-old athletes before participating in physical activities; this included

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DOI: https://doi.org/10.36660/ijcs.20220052

Manuscript received March 28, 2022; revised manuscript November 6, 2022; accepted December 16, 2022.

electrocardiogram (ECG), medical history and clinical examination; after 15 years, a 90% reduction in the incidence of sudden death was observed.[7] In 2004, the International Olympic Committee and, in 2005, the European Society of Cardiology established protocols recommending the inclusion of ECG in routine evaluation of athletes,[7,10] in contrast to the American Heart Association (AHA), that does not recommend including ECG in the evaluation of all athletes prior to sports activities. The AHA recommends a medical history focusing on personal and family history of heart disease in addition to clinical examination,[10-13] which is followed by the American Academy of Pediatrics.[14]

In 2013, the Brazilian Society of Cardiology and the Brazilian Society of Sports Medicine 1st Guideline on Sports and Exercise Cardiology was published, recommending ECG for children and adolescents before physical activities, which was confirmed in 2019.[15,16]

Considering this divergence in orientation between the main cardiology societies in the world, our study aims to identify cardiac changes detected only by ECG in the evaluation of children and adolescents before the practice of physical activities.

Methods

We recruited asymptomatic children and adolescents between five and 17 years old who wanted to practice regular physical activities, mainly soccer or futsal. Convenience sampling was used from social projects in the city . Invitees were included in the study when parents or legal guardians (and those over 10 years old) agreed to participate and signed the free and informed consent form, in accordance with the norms of the National Commission of Ethics in Research (CONEP).

The assessment consisted of four stages: identification; anthropometry; clinical examination with attention to cardiovascular status; and ECG. Before the evaluation, medical history was taken with the parents or guardians to exclude patients with any known heart disease or electrocardiographic alterations.

Anthropometric measurements, clinical examination and ECG were performed during participants' social project activities. Weight and height were measured with participants wearing light clothes and no shoes, and then body mass index (BMI) and its respective BMI-for sex/age Z score (World Health Organization – WHO) were calculated using AnthroPlus software.[17,18]

Clinical examination was focused on cardiovascular health status. Blood pressure (BP) was measured in the right arm after a period of rest, with individuals seated and cuff size appropriate to the arm circumference. BP was considered increased when systolic or diastolic BP measurements were above the 90th percentile for height, age and gender.[19,20]

Standard 12-lead ECG was performed at rest, with individuals in the supine position, by a pediatric cardiologist using a Tecnologia Eletrônica Brasileira (TEB) device and the ECGPC software. All ECG were recorded on the researcher's personal computer and backed up.

Statistical analysis

Associations between participant's gender and nutritional status, and clinical and electrocardiographic changes were assessed using the Goodman association test, with measurement of divergence between two multinomial populations.[21] All analyses were carried out considering a 5% level of significance. After the Kolmogorov-Smirnov[21] test, we found that age did not have a normal distribution and thus was expressed as medians and interquartile ranges. The remaining parameters were analysed as categorical variables and arranged in contingency tables. These tables were constructed using the SPSS Statistics 17.0 software, and contrasts between Goodman test[22] proportions were calculated with the help of a Microsoft Excel 2010 spreadsheet.

This study was approved by the Research Ethics Committee (protocol 3987/2011) of the institution, in accordance with the CONEP rules.

Results

This study included a convenience sample of 983 children and adolescents, of which 835 (84.9%) were male. Participant distribution by age and gender is shown in Table 1. Median age for males was 10.8 years (IQR, interquartile range 8.3 -13.6 years). Female median age was 11.2 years (IQR 9.3 - 13.0 years).

Concerning nutritional status (Table 2), a higher frequency (not statistically significant) of overweight, obesity and severe obesity was observed in females than males, and a statistically higher frequency of normal weight in males than females.

Analysis of BMI Z-score distribution showed some differences compared to the WHO normality curve

Table 1 – Distribution of participants (n = 983) by age and gender

Age (years)	Gender		Subtotal: N (%)
	Male: N (%)	Female: N (%)	
5	48 (98.0 %)	1 (2.0 %)	49 (5.0%)
6	51 (91.1%)	5 (8.9%)	56 (5.7%)
7	83 (87.4 %)	12 (12.6 %)	95 (9.7 %)
8	85 (87.6 %)	12 (12.4 %)	97 (9.9 %)
9	85 (81.0 %)	20 (19.0 %)	105 (10.7 %)
10	78 (78.0 %)	22 (22.0 %)	100 (10.2 %)
11	97 (85.1 %)	17 (14.9 %)	114 (11.6 %)
12	68 (76.4 %)	21 (23.6 %)	89 (9.1 %)
13	57 (83.8 %)	11 (16.2 %)	68 (6.9 %)
14	61 (78.2 %)	17 (21.8 %)	78 (7.9 %)
15	62 (89.9 %)	7 (10.1 %)	69 (7.0 %)
16	31 (100.0 %)	0 (0.0 %)	31 (3.2 %)
17	29 (90.6 %)	3 (9.4 %)	32 (3.3 %)
Total	835 (84.9 %)	148 (15.1 %)	983 (100.0 %)

Table 2 – Distribution of participants (n = 983) by nutritional status and gender

Nutritional status	Gender		Subtotal: N (%)
	Male: N (%)	Female: N (%)	
Normal weight	568 (68.0 %)*	78 (52.7 %)	646 (65.7 %)
Overweight	147 (17.7 %)	37 (25.0 %)	184 (18.7 %)
Obesity	83 (9.9 %)	23 (15.5 %)	106 (10.8 %)
Severe Obesity	30 (3.6 %)	8 (5.4 %)	38 (3.9 %)
Underweight	7 (0.8 %)	2 (1.4 %)	9 (0.9 %)
Total	835 (84.9 %)	148 (15.1 %)	983 (100.0 %)

** $p < 0.05$ (Goodman association test[21])*

(Graph 1). We noticed that individuals in this study were generally shorter and heavier compared to WHO standard values.

Clinical changes are shown in Table 3. The most frequent was heart murmurs, in 182 cases (81.7% of the clinical findings and 18.5% in all the study sample). Elevated BP was observed in 26 (2.6%) participants, corresponding to 11.7% of the clinical changes. Heart murmur and pectus excavatum were more common in males, and high BP in females, with a statistically significant difference for pectus excavatum only ($p < 0.05$).

Electrocardiographic changes were detected (Table 4) in 32 (3.3%) children and adolescents. The main alterations were ventricular extrasystoles in seven (0.7%) participants, and intraventricular conduction disturbances, also in seven (0.7%). No statistical difference between genders was seen.

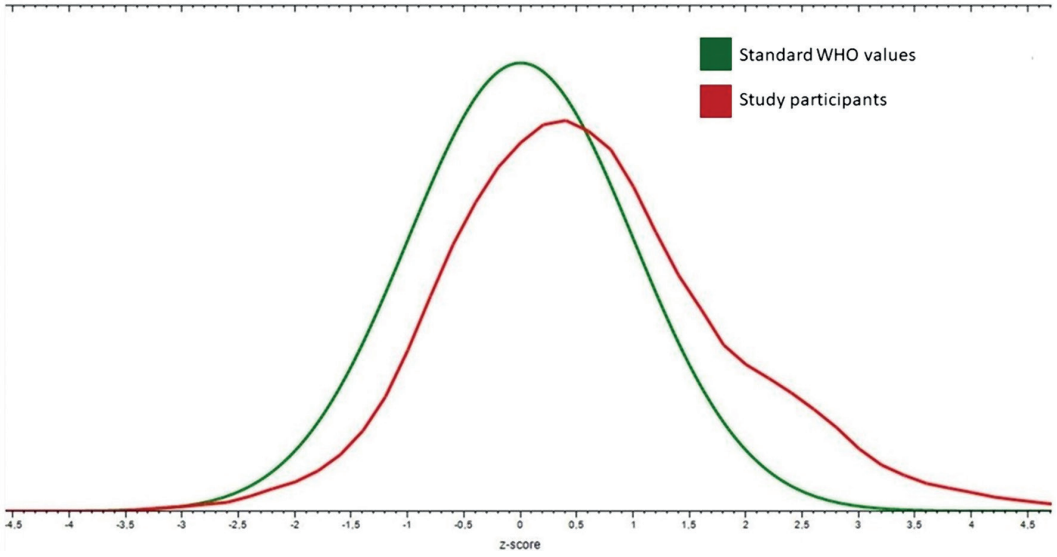
Of the 983 children and adolescents evaluated, 223 (22.6%) had clinical abnormalities (Table 3) and 32 (3.2%) electrocardiographic abnormalities (Table 4). Of these 13 participants showed both clinical and electrocardiographic abnormalities concomitantly.

Nineteen participants had electrocardiographic changes only, that is, had no personal or family history of heart disease and no clinical changes. In this subgroup, the following changes were found – ventricular extrasystoles; intraventricular conduction disorders; ectopic atrial rhythm; left ventricular overload; left anterior hemiblock; preexcitation syndrome (Wolff-Parkinson-White); first-degree atrioventricular block; sinus bradycardia and paroxysmal supraventricular tachycardia. This reinforces the importance of ECG in the evaluation of children and adolescents before beginning physical activities.

Discussion

In this study, distribution of participants by BMI z-score was different compared to the WHO curve. In females, there was a high prevalence of overweight and obesity, and these conditions are known to be associated with comorbidities[23-25] like arterial hypertension, insulin resistance, dyslipidemia, non-alcoholic fatty liver disease and metabolic syndrome. Although pharmacological treatment is possible, the main therapy is lifestyle change, with nutritional monitoring and regular physical activity.[23,25]

Although a few variables showed statistically significant differences between genders (prevalence of normal weight and pectus excavatum), our study has a selection bias due to the greater number of male participants, most of whom practiced soccer or futsal as their main sport. Sampling was by convenience, with



Graph 1 – BMI z-score distribution of the study group (red) and the WHO standard curve (green).

children and adolescents recruited from social projects, which may justify our findings.

While some medical societies such as the American Heart Association and the American Academy of Pediatrics do not recommend performing routine ECG in asymptomatic patients with no personal or family history of cardiovascular disease before physical activities.[10-13] Our results showed electrocardiographic abnormalities in asymptomatic children and adolescents that may lead to unfavourable outcomes. Although the frequency of these abnormalities was low, these children and adolescents may be at increased risk to develop heart diseases, and also sudden death from cardiac cause (e.g. Wolff-Parkinson-White syndrome and paroxysmal supraventricular tachycardia.[26-28] Our results support the recommendations of the European Society of Cardiology, the Brazilian Society of Cardiology and the Brazilian Society of Sports Medicine, that for the pediatric population undergo ECG before engaging in physical activities.[7,10,15,16]

We identified electrocardiographic changes not only in patients with cardiovascular abnormalities, but also in those with normal cardiovascular status at clinical examination. We can therefore say that a normal cardiovascular examination does not exclude the need for an ECG in evaluating children and adolescents who practice regular physical activities. Another important aspect is that both physical examination and ECG are performed with the patient at rest, but many heart diseases only generate symptoms during physical exertion; in other words, the number of alterations may be even greater if the patient was assessed during physical exertion or an exercise test.[29] Massin showed that the stress test can show specific alterations, mainly hemodynamic ones and, in terms of prognosis of heart disease, it plays an important role in evaluating these children.[29]

It is important to point out that some changes found in children and adolescents are physiological, such as an innocent heart murmur. However, differentiating between a physiological and a pathological change may be difficult, thus reinforcing the need for electrocardiographic evaluation. Even the American Heart Association recommends performing an ECG in patients with presumed physiological alterations.[10]

Parents or guardians of participants who presented clinical or electrocardiographic changes were informed about them and referred to the Pediatric Cardiology outpatient clinic of a public or private service, according to parental choice, for diagnostic investigation.

This study has some limitations. We studied a convenience with a predominance of males, as participants were recruited from social projects in which the main sports activities were soccer and futsal. In addition, some individuals already practiced regular physical activities, and we cannot rule out the possibility that the electrocardiographic changes found at rest may be in fact related to these activities. However, our objective was to

Table 3 – Clinical changes in the study population (n = 983) by gender

Clinical changes	Gender		Subtotal: N (%)
	Male: N (%)	Female: N (%)	
Heart murmur	151 (82.6 %)	31 (77.5 %)	182 (81.7 %)
High BP	17 (9.4 %)	9 (22.5 %)	26 (11.7 %)
Pectus excavatum	11 (6.0 %)*	0 (0.0 %)	11 (5.0 %)
Pectus carinatum	1 (0.5 %)	0 (0.0 %)	1 (0.4 %)
First heart sound	1 (0.5 %)	0 (0.0 %)	1 (0.4 %)
Third heart sound	1 (0.5 %)	0 (0.0 %)	1 (0.4 %)
Second heart sound hyperphonesis	1 (0.5 %)	0 (0.0 %)	1 (0.4 %)
Total	183 (82.1 %)	40 (17.9 %)	223 (100.0 %)

** p < 0.05 (Goodman association test21). BP: blood pressure.*

Table 4 – Electrocardiographic changes in the study population (n = 983) by gender

Electrocardiographic changes	Gender		Subtotal: N (%)
	Male: N (%)	Female: N (%)	
Ventricular extrasystoles	5 (17.9 %)	2 (50.0 %)	7 (21.9 %)
Intraventricular conduction disorder	5 (17.9 %)	2 (50.0 %)	7 (21.9 %)
Ectopic atrial rhythm	5 (17.9 %)	0 (0.0 %)	5 (15.6 %)
Left ventricular overload	4 (14.3 %)	0 (0.0 %)	4 (12.5 %)
Left anterior hemiblock	3 (10.7 %)	0 (0.0 %)	3 (9.4 %)
Preexcitation syndrome (Wolff-Parkinson-White)	2 (7.1 %)	0 (0.0 %)	2 (6.3 %)
First-degree atrioventricular block	1 (3.6 %)	0 (0.0 %)	1 (3.1 %)
ST segment elevation	1 (3.6 %)	0 (0.0 %)	1 (3.1 %)
Sinus bradycardia	1 (3.6 %)	0 (0.0 %)	1 (3.1 %)
Paroxysmal supraventricular tachycardia	1 (3.6 %)	0 (0.0 %)	1 (3.1 %)
Total	28 (100.0 %)	4 (100.0 %)	32 (100.0 %)

ST: segment of EKG.

detect electrocardiographic abnormalities that might be associated with an increased risk of sudden death and undetected by medical history or physical examination.

Conclusions

In addition to medical history and clinical examination, ECG should be part of the evaluation of children and adolescents before starting regular physical activities.

Author Contributions

Conception and design of the research: Silva DLM, Bonatto CPP, Fioretto JR, Bonatto RC; acquisition of data and analysis and interpretation of the data: Silva DLM, Bonatto CPP, Bonatto RC; statistical analysis: Padovani CR; writing of the manuscript and critical revision of the manuscript for intellectual content: Silva DLM, Fioretto JR, Bonatto RC.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This article is part of the thesis of master submitted by Diego Lineker Marquetto Silva, from Universidade Estadual Paulista (Unesp).

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the FMB/Unesp under the protocol numbe 3987/2011. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

References

1. Piercy KL, Troiano RP, Ballard RM, Health Govern/sites. Physical Activity Guidelines for Americans. JAMA. 2018;320(19):2020-8. doi: 10.1001/jama.2018.14854.2. Lauer RM, Burns TL, Daniels SR. Pediatric Prevention of atherosclerotic cardiovascular disease. Circulation.2007;115:e43-e44. doi: https://doi.org/10.1161/CIRCULATIONAHA. 3. Ribeiro RQ, Lotufo PA, Lamounier JA, Oliveira RG, Soares JF, Botter DA. Fatores adicionais de risco cardiovascular associados ao excesso de peso em crianças e adolescentes: o estudo do coração de Belo Horizonte. Arq Bras Cardiol. 2006;86(6):408-18. doi: 10.1590/s0066-782x2006000600002.

4. Santos MG, Pegoraro M, Sandrini F, Macuco EC. Fatores de risco para o desenvolvimento da aterosclerose na infância e adolescência. Arq Bras Cardiol. 2008;90(4):276-283. doi: 10.1590/s0066-782x2008000400012.

5. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. American college of sports Medicine Position stand. Exercise and hypertension. Med Sci Sports Exerc. 2004;36(3):533-53. doi: 10.1249/01.mss.0000115224.88514.3a.

6. Back GIC, Caramelli B, Pellanda L, Duncan B, Mattos S, Fonseca FH; Sociedade Brasileira de Cardiologia. I Diretriz de Prevenção da Aterosclerose na Infancia e na Adolescencia. Arq Bras Cardiol.2005;85(supl 6):4-36. PMID:16597097.

7. Corrado D, Basso C, Schiavon M, Pellicia A, Thiene G. Pre-participation screening of young competitive athletes for prevention of sudden cardiac death. J Am Coll Cardiol. 2008;52(24):1981-9. doi: 10.1016/j.jacc.2008.06.053.

8. Corrado D, Basso C, Rizzoli G, Schiavon M, Thiene G. Does sports activity enhance the risk of sudden death in adolescents and young adults? J Am Coll Cardiol. 2003;42(11):1959-63. doi: 10.1016/j.jacc.2003.03.002.

9. Maron BJ, Thompson PD, Ackerman MJ, Balady D, Berger S, Cohen D, et al. Recommendations and considerations related to pre-participation screening for cardiovascular abnormalities in competitive athletes: 2007 update: a scientific statement from the American Heart Association Council on Nutrition, Physical Activity and Metabolism. Circulation. 2007;115(12):1643-55. doi: 10.1161/CIRCULATIOAHA.107.181423

10. Sarina KB, Tanaya P, Anthony L. Practical Recommendations and Perspectives on Cardiac Screening for Healthy Pediatric Athletes. Curr Sports Med Rep. 2011;10(2):90-8. doi: 10.1249/JSR.0b013e3182141c1e.

11.Corrado D, Pellicia A, Bjornstad HH, Vanhees l, Biffi A, Borjesson M, et al. Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden cardiac death: Proposal for a common European protocol. Eur Heart J. 2005;26(5):516-24. doi: 10.1093/eurheartj/ehi108.

12. Papadakis M, Whyte D, Sharma S. Pre-participation screening for cardiovascular abnormalities in young competitive athletes. BMJ 2008;337:806-11. doi: 10.1136/bmj.a1596.

13. Myerburg R, Vetter VL. Should an electrocardiogram be included in routine participation screening of young athletes? Circulation. 2007;116(22): 2616-26. doi: 10.1161/CIRCULATIONAHA.107.733519.

14. American Academy of Family Physicians. Five things physicians and patients should question. [Internet] [Cited in 2023 Feb 23]. Available from: https://www.aafp.org/dam/AAFP/documents/about_us/initiatives/choosing-wisely-five-question.pdf.

15. Ghorayeb N, Costa RV, Castro I, Daher DJ, Oliveira Filho JA, Oliveira MA, et al. Diretriz em Cardiologia do Esporte e do Exercício da Sociedade Brasileira de Cardiologia e da Sociedade Brasileira de Medicina do Esporte. Arq Bras Cardiol. 2013;100(1Supl.2):1-41. PMID: 23568146.

16. Ghorayeb N, Stein R, Daher DJ, Silveira AD, Ritt LE, Santos DF, et al. Atualização da Diretriz em Cardiologia do Esporte e do Exercício da Sociedade Brasileira de Cardiologia e da Sociedade Brasileira de Medicina do Esporte - 2019. Arq Bras Cardiol. 2019;112(3):326-68. doi: 10.5935/abc.20190048.

17. Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ. 2007;85(9):660-7. doi: 10.2471/blt.07.043497.

18. Brasil. Ministério da Saúde. Sistema de Vigilância Alimentar e Nutricional - SISVAN. Nova classificação pontos de corte completo. Alexandre Brito. Classificação nutricional curvas OMS. SISVAN, 2009.

19. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. National Heart, Lung, and Blood Institute, Bethesda, Maryland. Pediatrics. 2004;114 (2 Suppl 4th Report):555–76. PMID: 15286277.

20. Flynn JT, Kaelber DC, Smith CM, Blowey D, Carroll AE, Daniels SR, et al. Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents. Pediatrics. 2017;140(3):e20171904. doi: 10.1542/peds.2017-1904.

21. Norman GR, Streiner DL. Biostatistics: The Bare Essentials. 3rd ed. St. Louis: Mosby Year Book; 2008. 393p.

22. Goodma LA. Simultaneous Confidence Intervals for Contrasts Among Multinomial Populations. Ann Math Statist. 1964;35(2):716-25. doi:10.1214/aoms/117703569.

23. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. 1985;100(2):126-131. PMID: 3920711.

24. Arraz FM. Importância da Atividade Física na Infância. Revista Científica Multidisciplinar Núcleo do Conhecimento. 2008;8(1):92-103. ISSN: 2448-0959

25. Weffort VR, Lamounier JA. Nutrição em Pediatria: da neonatologia à adolescência. São Paulo: Editora Manole; 2009.

26. Sharma S, Drezner JA, Baggish A, Papadakis M, Wilson MG, Prutkin JM, et al. International recommendations for electrocardiographic interpretation in athletes. Eur Heart J. 2018;39(16):1466-80. doi: 10.1093/eurheartj/ehw631.

27. Obeyesekere MN, Klein GJ. Preventing Sudden Death in Asymptomatic Wolf-Parkinson-White Patients. JACC Clin Electrophysiol. 2018 Apr;4(4):445-7. doi: 10.1016/j.jacep.2017.11.014.

28. Stiles MK, Wilde AA, Abrams DJ, Ackerman MJ, Albert CM, Behr ER, et al. 2020 APHRS/HRS expert consensus statement on the investigation of decedents with sudden unexplained death and patients with sudden cardiac arrest, and of their families. Heart Rhythm. 2021 Jan;18(1):e1-50. doi: 10.1016/j.hrthm.2020.10.010.

29. Massin MM. The role of exercise testing in pediatric cardiology. Arch Cardiovasc Dis. 2014 May;107(5):319-27. doi: 10.1016/j.acvd.2014.04.004.