Bulgarian Society of Medical Sciences Journal
7: e168566 (2025)
DOI: 10.3897/bsms.7.168566

Research Article | General Adult Cardiac

Exercise performance in fontan patients – a single-center Bulgarian study

Lyudmil Simeonov[1], Dimitar Pechilkov[1], Elena Ivanova[2], Anna Kaneva-Nencheva[1]

[1] *Department of Pediatric Cardiology, National Heart Hospital, Sofia, Bulgaria*
[2] *Department of Pediatric Anesthesiology and Intensive Care, UMHATEM N. I. Pirogov, Sofia, Bulgaria*

Corresponding author: Lyudmil Simeonov, Department of Pediatric Cardiology, National Heart Hospital, Sofia, Bulgaria;
E-mail: lyudmilsimeonov@yahoo.com

Academic editor: Tsvetomir Loukanov ♦ **Received:** 12 August 2025 ♦ **Accepted:** 6 October 2025 ♦ **Published:** 31 October 2025

Citation: Simeonov L, Pechilkov D, Ivanova E, Kaneva-Nencheva A. Exercise performance in fontan patients – a single-center Bulgarian study. Bulgarian Society of Medical Sciences Journal 2025;7:e168566. doi: 10.3897/bsms.7.168566.

Abstract

Aim: Exercise capacity in Fontan patients is reduced compared to healthy peers and progressive decline in cardiovascular function is expected over time. The purpose of this study is to present, analyze and discuss the initial Bulgarian experience with exercise performance of Fontan patients and to compare them to age-matched healthy peers. Additionally, we focused on understanding whether peak oxygen consumption can be predicted based on multiple independent variables.

Materials and methods: The research is a retrospective observational study of 11 patients aged 8y-18y, who had undergone the Fontan procedure and underwent cardiopulmonary exercise testing in National Heart Hospital in Sofia, Bulgaria. Data were collected for a 1-year period. Simultaneously, 11 age-matched healthy patients were selected for comparison.

Results: Patients with Fontan palliation had lower peak oxygen consumption (23.1 ml/kg/min vs. 30.1 ml/kg/min, P=0.046), percent-predicted peak oxygen consumption (52% vs. 76%, P<0. 001), percent-predicted peak work (56% vs. 82%, P<0.001), percent-predicted peak oxygen consumption at ventilatory anaerobic threshold (37% vs. 48%, P=0.04), resting saturation (93% vs. 97%, P<0.001) and saturation at peak work (84% vs. 95%, P<0.001). Male subjects and patients with left ventricular dominance exhibited a greater peak oxygen consumption.

Conclusion: Exercise capacity in the Bulgarian Fontan cohort is reduced relative to healthy controls. Male gender and subjects with left ventricular dominance have a greater peak oxygen consumption.

Keywords

Cardiopulmonary exercise testing, exercise performance, fontan procedure

Introduction

The Fontan operation is the last of series of operations for a group of congenital cardiovascular anomalies in which it is not possible to maintain two-ventricle physiology [1–2]. The procedure results in separating the systemic and pulmonary circulation by creating a total cavo-pulmonary connection [3–4]. Pulmonary blood flow in Fontan circulation is passive and its adequacy depends on low impedance to passively forward flow and to lower pulmonary vascular resistance (PVR). This newly constructed system is characterized by elevated central venous pressure and chronically low cardiac output (Fig. 1) [3]. Long term sequelae of the Fontan physiology is progressive decline in cardiovascular function [5].

Deterioration of cardiovascular efficiency leads to reduced exercise capacity. Contributing factors to exercise impairment include failure to increase stroke volume, chronotropic incompetence and reduced arterial blood saturation. Cardiopulmonary exercise testing (CPET) has an

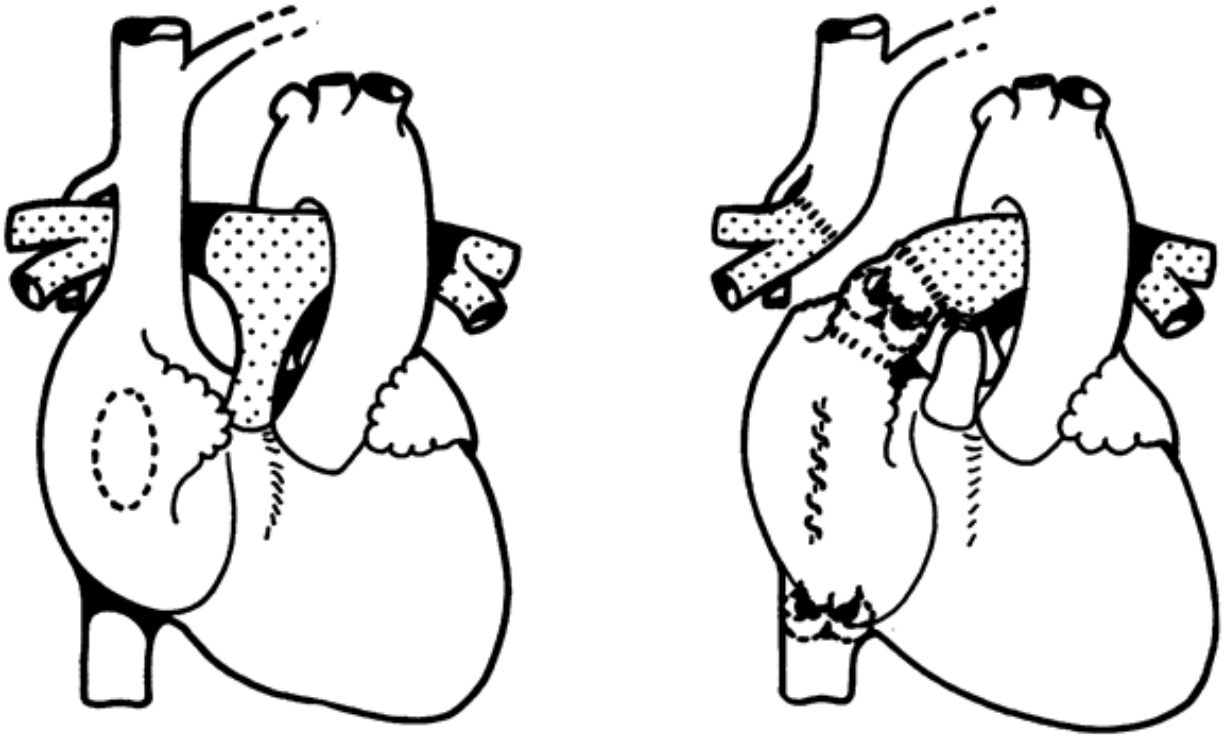

Figure 1. Schematic image of Fontane Procedure [3].

important role in the management of patients after Fontan operation. Peak oxygen uptake (peak VO_2) is a significant index of exercise capacity and has a prognostic value in patients with congenital heart disease [6]. Patients after Fontan procedure have percent predicted peak VO_2 from 60–65% [7–8]. Fernandes et al. reports that the hazard for death for patients with peak VO_2 less than 16.6 ml/kg/min was 7.5 times higher, compared to patients with higher peak VO_2 [9]. Worsening of peak VO_2 over time predicts poorer outcomes including death, transplant, and unscheduled cardiac-related rehospitalization [10–11].

The purpose of this study was to present the initial Bulgarian experience with exercise performance of Fontan patients and compare them to their healthy peers. This paper also focuses on understanding whether peak VO_2 can be predicted based on multiple independent variables.

Materials and methods

Patient characteristics

A retrospective observational study was conducted in Fontan patients referred to the Pediatric Cardiology Department in National Heart Hospital in Sofia, Bulgaria. This is the only center in the country involved in the surgical treatment of congenital heart defects. Patients aged 8y-18y with functionally univentricular heart who had undergone the Fontan procedure and had CPET were investigated. Exclusion criteria from the study were patients less than 8 or above 18 years of age and a submaximal effort test. Data were collected over a one-year period, from August 2021 to August 2022, involving the patients that met the inclusion criteria (11 out of 19 patients). Simultaneously, 11 age-matched healthy patients from outpatient visits were selected for comparison. Additional factors assessed included ventricular morphology (right, left), ventricular dysfunction and more than moderate atrioventricular valve regurgitation, evaluated by echocardiography. The Ethics Committee in our institution approved the study protocol and waived the need for patient consent due to the study's retrospective nature.

Primary and secondary outcomes

The authors reviewed patients' medical files for baseline characteristics and anatomic details. We defined the primary outcome of interest: peak VO_2, a direct measurement of cardiorespiratory fitness [12]. Secondary outcomes included peak work rate, peak heart rate, peak oxygen pulse, oxygen consumption (VO_2) at ventilatory anaerobic threshold (VAT), minute ventilation/carbon dioxide production slope (VE/VCO_2 slope) at VAT, oxygen saturation at rest and at peak exercise. Peak VO_2, VO_2 at VAT, work rate and heart rate are also expressed as a percentage of predicted normal values in order to eliminate sex, height and weight differences [13–14].

Echocardiography

Transthoracic echocardiography was performed using Philips Epic 7c ultrasound system with X5-1 transducer. We graded atrioventricular valve regurgitation (AVVR) according to the American Society of Echocardiography recommended crite-

ria: none to trivial, 0; mild, 1; mild to moderate, 2; moderate to severe, 3; and severe, 4 [15]. Ventricular dysfunction was assessed by the modified Simpson method using 4 chamber frames at end systole and end diastole, and was classified as follows: mildly abnormal, 41–51%; moderately abnormal, 30–40%; severely abnormal, <30% [16–17].

Cardiopulmonary exercise testing

All patients underwent CPET on an electrically braked cycle ergometer (Lode Corival; Lode BV, Groningen, The Netherlands). Meanwhile, VO_2 was measured using a commercial, breath-by-breath gas analysis system (Ultima-CPX, MGC Diagnostics Corp., St. Paul, Minnesota). A RAMP protocol was used, in which the patient should maintain a pedaling speed of about 60/minute. After an initial warm-up period of 2–3 minutes, the pedal resistance is gradually increased at a rate, based on the patient's age, weight, gender, and level of fitness so that they reach peak exertion in 8–12 minutes. Anaerobic threshold was calculated using the V-slope method (170029). Oxygen pulse - a surrogate for stroke volume - was measured by dividing absolute oxygen uptake by heart rate. Also, VE/VCO_2 slope was assessed at VAT. Blood pressure was measured every 2 minutes with an automatic cuff and a 12-lead ECG was obtained throughout the whole exercise. A maximal effort test was defined as peak respiratory exchange ratio (RER)[3] 1.05.

Statistical analysis

The authors used descriptive statistics to provide frequencies and percentages for categorical variables and medians, and interquartile ranges for continuous variables. We used the students t-test to compare variables between Fontan patients and healthy patients. Normality was checked based on the normal Q-Q plot and histogram. Gender, age at Fontan, age at CPET, ventricular dominance, pulmonary vasodilator therapy, more than moderate AVVR and ventricular dysfunction were assessed for linearity with peak VO_2. Out of the 7 independent variables only gender and ventricular dominance were significantly linearly related. A multiple regression was run to predict peak VO_2 from gender and ventricular dominance. A value of P£0.05 indicated statistical significance. We used IBM SPSS Statistics 24 (IBM Corp., Armonk, N.Y., USA) for statistical analysis.

Results

Study group characteristics

We had 19 Fontan patients who were referred to the Pediatric Cardiology Department in National Heart Hospital in Sofia, Bulgaria between August, 2021 and August, 2022. A total of 11 patients were included in the study, regarding the including criteria. Fontan patients' characteristics are summarized in Table 1.

Table 1. Fontan patients' characteristics.

Variable	Fontan (N=11)
Male (n, %)	9 (82%)
Body mass index (BMI), median (range)	19.8 (15.1–22.6)
Age at CPET (years), median (range)	17 (11–17.9)
Diagnosis (n, %):	
• Tricuspid atresia	2 (18.2%)
• Pulmonary atresia/intact ventricular septum	3 (27.3%)
• Double outlet right ventricle	1 (9.1%)
• Complex transposition of the great arteries	2 (18.2%)
• Double inlet left ventricle	3 (27.3%)
Dominant left ventricle (n, %)	7 (63.6%)
More than moderate AVVR (n, %)	1 (9.1%)
Ventricular dysfunction (n, %)	
• Mild	4 (36.4%)
• Moderate	0
• Severe	0
Age at Fontan completion (years), median (range)	3.3 (2.9–4.8)
Conduit size (n, %):	
• 16 mm	3 (37.3%)
• 18 mm	6 (54.5%)
• 19 mm	1 (9.1%)
• 20 mm	1 (9.1%)
Fenestration (n, %)	3 (27.3%)
Pulmonary vasodilator (n, %)	4 (36.4%)

* Abbreviations: CPET – cardiopulmonary exercise testing; AVVR - atrioventricular valve regurgitation.

It is accurate to note that Only 1 patient (9.1%) had more than moderate AVVR and none of the observed patients had neither moderate, nor severe ventricular dysfunction and this may explain the fairly preserved numbers compared to larger registries. Hereby, we should mention that low burden of ventricular dysfunction in this group might bias results toward better exercise outcomes.

All of the single ventricle patients had an extracardiac Fontan procedure. Comparison between Fontan patients and healthy subjects is presented in Table 2. Age at CPET, body mass index and gender distribution were similar between the two groups for the purposes of objectivity.

Table 2. Comparison between Fontan and healthy patients.

Variable	Healthy patients (N = 11)	Fontan patients (N = 11)	P
Male (%)	7 (63.6)	9 (82)	0.35
Body mass index (BMI), median (range)	19.3 (14.7–22.9)	19.8 (15.1–22.6)	0.89
Age at CPET (years), median (range)	14.1 (9.4–17.2)	17 (11–17.9)	0.13

* Abbreviations: CPET - cardiopulmonary exercise testing.

Bulgarian Society of Medical Sciences Journal

Table 3. Cardiopulmonary exercise testing parameters between the two groups.

Variables	Healthy patients (N = 11)	Fontan patients (N = 11)	P	Mean difference	95% CI	
					LL	UL
Ramp protocol (W), median (range)	15 (10–20)	15 (10–20)	0.71	0.45	-2.326	3.235
Peak work (W), median (range)	126 (77–186)	125 (45–189)	0.51	18.20	-16.35	52.71
Percent-predicted peak work (%), median (range)	82 (60–100)	56 (27–75)	<0.001	23.73	11.632	35.822
Peak oxygen consumption (ml/kg/min), median (range)	30.1 (19.4–42.3)	23.1 (15.2–40.3)	0.046	5.73	-0.589	12.043
Percent-predicted peak oxygen consumption (%), median (range)	76 (65–100)	52 (31–91)	<0.001	27.20	13.690	40.672
Peak RER, median (range)	1.16 (1.05–1.51)	1.24 (1.06–1.30)	0.53	-0.12	-0.103	0.101
Peak oxygen pulse (%), median (range)	86 (48–98)	63 (53–108)	0.21	7.73	-8.328	23.783
Peak heart rate (bpm), median (range)	176 (149–195)	162 (103–196)	0.09	16.10	-2.625	34.807
Percent-predicted peak heart rate (%), median (range)	84 (71–96)	80 (49–96)	0.12	7.10	-2.456	16.638
Percent-predicted peak oxygen consumption at VAT (%), median (range)	48 (28–65)	37 (25–60)	0.04	10.23	0.385	20.069
VE/VCO_2 at VAT, median (range)	28 (25–31)	32 (21–41)	0.14	-3.10	-7.083	0.901
Resting saturation (%), median (range)	97 (96–99)	93 (78–96)	<0.0001	6.45	2.800	10.108
Saturation at peak exercise (%), median (range)	95 (93–98)	84 (70–94)	<0.0001	10	5.433	14.566
ECG abnormalities	0	0	0.98	0	-0.872	0.145
Abnormal blood pressure response	0	1	0.32	0	-0.090	0.281

* Abbreviations: RER - respiratory exchange ratio; VAT - ventilatory anaerobic threshold; $VE/VECO_2$ - ratio of minute ventilation to carbon dioxide production; LL - lower limit; UL - upper limit; p – statistical significance.

Cardiopulmonary exercise testing parameters between the two groups

All of the study subjects achieved maximal effort test. Exercise capacity in our Fontan cohort was reduced compared to healthy peers - patients after Fontan palliation had lower peak VO_2 (23.1 ml/kg/min vs. 30.1 ml/kg/min, P=0.046), percent-predicted peak VO_2 (52% vs. 76%, P<0.001), percent-predicted peak work (56% vs. 82%, P<0.001), percent-predicted peak VO_2 at VAT (37% vs. 48%, P=0.04), resting saturation (93% vs. 97%, P<0.001) and saturation at peak work (84% vs. 95%, P<0.001). None of the patients exhibited ECG abnormalities and one Fontan patients had an abnormal blood pressure response. Comparison of CPET parameters between the two groups is demonstrated in Table 3.

Predicting peak oxygen consumption

A multiple regression was run to predict peak VO_2 from gender and ventricular dominance. The multiple regression model statistically significantly predicted peak VO_2, F (2, 8) = 12.998, P = 0.003, adj. R2= .71. Both gender and ventricular dominance added statistically significantly to the prediction, P=0.003. Male Fontan patients exhibited higher peak VO_2 of 11.925 ml/kg/min. Peak VO_2 for patients with left ventricular dominance was 7.738 ml/kg/min, greater than patients with right ventricular dominance. Regression coefficients and standard errors can be found in Table 4.

Table 4. Multiple regression results for peak oxygen consumption.

Variables	B	SE B	P	95% CI for B	
				LL	UL
Constant	8.712	3.394	0.033	0.886	16.539
Gender	11.925	2.936	0.004	4.925	18.925
Ventricular dominance	7.738	2.036	0.005	3.041	12.434

* Abbreviations: B – unstandardized regression coefficient; SE B – standard error of the coefficient; CI – confidence interval; LL – lower limit; UL – upper limit; p – statistical significance.

Discussion

Patients with functionally univentricular heart survive satisfactory into adulthood after Fontan completion [18–19]. The creation of such an unconventional circulation results in improved exercise capacity compared to preoperative state, but it is still reduced in comparison with healthy subjects. Patients after the Fontan procedure are expected to have a decline in cardiovascular function over time with subsequent decrease in exercise performance [5]. This leads to poorer outcomes, including death, transplant, and unscheduled cardiac-related rehospitalization. [10–11].

Cardiopulmonary exercise testing (CPET) is a crucial tool to objectively assess exercise performance and functional capacity in patients with congenital heart disease. Access to CPET in Bulgaria is not routine and scarce experience has been gained in recent years. This method provides objective data for assessing functional limitations, tracking disease progression, and guiding personalized treatment strategies. By monitoring objective metrics over time, CPET helps tailor exercise prescriptions, optimize timing for interventions, identify early signs of complications, and guides the creation of personalized, safe exercise programs to improve long-term outcomes.

This study documents that in practice, exercise capacity in Bulgarian Fontan patients is reduced compared to healthy peers. The performed multiple regression analysis reveals that male patients and patients with left ventricular dominance have a greater peak VO_2.

We demonstrated that peak VO_2, as well as VO_2 at VAT and percent-predicted peak work vary significantly between Fontan patients and healthy subjects. These finding extend those of others [7–8, 20–22], confirming that exercise capacity is impaired in Fontan patients. Known causes of depressed exercise function may include: inability to increase stroke volume normally in response to exercise; chronotropic incompetence; arterial desaturation; pulmonary abnormalities; deconditioning [23]. Interestingly, peak oxygen pulse, percent-predicted peak heart rate and VE/VCO_2 slope were similar between the two studied groups.

In accordance with previous findings [24–28], anatomic morphology may be associated with difference in exercise performance. Fontan patients with left ventricular dominance had greater peak VO_2 than patients with right ventricular dominance. It would seem reasonable that a systemic right ventricle would less likely adapt to hemodynamic changes, leading to progressive decline in cardiovascular function and exercise intolerance. Dominant right ventricle morphology is associated with poorer outcomes on a long-term follow up [29].

There are limited data on patients with Fontan physiology regarding exercise parameter difference between males and females. Seckeler and colleagues previously reported that peak VO_2 decreased by 32% through adolescence in females and did not have the typical increase for adolescence for males [30]. Our study reveals that male patients have a higher peak VO_2.

Study limitations

Some limitations are worth noting. A RAMP protocol was used via cycle ergometer, which means that obtained peak VO_2 is lower than uphill treadmill running. Cycle ergometry was used mainly because of the relatively young patients age. Another limitation is the single-center, retrospective, non-randomized design of the study. Also, the small sample size in this research may limit the ability to observe significant differences.

Conclusion

Cardiopulmonary exercise testing has an important role in management of patients after Fontan operation. Our current data on the topic provide the first description of exercise capacity in Bulgarian Fontan patients. Our initial experience revealed that patients after the Fontan procedure have impaired exercise performance compared to healthy peers. Male gender and left ventricular dominance are associated with greater peak VO_2. These findings address the need for serial cardiopulmonary exercise testing in Fontan patients to monitor for declining peak oxygen consumption. Future multicenter collaborations with larger Fontan cohorts are needed for better understanding exercise capacity trajectories and identifing factors associated with outcomes over time.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalised human and animal cell lines were used in the present study.

Use of AI

No use of AI was reported.

Funding

No funding was reported.

Author contributions

All authors have contributed equally.

Author ORCIDs

Lyudmil Simeonov https://orcid.org/0000-0002-1853-9739
Dimitar Pechilkov https://orcid.org/0000-0002-9734-0479
Anna Kaneva-Nencheva https://orcid.org/0000-0001-7902-5494

Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

1. Jacobs JP, Maruszewski B. Functionally univentricular heart and the Fontan operation: lessons learned about patterns of practice and outcomes from the congenital heart surgery databases of the European association for cardio-thoracic surgery and the society of thoracic surgeons. World J Pediatr Congenit Heart Surg. 2013;4(4):349–355.
2. Wilkinson JL, Anderson RH. Anatomy of functionally single ventricle. World J Pediatr Congenit Heart Surg. 2012;3(2):159–164.
3. Fontan F, Baudet E. Surgical repair of tricuspid atresia. Thorax. 1971;26(3):240–248.
4. Kreutzer G, Galíndez E, Bono H, De Palma C, Laura JP. An operation for the correction of tricuspid atresia. J Thorac Cardiovasc Surg. 1973;66(4):613–621.

5. Atz AM, Zak V, Mahony L, et al. Longitudinal Outcomes of Patients With Single Ventricle After the Fontan Procedure. J Am Coll Cardiol. 2017;69(22):2735–2744.
6. Diller GP, Dimopoulos K, Okonko D, et al. Exercise intolerance in adult congenital heart disease: comparative severity, correlates, and prognostic implication. Circulation. 2005;112(6):828–835.
7. Müller J, Christov F, Schreiber C, Hess J, Hager A. Exercise capacity, quality of life, and daily activity in the long-term follow-up of patients with univentricular heart and total cavopulmonary connection. Eur Heart J. 2009;30(23):2915–2920.
8. Paridon SM, Mitchell PD, Colan SD, et al. A cross-sectional study of exercise performance during the first 2 decades of life after the Fontan operation. J Am Coll Cardiol. 2008;52(2):99–107.
9. Fernandes SM, Alexander ME, Graham DA, et al. Exercise testing identifies patients at increased risk for morbidity and mortality following Fontan surgery. Congenit Heart Dis. 2011;6(4):294–303.
10. Henaine R, Vergnat M, Bacha EA, et al. Effects of lack of pulsatility on pulmonary endothelial function in the Fontan circulation. J Thorac Cardiovasc Surg. 2013;146(3):522–529.
11. Khambadkone S, Li J, de Leval MR, Cullen S, Deanfield JE, Redington AN. Basal pulmonary vascular resistance and nitric oxide responsiveness late after Fontan-type operation. Circulation. 2003;107(25):3204–3208.
12. Kokkinos P, Myers J. Exercise and physical activity: clinical outcomes and applications. Circulation. 2010;122(16):1637–1648.
13. Jones NL, Makrides L, Hitchcock C, Chypchar T, McCartney N. Normal standards for an incremental progressive cycle ergometer test. Am Rev Respir Dis. 1985;131(5):700–708.
14. Jones NL. Clinical Exercise Testing. 3rd ed. Philadelphia: Saunders 1988.
15. Zoghbi WA, Enriquez-Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. J Am Soc Echocardiogr. 2003;16(7):777–802.
16. Lang RM, Badano LP, Mor-Avi V, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2015;28(1):1–39.e14.
17. Gaskill SE, Ruby BC, Walker AJ, Sanchez OA, Serfass RC, Leon AS. Validity and reliability of combining three methods to determine ventilatory threshold. Med Sci Sports Exerc. 2001;33(11):1841–1848.
18. d'Udekem Y, Iyengar AJ, Galati JC, et al. Redefining expectations of long-term survival after the Fontan procedure: twenty-five years of follow-up from the entire population of Australia and New Zealand. Circulation. 2014;130(11 Suppl 1):S32–S38.
19. Cordina R, du Plessis K, Tran D, d'Udekem Y. Super-Fontan: Is it possible?. J Thorac Cardiovasc Surg. 2018;155(3):1192–1194.
20. Terol Espinosa de Los Monteros C, Harteveld LM, Kuipers IM, et al. Prognostic Value of Maximal and Submaximal Exercise Performance in Fontan Patients < 15 Years of Age. Am J Cardiol. 2021;154:92–98.
21. Harteveld LM, Blom NA, Terol Espinosa de Los Monteros C, et al. Determinants of exercise limitation in contemporary paediatric Fontan patients with an extra cardiac conduit. Int J Cardiol. 2021;341:31–38.
22. Inuzuka R, Diller GP, Borgia F, et al. Comprehensive use of cardiopulmonary exercise testing identifies adults with congenital heart disease at increased mortality risk in the medium term. Circulation. 2012;125(2):250–259.
23. Opotowsky AR, Allen KY, Bucholz EM, et al. Pediatric and Congenital Cardiovascular Disease Research Challenges and Opportunities: JACC Review Topic of the Week. J Am Coll Cardiol. 2022;80(23):2239–2250.
24. Goldberg DJ, Zak V, McCrindle BW, et al. Exercise Capacity and Predictors of Performance After Fontan: Results from the Pediatric Heart Network Fontan 3 Study. Pediatr Cardiol. 2021;42(1):158–168.
25. Weinreb SJ, Dodds KM, Burstein DS, et al. End-Organ Function and Exercise Performance in Patients With Fontan Circulation: What Characterizes the High Performers?. J Am Heart Assoc. 2020;9(24):e016850.
26. Ohuchi H, Yasuda K, Hasegawa S, et al. Influence of ventricular morphology on aerobic exercise capacity in patients after the Fontan operation. J Am Coll Cardiol. 2001;37(7):1967–1974.
27. Giardini A, Hager A, Pace Napoleone C, Picchio FM. Natural history of exercise capacity after the Fontan operation: a longitudinal study. Ann Thorac Surg. 2008;85(3):818–821.
28. Tran DL, Celermajer DS, Ayer J, et al. The "Super-Fontan" Phenotype: Characterizing Factors Associated With High Physical Performance. Front Cardiovasc Med. 2021;8:764273.
29. Khairy P, Fernandes SM, Mayer JE Jr, et al. Long-term survival, modes of death, and predictors of mortality in patients with Fontan surgery. Circulation. 2008;117(1):85–92.
30. Seckeler, M. D., Barber, B. J., Colombo, J. N., Bernardi, A. M., Hoyer, A. W., Andrews, J. G., & Klewer, S. E. (2021). Exercise Performance in Adolescents With Fontan Physiology (from the Pediatric Heart Network Fontan Public Data Set). The American journal of cardiology, 149, 119–125.