Maximal Oxygen Uptake and Ventilatory Anaerobic Threshold with Pediatrics Aged Group in Non-operated Ventricular Septal Defect and Surgically Repaired Tetralogy of Fallot

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Abstract
Objective
1) To determine there is a subnormal exercise performance in children with non-operated ventricular septal defect and operated tetralogy of fallot compared to normal controls and 2) To determine physical activity is an important factor for lower exercise performance in these conditions.

Design and Setting
Retrospective Study. The data were collected from the cardio pulmonary exercise testing and physical activity questionnaire at Department of Pediatrics Cardiology and Department of Cardiovascular Rehabilitation, U.Z. Hospital, Leuven, Belgium.

Patients and Methods
Exercise testing was performed on a treadmill and respiratory gas exchange was measured on a breath by breath technique using mass spectrometry (Marquette MGA 1100, Milwaukee, USA). Exercise testing was performed on a motor driven treadmill. The treadmill speed was set at 5.6 km/hr for children six years or older. The exercise tests started at 0% inclination and systematically increased 2% per minute until the patient was exhausted or symptom-limited or at target heart rate of 170 beats / min were reached. The habitual level of physical activity was measured using standardized physical activity questionnaire.19 subjects with non-operated ventricular septal defect (VSD) (mean (SD) age at testing 11.6 (2.7) years) and 24 subjects who undergone surgically repaired tetralogy of Fallot (TOF) (age 12.7 (2.5) years) performed graded exercise testing and completed physical activity questionnaire were compared with 257 age matched normal controls.

Results
Subjects with non-operated ventricular septal defects compared to normal have mean and standard deviation of ventilatory anaerobic threshold (VAT) averaged 32.70 (6.76) ml kg-1 min-1 and 29.39 (2.68) ml kg-1 min-1 and maximal oxygen uptake(peak vo2) averaged 46.57 (7.83) ml min-1 kg-1 and 47.43 (4.54) ml min-1 kg-1. The unpaired t-test value showed no significance difference for maximal oxygen uptake (p=0.0790) and ventilatory anaerobic threshold (p=0. 7060) in patient with non-operated VSD compared to normal controls. Similarly, Subjects with surgically repaired tetralogy of fallot compared to normal have mean and standard deviation of ventilatory anaerobic threshold averaged 27.77 (3.09) ml kg-1 min-1 and 30.96 (2.76) ml kg-1 min-1 and maximal oxygen uptake (peak vo2) averaged 30.96 (2.76) ml min-1 kg-1 and 50.59 (4.97) ml min-1 kg-1.The unpaired t- test showed a significant difference for maximal oxygen uptake (p = 0.0005) and ventilator anaerobic threshold (p = <0.0001) in patients with operated TOF compared to normal controls.
The habitual level of physical activity was log transformed. There was no significance difference for physical activity (p = 0.9299) in patient with Non-operated VSD [averaged 0.68 (0.11)] compared to Normal controls [average 0.68 (0.07)]. There was a significant difference for physical activity (p =0.0043) in patients with surgically repaired TOF [averaged 0.63(0.12)] compared to normal control [averaged 0.72(0.05)]

Conclusion
Exercise performance was reduced in patients with operated tetralogy of fallot .One of the contributing factor for reduced exercise performance seems to be reduced physical activity. Hence, physical activity has to be encouraged in subjects with reduced exercise performance namely surgically repaired tetralogy of fallot.

Keywords: Ventricular septal defect (VSD), Tetralogy of Fallot (TOF), Ventilatory anaerobic threshold, Maximal oxygen uptake, Habitual level of physical activity

I. INTRODUCTION

Congenital heart disease (CHD) is a structural abnormality in the heart due to a malformation develops in gestational period (first 8 weeks) that is present at birth [1].The incidence of congenital heart disease is about 75 per 1000 live birth [2].Due to medical, surgical, diagnostic advancement, life expectancy has increased resulting in 90% of congenital heart disease survive into adulthood [3]. Ventricular septal defect and tetralogy of Fallot are the common acyanotic and cyanotic congenital heart defects.

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Ventricular septal defect (VSD) is a defect in the septal wall present between the two ventricles (right and left) [4].VSD is classified into small, moderate and large defects. During first 2 year of life, spontaneous closure was seen in small ventricular septal defect about 75 to 80%[4] Surgical intervention or percutaneous closure was done in moderate and larger ventricular defect patients who have Qp/Qs ratio above 1.5[5].

Tetralogy of Fallot (TOF) is an embryonic defects result in four cardiac abnormalities namely ventricular septal defect, pulmonary stenosis, aortic override and right ventricular hypertrophy [4]. Intracardiac total repair is a definitive treatment for tetralogy of Fallot. Surgical outcome in tetralogy of fallot has shown to improve clinical status and quality of life [6] with residual hemo dynamic abnormalities.

Cardiopulmonary exercise testing is an objective measure used to determine the exercise intolerance and functional capacity of children with congenital heart disease [5, 7]. Maximal oxygen uptake and ventilator anaerobic threshold are the two objective parameter used to assess exercise performance [7, 11, 12].

Studies suggested that reduced physical activity as an important factor for reduced exercise performance [9,12,18,20].Exercise training and Physical activity has improved physiological benefit and psychological development in the children with congenital heart disease [10].Hence, It was hypothesized 1] To determine there is a subnormal exercise performance in children with nonoperated ventricular septal defect and tetralogy of fallot compared to normal controls 2] To determine physical activity is an important factor for lower aerobic capacity in these pathologies.

II. PATIENTS AND METHODS

A. Study Design

The study was a retrospective design. It was hypothesized the data were collected from the cardio pulmonary exercise testing and physical activity questionnaire at the pediatric cardiology unit, U.Z. Hospital, Leuven, Belgium. The medical diagnosis was determined from the hospital records.

B. Subjects

The exercise response was studied retrospectively in a total sample of 60 patients with operated ventricular septal defects and surgically repaired tetralogy of fallot. This group was divided in 2 groups.

The first group consisted of nineteen patients with nonoperated ventricular septal defect (10 boys and 9 girls).The age at testing varied from 7 to 16.2 years, mean 11.6(2.7) years. All patients were in sinus rhythm at the time of exercise testing.

The second group was composed of twenty four subjects with tetralogy of Fallot (20 males and 4 females) studied after total surgical repair of tetralogy of Fallot .Three Patients had Blalock-Tausig anastomosis 1 year before surgical repair. Twelve patients has Trans annular patch, seven with infundibular patch, four corrected repair and one with pericardial patch. Surgical repair performed between Nov 1984 to Nov 1993 Age at testing varies from 8.2 years to 17 years and mean 12.7(2.5) years. Exercise studies were done 6-16 years averaged 10.9 years after surgical repair. At the time of operative repair, the patients were 1 to 3 years of age averaged 1.6 years. All patients were in sinus rhythm at the time of exercise testing. Right bundle branch block was seen in all patients.

TABLE 1. ANTHROPOMETRIC CHARACTERISTICS OF PATIENTS

Variables	**VSD (n = 26)**	**TOF(n = 24)**
Boys No.	10	20
Girls No.	9	4
Age, yrs.	11.5 (2.7)	12.7(2.4)
Height, cms	151.5(17.5)	156.8(15.3)
Body mass, kg	42.2(14.5)	44.3(12.3)

VSD = Ventricular septal defects and
TOF = Tetralogy of fallot
All data are expressed as mean (SD)

All patient groups were compared to normal values on a 1/1 basis obtained in a group of 265 healthy children, who were studied at the same laboratory (16).

C. Cardiopulmonary exercise testing

Informed consent was obtained from parents or patient after the nature of the test procedure has fully explained. The study was approved by the local medical ethics committee, Leuven.

A graded maximal exercise test was performed on a treadmill**.** The speed was set at 5.6 km/h and the inclination was increased by 2% every minute until exhaustion, severe leg fatigue or symptoms such as dyspnoea. In children who underwent exercise testing before 2000, exercise testing was intentionally submaximal until a target heart rate of 170 bpm was reached. The respiratory gas exchange was measured on a breath-by-breath [13] basis by a computerised system using a mass spectrometer (Marquette MGA 1100; Milwaukee, USA). The system was calibrated before each exercise test with test gas of known

composition. Heart rhythm was continuously monitored during exercise and a twelve lead electrocardiogram was recorded every minute.

D. Habitual level of physical activity

The habitual level of physical activity questionnaire was completed by parents or patients. The questionnaire consists of 8 items: number of hours of physical education session at school, Participation in sports club, number and hours of training and competition, sport activities in vacation, weekend and holidays, Participation in the youth movement and further questions on hobbies and on how the children go to and from school. The reproducibility of the questionnaire was done on a subgroup of 28 children and repeated within 30 days. The scores were found to be reproducible (r = 0.9) [14].

III. OUTCOME MEASURES

A. Ventilatory anaerobic threshold

Cardiorespiratory exercise performance was assessed by determination of the ventilatory anaerobic threshold (VAT). This was defined as the inflection point of carbon dioxide output (VCO2) vs. oxygen uptake (VO2) (V-slope method), which shows a steeper increase in VCO2 above the VAT. The VAT was calculated by a computer algorithm [15] and further checked by visual inspection. The VAT was also expressed as ml/min/kg or as a percentage of the normal mean value for age and gender. The same exercise protocol was used in the patient and normal controls.

B. Maximal Oxygen uptake

Exercise performance was further assessed by determination of the peak oxygen uptake (VO_2 peak), or symptom-limited oxygen uptake (VO_2 SL) the values for VO_2 peak were expressed as ml/min/kg or as a percentage of the normal mean value for age and gender. It is defined as highest value of VO_2 reached during the exercise test.The values were calculated using a computer algorithm.

C. Physical Activity

The habitual level of physical activity was assessed using standardized questionnaire. It measures the behavioral characteristic of physical activity. The questionnaire used in this study has an arbitrary score system. If any one of the behavioral characteristic was expressed by the subjects, one point was allotted. If they were not participating in any activity, zero point was given. The total point in each items are calculated and expressed as arbitrary scores. The value for normal healthy children was determined using age matched pooled habitual level of physical activity values published by weymans et al [14].

IV. STATISTICAL ANALYSIS

The results were analyzed using a computer with commercial available software [Excel 2000, Graph pad software Inc.]. Data distributions were inspected visually and statistically for normality. Normally distributed data was described using mean and standard deviation (S.D.). Non-normally distributed variables were log-transformed prior to use with parametric statistics. Difference for parameter between normal and patient group were studied using the student unpaired T-test. Relationship between the variables was determined using mean and standard deviation of the data.

V. RESULTS

The ventilatory anaerobic threshold, maximal oxygen uptake and habitual level of physical activity values of nonoperated ventricular septal defects and surgical repair tetralogy of Fallot were compared with age and gender matched normal healthy children's.

A. Exercise Performance Values: Non operated Ventricular septal defects

No significant difference was found between unoperated ventricular septal defect and age matched healthy control subjects. The ventilator anaerobic threshold was 110% of predicted normal (95% confidence limits: 92 – 108%) and 7/16 patients have maximum oxygen uptake value below the lower limit of normal (95% confidence limits 92 – 108%)

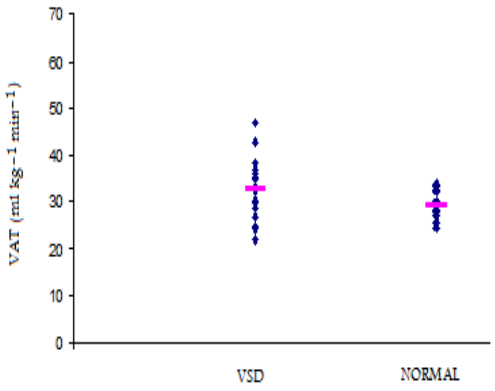

Fig. 1 (a) Ventricular Septal Defect vs. Normal; Ventilatory Anaerobic Threshold: (ml $kg^{-1}min^{-1}$ or % of normal)

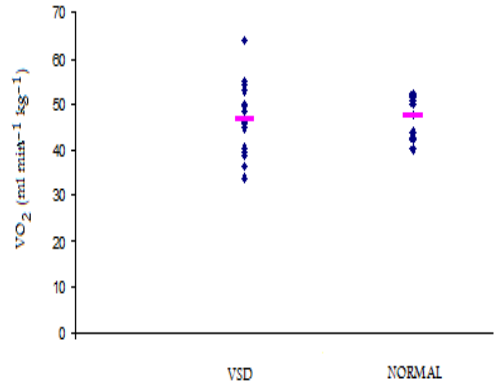

Fig. 1 (b) Ventricular Septal Defect vs. Normal; Maximal Oxygen Uptake: (ml min^{-1} kg^{-1})

B. Exercise Performance: Surgical Tetralogy of fallot

Significant difference was found between patients with tetralogy of fallot and normal groups. The ventilatory anaerobic threshold was 89% of predicted normal (normal 95% confidence limits: 92 – 108%).The maximal oxygen uptake was 74% predicted normal.

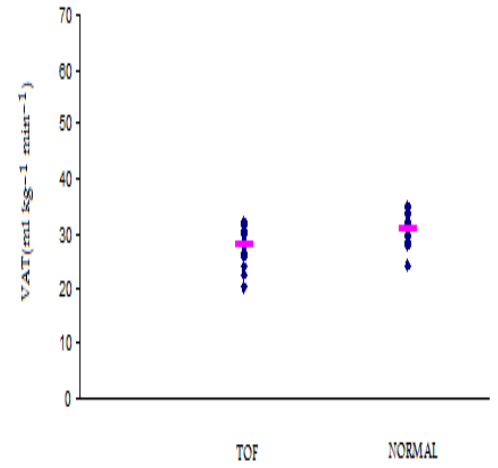

Fig. 2(a) Tetralogy of Fallot vs. Normal; Ventilatory Anaerobic Threshold (ml kg^{-1} min^{-1})

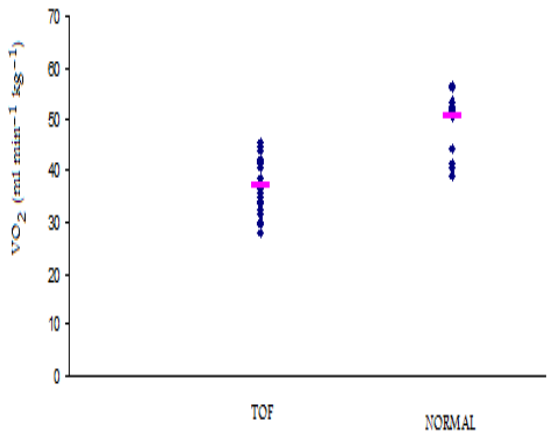

Fig. 2(b) Tetralogy of Fallot vs. Normal; Maximum oxygen uptake (ml min^{-1} kg^{-1})

C. Habitual level of Physical activity (HLPA)

It is expressed as arbitrary scores. The scores was log transformed to use parametric statistics. Compared to normal, the physical activity score was normal for patients with nonoperated ventricular septal defect and lower for patients with tetralogy of fallot

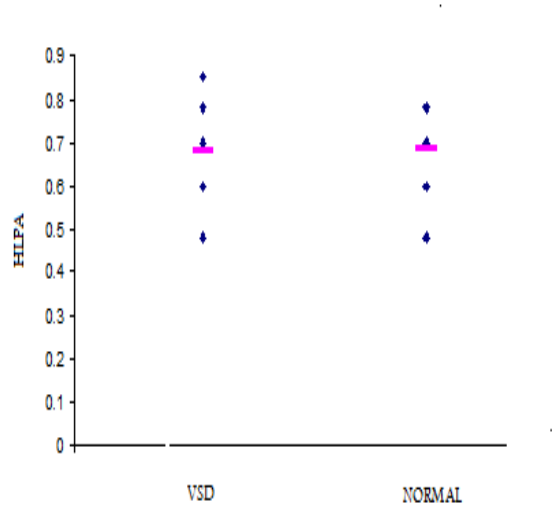

Fig 3 (a) Ventricular Septal Defect vs. Normal; Habitual level of physical activity

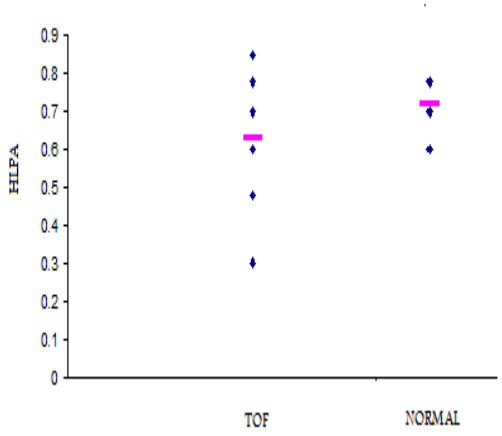

Fig 3 (b) Tetralogy of Fallot vs. Normal; Habitual level of physical activity

D. Relation between aerobic capacity and habitual level of physical activity

Perhaps, it appears that the above or normal value of aerobic performance was associated with the above or normal value of habitual level physical activity in patients with ventricular septal defect and similarly, lower value of daily physical activity was co related with the subnormal values of aerobic performance in patients with tetralogy of fallot.

VI. DISCUSSION

A. Nonoperated ventricular septal defect

Reybrouck et al [18] examined 14 patients with nonoperated VSD showed that a reduced value of ventilatory anaerobic threshold was 90% predicted normal related with reduced level of habitual physical activity compared to control groups. However, the finding of the current study do not support the previous research which showed significance difference for VAT and physical activity compared to normal. Previous research shows that physical activity plays a contributing factor in these patients. It is further supported by serial exercise studies done on ventricular septal defects (non-operated)[12].But, The finding of the results in the present study do not support that physical inactivity was an important factor for the lower level of aerobic capacity in patients with non-operated ventricular septal defect.

Bendien et al [19] studied haemo dynamic changes of exercise in 35 patients with small to moderate ventricular septal defect and found that the left to right shunt volume decreases during increase in exercise in spite of chronic volume workload of left ventricle. The systematic blood flow rises normally during dynamic exercises. It seems the hemodynamic factor has a minimal effect on exercise capacity in unoperated ventricular septal defect. It agrees with our study which showed normal ventilator anaerobic threshold and maximal oxygen uptake in patient with nonoperated ventricular septal defect.

B. Repaired Tetralogy of fallot

For VAT, reduced values was 90% predicted normal. The present study corroborates the earlier finding done on thirty nine patients by Reybrouck et al, [20] where the mean VAT value was 89.3 ±15.7 % of predicted normal value for age.14/24(58%) of the sample had a value for VAT below normal values (95% confidence limits; (92% -108%).
Fredriksen et al[21] studied cardiopulmonary exercise testing on 24 patient with tetralogy of Fallot compared with 196 reference children performed on treadmill showed a VO_2 peak (ml min-1 kg-1) value 11.1 ml below the mean value of normal group. It agrees to our study, where we had a VO_2 peak value 13.3 ml below the mean value of 257 healthy children. The reduced mean value seems to be the different protocol used in our study. As mention in the review done by Wessel and Paul, there was a value of VO_2 max about 81% of normal in patients after repaired tetralogy of Fallot [11]. In present study, the value for VO_2 max was 74% of predicted normal. The increase value seen in review seems to be various methodology used in different studies.

The study showed that physical activity levels assessed by using standardized questionnaires in repaired tetralogy of fallot mean 4.4 (1.1) has lower values compared to normal averaged 5.2 (0.6). Similarly, In the study of Reybrouck et al, [18] The habitual level of physical activity was lower in tetralogy of fallot subjects averaged 2.8 (1.4) compared to age matched control group was mean 4.3 (0.9).This result may be explained by the fact that restriction of physical activity was seen in these patients before and after the surgery leads to deconditioning [11].

There are several possible explanations for reduced maximal oxygen uptake, ventilator anaerobic thresholds and physical activity in these studies such as residual hemodynamics abnormalities,[11, 20] reduced heart rate response [1, 8, 11, 20] and restriction of physical activity [11, 18].

Wessel and Paul [11] suggested that mild pulmonary insufficiency with right ventricular outflow obstruction (RVOT) and pulmonary stenosis have impaired exercise tolerance. Indeed in our study, four patients with mild pulmonary stenosis, one subject with residual ventricular septal defect, one patient with RVOT and with only mild pulmonary insufficiency had a ventilator anaerobic

threshold value > 90% predicted normal and maximal oxygen uptake value >81% predicted normal.It appears that hemodynamic factor has minimal impact on aerobic capacity while it is difficult to conclude in our study since we have concentrated on functional abnormalities rather than hemodynamic mechanism.
Exercise training and rehabilitation appears to improve exercise performance in surgical and complex congenital heart diseases [25, 26].

VII. LIMITATION

The study was a retrospective design. The study constrained to available data. Physical activity questionnaire is a generic instrument to measure the habitual level of physical activity.

VIII. CONCLUSION

It appears that Physical inactivity to be one of the major contributing factors for patient with non operated ventricular septal defect and surgical tetralogy of Fallot. Physical activity has to be encouraged in patient with reduced exercise performance thereby improve the self-actualization of the children and adolescent with congenital heart diseases.

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