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Original article

Cardiopulmonary Stress Testing in Children Who Have Had Congenital Heart Disease Surgery. Physical Exercise Recommendations During School Hours

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ABSTRACT

Introduction and objectives: To analyze and discover if stress testing with exhaled gases in children who have had congenital heart surgery is useful so we could make physical exercise recommendations according to heart disease, type of surgery performed, present hemodynamic state and level of exercise practiced.

Methods: Prospective study of 108 children, who performed stress testing with exhaled gases, electrocardiogram monitoring and blood pressure. A questionnaire was used to obtain variables concerning heart disease, surgery, present functional condition and level of exercise practiced. Exercise recommendations were given after stress testing, and after a year 35 patients answered a questionnaire.

Results: There were significant differences between lesion severity and heart rate at rest and during effort, systolic pressure at rest and during effort, oxygen uptake, oxygen pulse, carbon dioxide production and test duration. A relationship was observed between level of weekly exercise and greater oxygen uptake and test duration, but this was not observed with the underlying heart disease. We observed that best performance occurred with fast repairing for 59 children with cyanotic heart disease. Increased exercise level was recommended for 48 children.

Conclusions: The cardiopulmonary function study allows us to examine the physical performance of children who have had congenital heart surgery and provides us with important data so that we can recommend better physical exercise planning.

Prueba de esfuerzo con función cardiopulmonar en niños operados de cardiopatía congénita. Recomendaciones de ejercicio físico en el ámbito escolar

Palabras clave:
Cardiopatía congénita
Cirugía cardiaca
Prueba de esfuerzo cardiopulmonar
Ejercicio físico

RESUMEN

Introducción y objetivos: El objetivo es analizar la utilidad de la prueba de esfuerzo con determinación de gases espirados en niños operados de cardiopatía congénita en edad escolar, para valorar la recomendación de ejercicio físico en relación con la cardiopatía de base, el tipo de cirugía realizada, la situación hemodinámica actual y el nivel de ejercicio habitual.

Métodos: Estudio prospectivo de 108 niños que realizaron una prueba de esfuerzo con análisis de gases, monitorizando electrocardiograma y presión arterial. Se recogieron por cuestionario variables sobre cardiopatía de base, cirugía practicada, estado funcional actual y nivel de ejercicio habitual. Se emitió una recomendación de ejercicio después de la ergometría, y al año se controló por cuestionario a 35 de los pacientes.

Resultados: Se observaron diferencias significativas entre la gravedad actual de la lesión y la frecuencia cardiaca de reposo y esfuerzo, la presión arterial sistólica en reposo y en esfuerzo, el consumo de oxígeno, el pulso de oxígeno, la producción de dióxido de carbono y la duración de la prueba. Se detectó relación entre el nivel de ejercicio semanal y mayores consumo de oxígeno y duración de la ergometría, pero no con la cardiopatía subyacente. En los 59 niños con lesiones cianóticas, se observó que la mejor capacidad funcional se correspondía con reparación de la lesión más precoz y mejor. Se pudo recomendar un incremento del nivel de ejercicio a 48 niños.

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Conclusiones: La prueba ergoespirométrica permite explorar la capacidad funcional de los niños operados de cardiopatía congénita y aporta datos importantes para una mejor planificación del ejercicio físico aconsejable.

Abbreviations

CHD: congenital heart disease
HR: heart rate
VO_2: oxygen uptake

INTRODUCTION

Children with congenital heart diseases (CHD) represent 0.8%–1% of all live newborns.[1] A high percentage of them require surgery in their first years of life, the total mortality rate for them is less than 5%.[2] One consequence of this is that the number of children with CHD who reach school age is high and is rising. The improvement in surgical techniques, together with advances in complementary tests, has enabled better diagnosis and follow-up of these children and this, amongst other things, facilitates their social integration, including the most appropriate physical exercise and, as far as possible, physical exercise which can be done during school hours.[3]

Although there are guidelines on physical exercise recommendations for children with CHD, based on the underlying heart disease and tests performed when the patient is at rest,[4] there is generally little correlation with the capacity for effort,[5] given that numerous factors are involved in the adaptation to exercise, such as chronotropic function or the use of muscular oxygen. Furthermore, they are not properly evaluated with imaging techniques like echocardiography or cardiac magnetic resonance. Dynamic tests, such as the cardiopulmonary stress test are necessary in order to better understand adaptation to effort.[6–8] Their use in CHD children is justified by the need to make a functional evaluation using rigorous criteria in patients who, owing to their underlying disease and their social circumstances, require a lot of information about their clinical status both at rest and under stress, in order to optimize the benefits of exercise and reduce any possible risk.[6,7] Having information about individual capacity for effort enables the child with CHD and his/her parents and physical education teacher to have a better idea of the level of exercise the child can do and to avoid his/her exclusion from physical education lessons or activities.

This study was conducted with the aim of analyzing whether the cardiopulmonary stress test can be used in children with a significant CHD and whether the results are related to variables associated with the disease or the usual level of exercise, in order to make better exercise recommendations.

METHODS

This is a prospective study of children of school age who were able to do exercise at the time of the study. The children had had surgery to treat CHD in the two reference hospitals in Catalonia (*Hospital de Sant Joan de Déu* and *Hospital de la Vall d'Hebron*). The disease distribution is shown in Figure 1.

One hundred and eight children with an average age of 10.5 ± 3.1 years were included in the study. Of these, 73 were males (10.6 ± 3 years) and 35 (10.3 ± 3.4 years) were females, and there were no age-related differences in sex distribution. The age when they last had surgery was 3.5 ± 4 years and the interval between their last intervention and the stress test was 85 ± 52 (interval 3–191) months. The statistical data is shown in Table 1.

All children (with the collaboration of their parents and in the presence of a doctor from our team) completed a questionnaire designed for the study, which included: socio-demographic variables, clinical variables related to the type of CHD, surgery, data from the echocardiogram performed within the year prior to the test and variables related to the level of physical exercise performed during and outside of school hours. All the variables were measured in hours of exercise/week. The exercise preferences of the children were also recorded. Depending on the type of heart disease, the physical exercise and competition sport recommendations of the *Sociedad Española de Cardiología* (SEC)[9] were also followed and studied as a variable.

Using a ramp protocol,[10] a stress test was performed on a Schiller STM–55/65 model treadmill, which was designed by our department and had already been validated. The initial speed was 3 km/h during the first 2 min, with an increase in speed of 0.3 km/h for each subsequent minute. The initial slope was zero, increasing 1.4% after the second stage until a maximum of 12% was reached. Twelve-lead ECG (CS-200) recordings were made and blood pressure was taken with a Riester sphygmomanometer. A mask was used to collect exhaled gases. The following parameters were determined using a Ganshorn Power-Cube gas analyser: oxygen uptake (VO_2) in ml·kg·min; oxygen pulse (PO_2) in ml/beats; carbon dioxide production (VCO_2) in l/min; respiratory quotient (RQ); baseline heart rate (HR) and maximum HR under stress (stress HR); ventilatory anaerobic threshold (VAT) expressed in relation to HR, percentage of VO_2 achieved in the VAT (%VO_2), and exhaled volume (EV) in l/min. Baseline and maximum blood pressure (BP) were determined at each stage, as well as test duration in minutes. The criteria for finalising the test were a lack of increase in VO_2, physical exhaustion or the reiterated request of the patient to end the test. The criteria for the test maximum were the appearance of a VO_2 plateau or of the VAT if the former parameter was lacking. In younger children it is difficult to find RQ values higher than 1.1 due to insufficient maturation of anaerobic glycolysis. There are cases in which none of the above parameters provide enough information and the tests are not very reliable.

Owing to the multiplicity of the underlying CHDs (Fig. 1) and the different surgical interventions which had been performed, residual heart disease status was classified as mild, moderate or severe. This classification was made by an expert cardiologist, who had no direct relationship with the patient and was unaware of the result of the stress test, and was based on clinical, surgical and echocardiographic data, and on the recommendations of clinical practice guidelines. The following factors were taken into consideration: the classification recommended by the SEC[9] (Table 2), the result of surgery (evaluating the presence of residual lesions), sequelae or possible complications, hemodynamic status, functional class and the likelihood of any hospital admissions as a result of heart failure. If the lesions were obstructive or regurgitant, they were classified as mild, moderate and/or severe, in accordance with the internationally accepted classification published in clinical practice guidelines.[9] If the main problem was dilation or dysfunction of the corresponding ventricular cavities, they were classified using

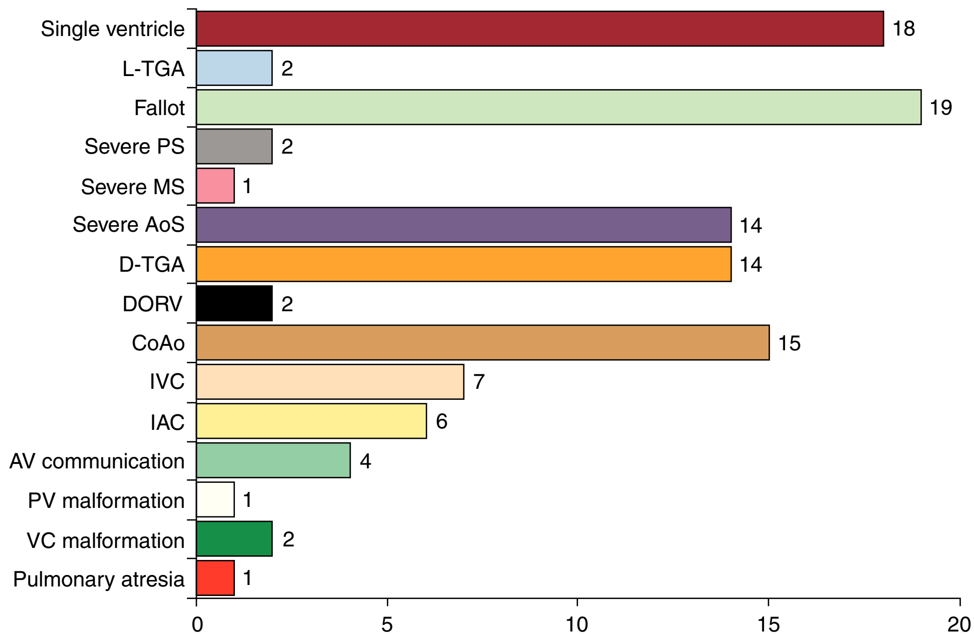

Figure 1. Disease distribution. AoS, aortic stenosis; AV, atrioventricular; CoAo, coarctation of the aorta; DORV, double outlet right ventricle; D-TGA, dextro-transposition of the great arteries; IAC, interatrial communication; IVC, interventricular communication; L-TGA, levo-transposition of the great arteries; MS, mitral stenosis; PS, pulmonary stenosis; PV, pulmonary veins; VC, vena cava.

the information obtained primarily from two-dimensional Dppler echocardiographic studies. Nine cases could not be classified based on the concepts mentioned above so their classification was based on the experience of the expert in CHD, who combined clinical details with data from complementary procedures.

A subgroup of patients was classified as having cyanotic CHD due to their underlying disease, irrespective of whether their arterial oxygen saturation was less than 90% during the stress test, a figure which is generally used to place a patient in this group. This was due to the fact that a considerable number of children had undergone palliative or corrective surgery. Patients within this group were also graded in relation to their current status, but the persistence of cyanosis was particularly important. So, depending on the underlying disease, the surgery which had been performed and the current results of the complementary tests, the same expert classified the patients as having a good, acceptable or poor result.

The study protocol was approved by the clinical trial committee of our hospital and, when the patients joined the study, the informed consent of parents and/or guardians was obtained.

After the test, physical exercise recommendations were made, depending on the ability that the patient demonstrated during the test. Twelve months later a subgroup of 35 patients completed a questionnaire about their current level of exercise.

Table 1
Statistical Data of the Sample (n = 108)

	Mean ± SD	Minimum	Maximum
Age (years)	10.5 ± 3.1	5.5	18.6
Weight (Kg)	39 ± 16.2	15	80
Height (cm)	143 ± 19.7	101	183

SD: standard deviation.

Table 2
Classification of the Severity of the Congenital Heart Diseases Used in the Study[10]

Mild
Stenotic valvular lesions with an important with reduction of the gradient following surgery or graft implantation leaving patient with a slight obstruction
Slight regurgitant lesions
CoAo with reduction of the gradient to below 20 mm Hg after surgery
IAC with good closure result
IVC with good closure result
Drainage of pulmonary veins to the coronary seat with good correction
Cor triatriatum with persistent LSVC drainage to the coronary seat and corrected IAC
Moderate
Moderate residual obstructive or regurgitant valvular lesions
D-TGA with good Jatene-type correction
Valvular prostheses
Fallot corrected with slight residual LF
Pulmonary atresia with corrected IVC. Homograft with slight-moderate gradient and moderate TF
Severe
Severe obstructive or regurgitant valvular lesions
Severe CoAo
D-TGA with physiological correction (Mustard or Senning)
TA or single ventricle with Glenn or Fontan
Fallot with severe LF and/or RV dysfunction
DORV with Rastelli-type correction

CoAo, coarctation of the aorta; DORV, double outlet right ventricle; D-TGA, dextro-transposition of the great arteries; IAC, interatrial communication; IVC, interventricular communication; LF, lung failure; LSVC, left superior vena cava; RV, right ventricle; TA, tricuspid atresia; TF, tricuspid failure.
If there are several lesions, the patient will be classified as having the most serious or severe one.

Statistical Analysis

The stress test data, clinical questionnaire and exercise level were stored in a database designed for this study. A descriptive analysis of the variables which were collected was performed, providing the percentage and number of cases for categorical variables. For quantitative variables, the average value (mean) and a statistical value for variability (standard variation) were calculated. The level of compliance was described by calculating the average value (standard deviation), in addition to the 95% confidence interval (CI) for said measurement. The most important results obtained from the stress test are also described, supplying average values (standard deviation) and the 95% CI.

The stress test results were compared with demographic variables (age and sex) and with the level of importance of the underlying CHD in accordance with the classification described above. Multivariate analysis was performed using multiple regression models, in which VO_2 was regarded as an independent variable. A separate analysis was performed on the cyanotic CHD patient subgroup, depending on the result of surgery. Finally, in the subgroup of patients with data on their exercise at 12 months, the influence of the recommendation to increase their level of exercise and their reasons for doing so were evaluated.

All the analyses were performed using a bilateral approach and the levels of significance were the usual 5% and 1% values ($P < .05$ and $P < .01$ respectively).

RESULTS

After a brief period of adaptation to the mask and the calibration of the gas measurement systems, the stress test was performed on all the patients following the protocol described above. No events which obliged us to suspend the test were recorded, neither were any problems detected during the post-stress recovery period. The data recorded during the stress test in the group of 108 children is shown in Table 3. The maximal VO_2 obtained must be regarded as the VO_2 peak in cases in which it was not possible to measure the VAT or when VO_2 stabilisation was not observed at the end of the test. Using this observational strategy, we obtained a VO_2 peak in 66 individuals and VO_{2max} in 42. The VAT was necessarily determined above RQ = 1 and evaluating the greatest exponential increase in the O_2 respiratory equivalent after this point.

When the results were compared in terms of sex, no significant differences were detected in the hemodynamic or spirometric parameters. Test duration was the same for both genders.

Results Classified According to the Residual Lesion After Congenital Heart Disease Surgery

In accordance with the methodology described above, the grade of cardiac disease and the hemodynamic status of the residual lesion following surgery were classified as mild in 30 children, moderate in 35 and severe in 38. In 5 cases the clinical and echocardiographic data did not allow the expert to determine the level of residual severity and they were excluded from this analysis.

The comparison of the three groups showed that there were no significant differences in age, age at which the last surgical intervention was performed or the length of time since surgery was performed. However, significant differences were detected amongst the groups, with a clear gradient between them. Except for the resting HR, the maximum differences were obtained between mild and severe residual lesions, while moderate lesions had an intermediate status which was closer to that of severe lesions than mild ones (Table 4).

Table 3
Haemodynamic and Spirometric Parameters of the Study Group of Children (N = 108)

Parameter	Mean ± SD	Minimum	Maximum
Resting HR (lpm)	86 ± 14	52	121
Effort HR (lpm)	162 ± 25	77*	204
Resting SBP (mm Hg)	98 ± 12	80	140
Effort SBP (mm Hg)	127 ± 19	90	180
Resting DBP (mm Hg)	64 ± 8	40	80
Effort DBP (mm Hg)	75 ± 7	50	90
VO_2 (ml·kg·min)	35.6 ± 10.1	12	61
PO_2 (ml/beat)	8.4 ± 3.6	3	21
EV (l/min)	40 ± 19	15	104
%VO_2 of the VAT (n = 56)	84 ± 9	59	99
HR of the VAT (lpm) (n = 56)	159 ± 18	121	199
RQ	1.04 ± 0.1	0.73	1.34
VCO_2 (l/min)	1479 ± 822	388	4.360
Test duration (min)	12.8 ± 3.9	6	24

DBP, diastolic blood pressure; EV, exhaled volume; HR, heart rate; PO_2, oxygen pulse; RQ, respiratory quotient; SBP, systolic blood pressure; SD, standard deviation; VAT, anaerobic threshold; VCO_2, carbon dioxide production; VO_2, oxygen uptake.
* Patient with full atrioventricular obstruction-.

Results in Children With Cyanotic Congenital Heart Disease

A subgroup of 59 children with cyanotic CHD was analyzed. In this group the average age was 10.4 ± 3 years (interval 5–17). Thirty seven of them were boys with an average age of 11.1 ± 3 years and 22 were girls aged 9.1 ± 2.9 years, the latter being significantly younger ($P < .05$). The age corresponding to their last surgical intervention was 3.6 ± 4.1 years (interval 0–14) and the length of time since they last had surgery was 83 ± 52 months (interval 2–191).

Depending on the intervention that was performed and its result, the patients were classified as having a good result (21 children), an acceptable result (14) or a poor result (21). In 3 patients the clinical and echocardiographic data was insufficient for classification purposes and they were excluded from this analysis (final number 56 patients).

The results (Table 5) showed significant differences amongst the three groups with respect to the age when the patients had surgery, how long ago they had had surgery, their resting HR, VO_2 and the duration of the test. In the *post-hoc* analysis the children with cyanotic CHD classified as having a poor post-surgical result showed less functional capacity than children with a good or acceptable result. Differences were not found between children with good and acceptable results.

Analysis of Level of Physical Activity

The physical activity the children performed up until the day when they completed the questionnaire was classified into three levels, depending on the hours of effective practice per week. In 48 children we found that they did 2 h or less per week and they were classified as low level; 31 did exercise 3-4 h/week, which was classified as intermediate level, and 28 did more than 4 h of exercise a week, which was classified as high level. In one case the data was incomplete. When the groups were compared, differences were detected in the VO_2, which was higher for the children who did exercise at a high level than in children at a low or intermediate exercise level. Significant differences were also detected in the duration of the test between the intermediate and high level children and those of low and high level (Table 6).

Table 4
Haemodynamic and Spirometric Values Depending on the Classification of the Underlying Heart Disease

Parameter	Residual heart disease (n = 103)			*P*
	Mild (n = 30)	Moderate (n = 35)	Severe (n = 38)	
Resting HR (lpm)	87 ± 15	83 ± 14[a]	91 ± 13	<.05
Effort HR (lpm)	174 ± 15[b]	161 ± 29	155 ± 24	<.01
Resting SBP (mm Hg)	104 ± 12[b]	97 ± 10	95 ± 11	<.05
Effort SBP (mm Hg)	134 ± 17[b]	128 ± 17	122 ± 20	<.05
VO_2 (ml·kg·min)	40 ± 8[b]	36 ± 11	31 ± 9	<.05
PO_2 (ml/beat)	11.3 ± 9.8[b]	8.7 ± 3.2	7.4 ± 3.5	<.05
VCO_2 (l/min)	1829 ± 939[b]	1518 ± 78	1217 ± 704	<.05
Test duration (min)	14.3 ± 3.6[b]	12.9 ± 3.8	11.4 ± 3.7	<.01

HR, heart rate; PO_2, oxygen pulse; SBP, systolic blood pressure; VCO_2, carbon dioxide production; VO_2, oxygen uptake.
[a] Significant differences between moderate and severe.
[b] Significant differences between mild and severe.

Table 5
Differences Between the Three Types of Results of Surgery in Cyanotic Lesion Patients

Parameter	Post-surgical result (n = 56)			*P*
	Good (n = 21)	Acceptable (n = 14)	Poor (n = 21)	
Age at time of surgery (years)	2.6 ± 3.5[a]	2.3 ± 3[b]	5.7 ± 4.7	<.05
Time since surgery (months)	96 ± 43[a]	103 ± 56[b]	53 ± 51	<.05
Resting HR (lpm)	84 ± 11[a]	80 ± 13[b]	95 ± 10	<.01
VO_2 (ml·kg·min)	38 ± 11[a]	38 ± 11[b]	28 ± 9	<.05
Test duration (min)	13.8 ± 4.4[a]	13.9 ± 2.1[b]	10 ± 4	<.01

HR, heart rate; VO_2, oxygen uptake.
[a] Significant differences between good and poor.
[b] Significant differences between acceptable and poor.

The differences detected between the low and intermediate levels did not reach statistical significance.

No statistical correlation was found between the residual post-surgical haemodynamic status and the number of training hours and their distribution was completely random. Neither was any correlation observed between the hours of training variable and the theoretical classification of exercise in the SEC clinical practice guidelines.[9]

Multivariate Analysis

Functional capacity is the ability of an individual to do aerobic work defined by VO_2. A higher VO_2 corresponds to more minutes of exercise during the stress test and, consequently, to a greater capacity to do exercise. In the multivariate analysis VO_2 was treated as an independent variable and when the variables age, body mass index (BMI), hemodynamic status and hours of exercise per week were included in the equation, it was demonstrated that BMI, post-surgical hemodynamic status and training hours were independent of VO_2, and age failed to affect the results (Table 7).

Exercise Recommendations Following the Stress Test

At the end of the test physical exercise recommendations were made, depending on the type of heart disease, post-surgical hemodynamic status and the results of the stress test (mainly the chronotropic response and the VO_2 obtained). The recommendation was classified as: unlimited exercise, moderately intense exercise, low-intensity exercise or medical prohibition of exercise. The preferences of the child and the type of sport according to the Bethesda classification were also taken into account.[11] The level of exercise performed before the stress test, both during school (Fig. 2) and outside of school (Fig. 3) hours was compared with the recommendations made after the test. The number of children who did more exercise increased substantially. Figure 4 shows the situation before the stress test and the recommendations on practicing competition sport. As we can see, a high percentage of patients were no longer interested in practicing competition sport, but an acceptable number were and the latter recommendation enabled these children to take it up, with appropriate limitations depending on the case in point.

Table 6
Differences Between Levels of Physical Activity

Parameter	Level of physical activity (n = 107)			*P*
	Low (n = 48)	Intermediate (n = 31)	High (n = 28)	
VO_2 (ml·kg·min)	32 ± 9[a]	35 ± 8[b]	42 ± 11	<.01
Test duration (min)	11.8 ± 3.9[a]	12.7 ± 3.4[b]	15 ± 3.4	<.01

VO_2, oxygen uptake.
[a] Significant differences between low and high.
[b] Significant differences between intermediate and high.

Table 7
Multivariate Analysis With Oxygen Uptake as an Independent Variable

Parameter	Standardized β	*P*
Residual haemodynamic status (mild, moderate, severe)	−3.003	.003
Weekly exercise (h/week)	3.534	.001
Age	1.246	.216
BMI	−2.156	.034

BMI, body mass index.

In a subgroup of 35 children we were able to conduct a follow-up assessment (questionnaire) on the compliance with the exercise recommendations at 12 months, as well as on reasons for not following them. In the case of exercise during school hours, the recommendation did not change in 22 children, but it increased in 13 children. Ten of them started to engage in normal school PE and in 3 cases the recommendation was not followed, owing to the fact that the children were at the wrong age or because of difficulties in adapting at school. In relation to exercise outside of school hours, we recommended unlimited exercise to 20 children, advising 12 of them to do sports with slight limitations and moderate limitation in 3 cases. We recommended 12 out of the 35 children to do the exercise that they were already doing before the stress test, but 13 followed the new recommendation and 10 did not. With regard to competition sports, 23 children declared that they were not interested in practicing them. We recommended 11 of these children to do unlimited sport and 1 was banned from competing. Of the 11 children with a recommendation to do unlimited sport, 7 already practiced sports before the stress test, 2 took up a sport with a club and 2 failed to initiate sporting activities. In summary, the 35 children who were analyzed were given 40 new recommendations to increase their level of exercise. These were followed in 25 cases (62%) and 15 failed to heed our advice. The reasons for not following the recommendations were lack of time, opportunity or interest. In no case was a medical reason cited.

DISCUSSION

Physical exercise, performed either during school hours, outside of school hours or as a competition sport, is one of the mainstays of the educational, cultural and psychomotor development of children and adolescents. It is also one of the measures for promoting health and improving physical abilities. These are some of the arguments for recommending exercise to all children and avoiding unjustified limitations or exclusion. In general, physical exercise recommendations are based on clinical experience; however, the stress test with exhaled gas analysis is a basic instrument for determining the type of sport that children should practice and the appropriate intensity using objective criteria.

Knowledge of functional capacity and its correlation with the clinical information at our disposal is an essential part of the clinical monitoring of the majority of the children who have had an intervention to treat CHD which has been totally or partially corrected. In general, these children do little exercise[12,13] and a consequence of this may be that they are overweight. Both factors (sedentary life-style and obesity) are the most common independent causes of limitations to effort.

In the series in the present study we included children who had undergone interventions to treat CHD. The most common causes for surgery were tetralogy of Fallot, univentricular heart variants, transposition of the great arteries and coarctation of the aorta, all of which are conditions which may require one or several interventions in childhood (Fig. 1).

The results obtained with this test are consistent with the types of disease and their functional repercussions, as well as with the level of former training. We failed to find sex-related differences in the test results in the comparative analysis, as expected given the age of the patients. These differences are normally evident in puberty. As can be seen in Table 4, the spirometric results show significant differences in the different residual lesion grades. When the children with cyanotic lesions are analyzed separately, it is shown that there are differences in the VO_2 and the duration of the test between patients with a good surgical outcome and patients with a worse outcome. Different studies have been published in which the aerobic capacity of children who have had operations to treat different types of CHD is compared with that of the general population, but they do not show results by residual lesion grade or include data about the exercise that the children perform.[14]

The interpretation of the hemodynamic parameters has its limitations, owing to the tendency of HR to change, the slight increase in BP at the ages included in this study and the difficulty in

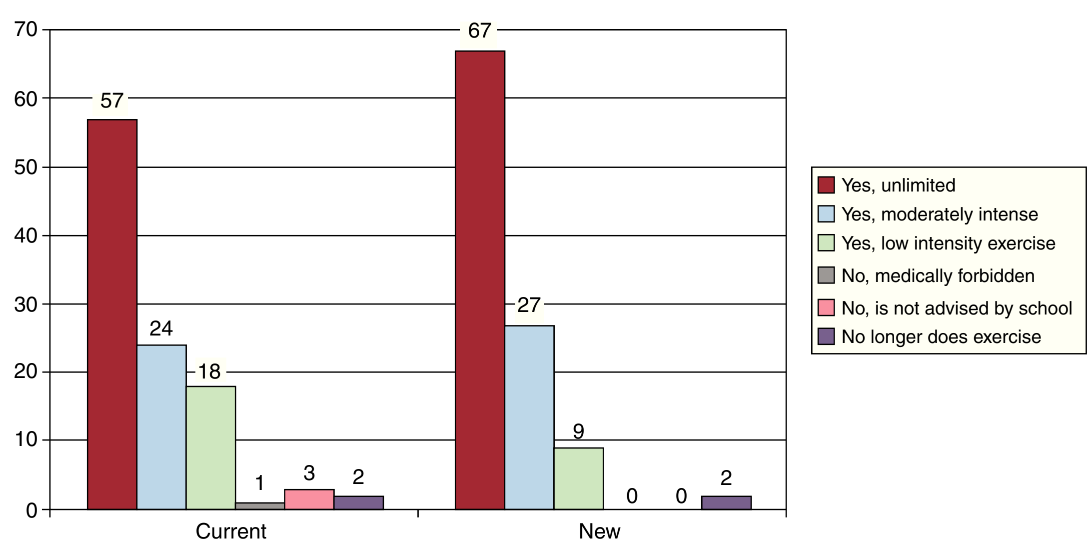

Figure 2. Physical exercise recommendations during school hours before and after stress spirometry testing. The results refer to 105 children; no information was provided in 3 cases.

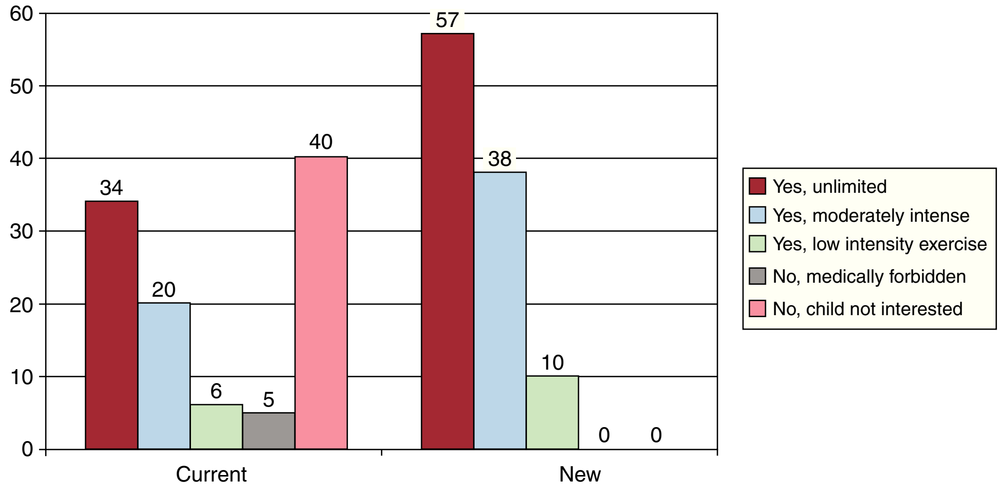

Figure 3. Physical exercise recommendations outside of school hours before and after stress spirometry testing. The results refer to 105 children; no information was provided in 3 cases.

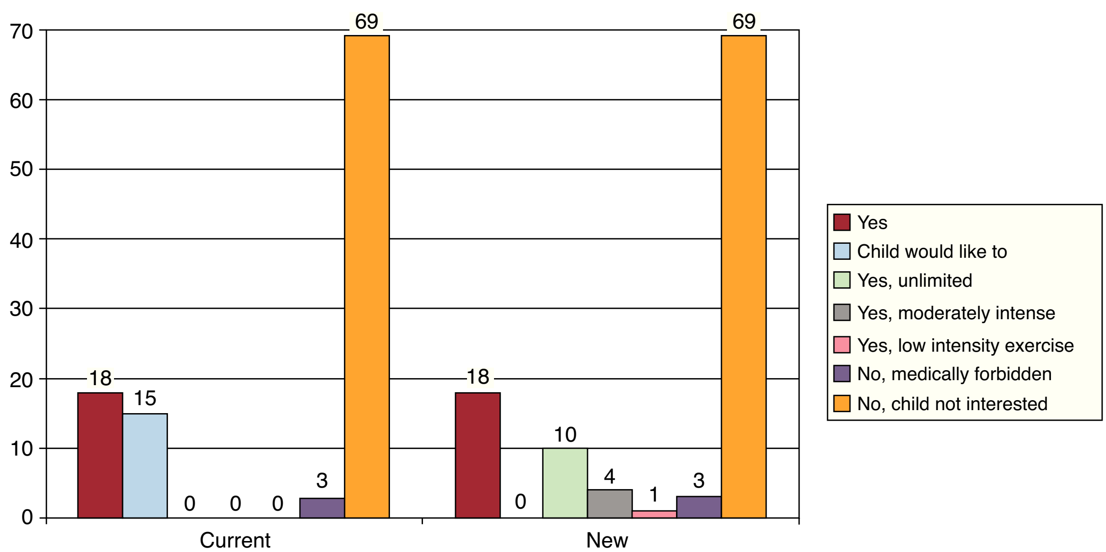

Figure 4. Competition exercise recommendations before and after stress spirometry testing. The results refer to 105 children; no information was provided in 3 cases.

recording effort in these children. This is why it is advisable to add an exhaled gas analysis to the conventional stress test to obtain objective data concerning the functional repercussions of CHD. VO_2 is the main parameter which is used to evaluate functional capacity. Exhaustion is a subjective symptom which, in children, depends a lot on the context and level of motivation, while stabilization of VO_2, RQ and VAT, when can be determined, indicate that the physiological limit of adaptation to effort have been reached. Exercise recommendations must be based on this data, the greatest limitation for this are the quality of testing and the learning curve of the investigator.

Both in the entire group of patients and the cyanotic CHD subgroup the longest duration of exercise, and the greatest VO_2 and PO_2 values, correspond to conditions in which the residual lesion was classified as mild or moderate. The HR attained during effort was lower in the more severe lesions and this corresponded to less effort being made. The increase in BP was also less in children with more severe lesions, although it should be remembered that increases in systolic BP on making effort are less marked in children than in adults. Significant evidence of important severity would be a fall in BP or a hypertensive reaction, but these responses were not observed.

Exercise Recommendations Following the Stress Test

The physiological limit of adaptation to effort is exhaustion. In children who have done little exercise the feeling of tiredness is subjective; actually, they can do it more intensely and in better conditions. The observation of the child during the test and the spirometric parameters objectively determine whether the stage of exhaustion has been reached. In this way, it is possible to distinguish whether the child is really tired or it is a subjective feeling. The cardiopulmonary stress test enabled new recommendations to be established when combined with the latest clinical documentation of reference cardiologists. After performing the stress test much less children had physical exercise limitations both inside and outside of school (Figs. 2 and 3). Furthermore, we observed changes in the same tendency amongst the children who did exercise with moderate or little intensity.

In the subgroup in which the recommendations which were made were monitored, we observed that the children who were advised to increase their level of exercise, 62% followed this recommendation and the main reason for not following it was a lack of opportunity or motivation.

A secondary benefit of this test is the confidence it transmits to parents when they are present during the procedure. They can see that the child generally makes a greater effort than he does during his/her normal activities and that he/she tolerates this extra effort perfectly well. In most cases we can see that the concern they feel with respect to the exercise or sport their children do is unfounded. This fact, together with the advice of the child's cardiologist and the work of psychologists, contributes to reaching a balance between what the child can do and what in practice he/she does in terms of exercise.

Stress spirometry testing is the most suitable method for determining functional capacity; however, it has limitations which can influence study objectives. Motivation, a lack of physical activity, obesity, and physical abilities which enable people to adapt themselves better to the treadmill or the discomfort of the mask are some of the factors implicated in the result. In addition to VO_2, there are other factors that have an impact on performance in sport and it is difficult to ascertain physical abilities objectively in certain cases and recommend the right level of exercise.

CONCLUSIONS

The cardiopulmonary stress test is a safe procedure which most children can do after the age of 5. It provides additional information to the clinical assessment, the physical examination and data obtained using diagnostic techniques performed when the patient is in a resting state. It allows recommending the most suitable sport and right level of intensity more objectively.

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CONFLICTS OF INTEREST

None declared.

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