Research Explained

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Resistance training improves cardiac output, exercise capacity and tolerance to positive airway pressure in Fontan physiology
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About this Study

Why is this study important?

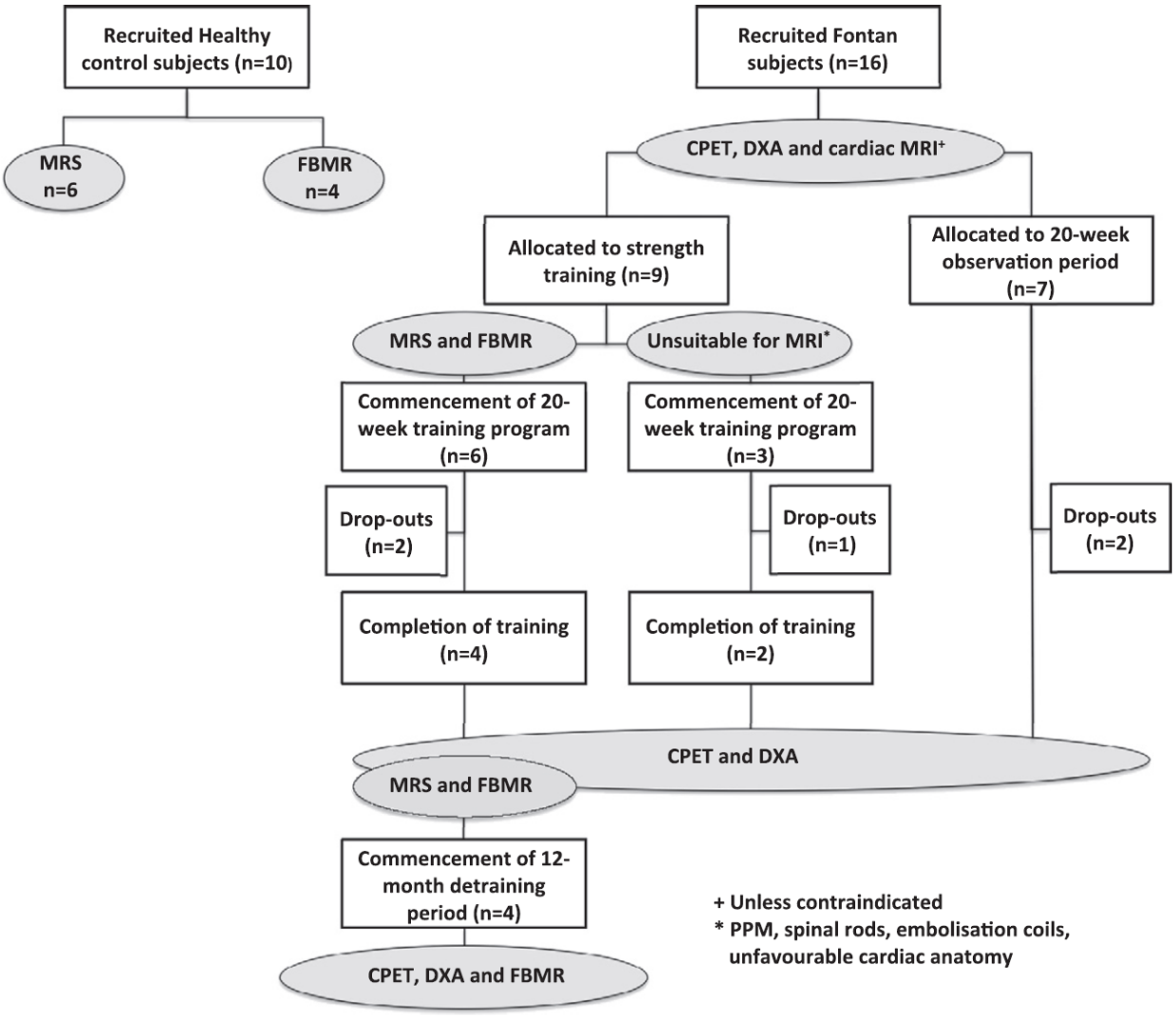
- Since its first description over 40 years ago, the Fontan surgery has become a commonly performed palliative surgery for patients with single ventricle congenital heart disease.
- More and more children undergoing the Fontan surgery are surviving into adulthood.
- As survival improves, we must find ways to improve long-term outcomes and optimize quality of life in this vulnerable patient population.
- The Fontan circuit functions without the benefit of a pumping ventricle, heavily relying on the pressure differences generated during spontaneous breathing.
- Traditionally, intensive exercise, especially strength training, has been discouraged in Fontan patients.
- It is possible that strength training and resultant increased skeletal muscle could improve cardiac filling and stroke volume by acting as a peripheral muscle pump. This would also reduce the Fontan circuits' dependence on the respiratory cycle for blood return to the heart.

How was this study performed?

- Adult subjects were recruited from the CHD database at Royal Prince Alfred Hospital, Sydney, Australia.
- Subjects were excluded for the following reasons: Frequent symptomatic arrhythmias, clinical evidence of heart failure, symptomatic inguinal hernia, severe aortic dilatation and functionally significant physical or intellectual impairment.
- Eleven Fontan subjects were recruited (after 5 dropouts). All subjects underwent baseline body composition and cardiac function assessments with

cardiopulmonary exercise testing (CPET), dual X-ray absorptiometry (DXA) and cardiac MRI (cMRI).

- Of the 11 subjects, 6 subjects underwent 20 weeks of high-intensity resistance training while the other 5 subjects served as non-exercising controls.
- After the training period, CPET and DXA was repeated on all 11 subjects. 4 subjects in the training group underwent MRI at rest, exercise and on CPAP (1 subject iin the training group was unsuitable for MRI).
- Lastly, the remaining 4 subjects in the training group underwent 12 months of detraining (no exercise). CPET, DXA and MRI were repeated at the end. See below:



What were the results of the research?

- Patient anatomic and clinical characteristics in the training group and non-training group were relatively similar. See below:

Training subjects

1. Tricuspid atresia
2. Dextrocardia, tricuspid atresia, VSD, subpulmonary stenosis and TGA
3. DILV, hypoplastic tricuspid valve and subpulmonary stenosis
4. Dual-SVC, mitral atresia, VSD and TGA
5. HLHS, VSD, subpulmonary stenosis and TGA
6. Dual-SVC, VSD, DORV, pulmonary stenosis

Non-training subjects

1. Tricuspid atresia, subpulmonary stenosis and TGA
2. Hypoplastic right ventricle, tricuspid valve and pulmonary valve, VSD and TGA
3. Dextrocardia, DILV, pulmonary atresia
4. DORV
5. Dextrocardia, right AV-valve atresia, cc-TGA, DORV and pulmonary stenosis

	Trainers (n=6)	Non-trainers (n=5)
Age (years)	31 +/− 4	32 +/− 1
Sex	1 female, 5 male	1 female, 4 male
Type of repair	2 APC, 3 intracardiac TCPC (1 with fenestration), 1 extra-cardiac conduit (converted from APC)	2 APC, 2 intracardiac TCPC, 1 extra-cardiac conduit
NYHA class	3 NYHA I, 3 NYHA II	3 NYHA I, 2 NYHA II
Sats (%)	97 +/− 1	99 +/− 1
Age at first surgery (years)	11 +/− 4	12 +/− 2
Time since last Fontan repair (years)	21 +/− 1	18 +/− 2
Ventricular function at echocardiography	3 normal, 2 mild impairment, 1 mild–moderate impairment	2 normal, 2 mild impairment, 1 mild–moderate impairment
Body mass index (kg/m^2)	27 +/− 1	25 +/− 1

- Among the training subjects, muscle strength increased by 43%, total muscle mass increased by 1.94 kilograms and peak VO_2, a measure of exercise capacity, increased significantly after 20 weeks of training.
- Conversely, calf muscle mass, peak workload (a measure of strength) and peak VO_2 decreased after a 12-month period of detraining.
- Stroke volume, a measure of cardiac function, decreased after a period of detraining. This was measured by CPET (pulse VO_2) and MRI.
- Expiratory IVC flow, a marker of cardiac filling, was significantly higher in the trained state versus the detrained state among Fontan subjects.

What are the limitations of this study?

- Small number of subjects (n=11)
- While the trained and non-trained Fontans appear fairly similar in baseline characteristics, it is a heterogeneous group of patients with variable cardiac physiology and surgical history. This may play a role in the results.
- Likewise, medication regimens (ie. Diuretics, pulmonary vasodilators) differed from patient to patient. This was not accounted for in the analysis and likely affected the results.

- CPET is a helpful test. However, it is effort-dependent on the part of the patient and, as a result, the results are not always straightforward for interpretation.
- There was no baseline FBMR data prior to training due to technical issues. Theoretically, this was compensated for by adding a detraining period and repeating the FBMR at the end (to use as a baseline). However, the effects of training may have still been reflected in the post-training FBMR.

What it all Means

- Strength training is safe in adult Fontan patients.
- Augmentation of the peripheral muscle pump is associated with improved exercise performance and increased cardiac output while breathing spontaneously and during CPAP.
- This is highly clinically relevant, as older Fontan patients will inevitably require surgical procedures (cardiac and non-cardiac) utilizing general anesthesia and positive pressure ventilation.
- Outpatient management of the older child and adult Fontan patient that emphasizes more intensive strength training may improve long-term outcomes and quality of life and perhaps delay need for cardiac transplantation among the growing adult Fontan population.