Name of research institute or organization:

Cardiovascular Prevention & Rehabilitation, Swiss Cardiovascular Centre Bern, University Hospital (Inselspital), 3010 Bern

Title of project:

Effect of high altitude exposure on hemodynamic response to exercise in patients with mild congenital heart disease

Project leader and team:

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Project description:

Clinical Background:
Spending time at high altitude for recreational activities such as skiing or ski touring, hiking or going snowshoeing is common practice in Switzerland. Being unable to participate with their peers in at least some of the less strenuous activities at high altitude poses a severe impact on the quality of life for the persons concerned. This is actually the case for a big number of adolescents with congenital heart disease.

Adolescents with congenital heart disease suffer from a reduced exercise tolerance compared to healthy subjects of the same age. The most obvious reason for this may be an altered hemodynamic response to exercise due to the underlying heart disease. However, it is known that central hemodynamic factors are not the main determinants of exercise capacity. Instead, training status and the condition of the peripheral muscles are much more important. The reason for the physical deconditioning often found in these patients may also originate from an overprotection of these children by their parents or carers during their childhood years, leading sometimes to almost complete exercise abstinence. Insecure parents often rely on clinicians to advise them on sports activities that their children can perform safely. Unfortunately, at this stage, there are no scientific grounds to base their recommendations on.

Based on our previous studies on patients with coronary artery disease and patients with stable heart failure we assume that the risk of serious adverse events with high altitude exposure in these patients is low. Nevertheless, for this first study of high altitude exposure of patients with congenital heart disease we selected patients with minor congenital heart disease in New York Heart Association (NYHA) functional class I or II. None of these patients are known for having significantly impaired cardiovascular circulation at low land, significant intracardiac shunts, elevated pulmonary artery pressure at rest, or decreased oxygen saturation. However, a rise in pulmonary artery pressure and a consecutive deterioration of right ventricular function with decrease of cardiac output during exercise at high altitude cannot be excluded in these patients.

Few studies have addressed the hemodynamic effects of altitude exposure in patients with congenital heart disease. Although we consider the risk of a cardiac incident as low, an abnormal adaptation of right ventricular function or a disproportionate rise in pulmonary or systemic arterial pressure with an impaired adaptation of cardiac output would discourage us from recommending high altitude activities. The aim of this study was therefore to measure the hemodynamic response of acute high altitude exposure during exercise in adolescents with congenital heart disease and to compare it to a healthy control group.

Trial population:
We included 16 adolescents with congenital heart disease (56% male, mean age 14.6 years) recruited at the Swiss Cardiovascular Centre Bern, University Hospital Bern, and 21 healthy age-matched adolescents (62% male, mean age 14.8 years) from a local school.

Research aim and hypothesis:
The aims of the study were to test the hemodynamic response (cardiac output) of a steady state exercise at high altitude (3454 m) in adolescents with congenital heart disease and to measure the influence of high altitude on single components of cardio-pulmonary response during a maximal exercise stress test.

We hypothesized that high altitude exposure of adolescents with congenital heart disease may be associated with a deterioration of right ventricular function during exercise and hence a decrease of cardiac output compared with healthy controls.

Fig. 1: Technical equipment at the Jungfraujoch: from left to right: echocardiography equipment, ergometer with set-up for inert gas rebreathing measurement (balloon mounted to the mouth piece) and cart with gas analyser (Innocor®) and monitor.

Trial design:
Baseline testing was performed at the Cardiovascular Prevention and Rehabilitation Centre at the University Hospital in Bern (altitude 540 m), and included echocardiography, cardiopulmonary exercise stress testing on a cycle ergometer, pulmonary function testing, measure of cardiac output during a submaximal steady state exercise test by the non-invasive inert gas rebreathing method (Innocor®) and a 24h ECG recording. Within a time period of ten weeks the same tests were performed on the Jungfraujoch (altitude 3454 m) in groups of three to five adolescents on a single day. Testing required approximately 2-3 hours and the subjects had an additional two hours for their own recreation on the Jungfraujoch.

Results:
Table 1 shows the hemodynamic response during a symptom limited exercise stress test at 540 m above sea level and at high altitude (3454m) among grown-up congenital heart disease (GUCH) patients in comparison with the healthy control group. Although the heart disease of the GUCH patients was only minor, their exercise capacity was significantly lower. This was also reflected by a lower heart rate and lower ventilation during maximal exercise at low land. However at high altitude, these differences were not significant anymore, indicating the good tolerance of hypoxia in this patient population.

	Bern (540m)			Jungfraujoch (3454m)		
Exercise parameters	Healthy	GUCH	p-value	Healthy	GUCH	p-value
Systolic BP, mmHg	109.6±7.6	113.1±16.1	.514	113.2±7.6	116.8±15.6	.254
Diastolic BP, mmHg	56.3±5.4	58.0±5.9	.338	60.3±6.3	60.5±8.3	.964
Hear rate at rest, 1/min.	67.5±9.3	64.6±7.9	.369	79.0±15.4	80.2±8.8	.293
Exercise capacity, Watt	199.7±39.3	164.1±52.2	.009	157.9±40.4	144.1±41.8	.752
Max. heart rate, 1/min.	188.8±10.4	179.4±13.1	.039	189.6±8.8	185.3±11.2	.198
O_2 saturation at rest, %	97.0±1.0	96.9±1.0	.883	91.6±1.5	90.8±0.9	.213
O_2 saturation at max. exercise, %	95.6±0.8	94.8±1.3	.044	83.9±2.5	82.7±2.0	.345
Peak O_2 uptake, ml/kg/min.	43.7±7.5	40.2±9.2	.262	35.4±6.7	35.9±6.7	.538
O_2 uptake at VT	21.9±5.2	21.8±8.9	.459	18.2±7.7	17.8±7.8	1.0
Max. ventilation, l/min.	92.8±22.9	75. 4±18.7	.018	89.4±27.3	82.9±15.3	.702
VE/VCO_2 slope	28.0±3.5	28.7±3.0	.440	36.6±4.9	36.2±4.3	1.0

Table 1: Cardiopulmonary exercise parameters of a symptom limited exercise stress test on a bicycle ergometer at low land (540m) and at the Jungfraujoch (3454m). P-value indicates differences between the groups.

BP: blood pressure; GUCH: grown-up congenital heart disease; VE/VCO_2 slope: ventilatory efficiency; VT: ventilatory (1st lactate) threshold.

Fig. 2: Patient during a steady state exercise test for cardiac output measurement by inert gas rebreathing technique. The upper screen shows heart rate and rhythm, the lower screen depicts O_2-uptake and CO_2 production (blue and red trace respectively).

The hemodynamic response to a submaximal steady state exercise showed a 22.7% and 16.6% increase in cardiac output for the healthy subjects and GUCH patients respectively (c.f. Figure 3). The difference between the groups was not statistically significant (p=0.666).

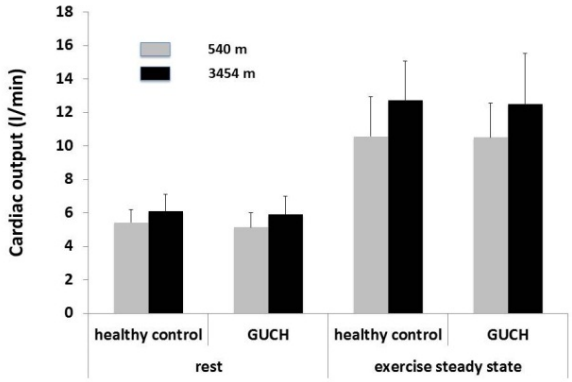

Fig. 3: Cardiac output measurements at rest and during steady state exercise at low land (540m) and high altitude (3454m).

No differences were noted between the healthy subjects and the GUCH patients.

Conclusions:
Adolescents with mild congenital heart disease reveal a reduced exercise capacity at low land when compared with age-matched healthy subjects. However, hemodynamic adaptation to exercise at high altitude is normal in terms of the rise of cardiac output as a compensatory mechanism for hypoxemia. Whether these results can be extended to patients with more severe congenital heart disease has to be explored further.

Key words:
Grown-up congenital heart disease, high altitude, cardiac output, exercise capacity

Scientific publications and public outreach 2012:

Refereed journal articles and their internet access

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Radio and television

"Wie viel Höhenluft ertragen kranke Herzen?", Television report about the study "Effect of high altitude exposure on hemodynamic response to exercise in patients with mild congenital heart disease, SRF, "Puls", June 4, 2012. http://www.srf.ch/gesundheit/forschung/wie-viel-hoehenluft-ertragen-kranke-herzen

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