Effects of altitude on exercise level and heart rate in patients with coronary artery disease and healthy controls

S.T. de Vries, P. Komdeur, S. Aalbersberg, G.C. van Enst, A. Breeman, A.W.J. van 't Hof

Background. **To evaluate the safety and effects of high altitude on exercise level and heart rate in patients with coronary artery disease compared with healthy controls.**
Methods. **Eight patients with a history of an acute myocardial infarction (ejection fraction >45%) with a low-risk score were compared with seven healthy subjects during the Dutch Heart Expedition at the Aconcagua in Argentina in March 2007. All subjects underwent a maximum exercise test with a cycle ergometer at sea level and base camp, after ten days of acclimatisation, at an altitude of 4200 m. Exercise capacity and maximum heart rate were compared between groups and within subjects.**
Results. **There was a significant decrease in maximum heart rate at high altitude compared with sea level in both the patient and the control group (166 vs. 139 beats/min, p<0.001 and 181 vs. 150 beats/min, p<0.001). There was no significant difference in the decrease of the exercise level and maximum heart rate between patients and healthy controls (-31 vs. -30%, p=0.673).**
Conclusion. **Both patients and healthy controls showed a similar decrease in exercise capacity and maximum heart rate at 4200 m compared with sea level, suggesting that patients with a history of coronary artery disease may tolerate stay and exercise at high altitude similarly to healthy controls. (Neth Heart J 2010;18:118-21.)**

Keywords: Altitude; Coronary Artery Disease; Exercise Tolerance; Heart Rate

Few studies exist on the effects of exposure to high altitudes in patients with a history of myocardial infarction, especially altitudes above 3500 m. Patients with stable ischaemic left ventricular dysfunction showed good tolerance while walking at an altitude of 2970 m.[1-4] A group of low-risk patients were sent up the Jungfrau in Switzerland, six months after revascularisation for an acute coronary event. Submaximal exercise at an altitude of 3454 m turned out to be safe.[5] However, in that study the patient group was not compared with a healthy control group.

Previous research has shown that exercise training is beneficial for patients after a myocardial infarction. Secondary prevention programmes improve coronary risk profiles, quality of life, reduce mortality and favourably modify long-term survival.[6] An individualised exercise programme proved to be best with the focus on physical functioning, modification of risk factors, weight loss or general prevention.[7]

When a lowlander ascends to altitude and acclimatises over days to weeks, both maximal exercise capacity and maximal cardiac output tend to decrease compared with sea level.[8] Exercising at high altitude is gaining in popularity.[5] An increasing number of people expose themselves to high altitude, including patients with coronary artery disease. Increasing altitude leads to circulatory changes with an increase in cardiac work and cardiac oxygen consumption, which may put cardiac patients at risk.[9] However, De Luca et al. showed that the majority of patients treated with percutaneous coronary intervention after myocardial infarction are at low risk of adverse events.[10] This type of low-risk patient was studied during the Dutch Heart Expedition at the Aconcagua in the Andes

S.T. de Vries
A. Breeman
A.W.J. van 't Hof
Department of Cardiology, Isala Clinics, Zwolle, the Netherlands
P. Komdeur
S. Aalbersberg
G.C. van Enst
Department of Sports Medicine, Isala Clinics, Zwolle, the Netherlands

Correspondence to: S.T. de Vries
Department of Cardiology, Isala Clinics, PO Box 10500, 8000 GM Zwolle, the Netherlands
E-mail: v.r.c.derks@isala.nl

in Argentina. The main goal of the expedition was to show that exercise at high altitude (4200 m) is safely possible with a history of coronary artery disease. The secondary purpose of this study was to evaluate the effects of altitude on exercise level and heart rate in this group of low-risk patients with a previous myocardial infarction compared with healthy controls.

Methods

Subjects
Eight patients with a history of an acute myocardial infarction (7 males, 1 female, 52±8 years, EF 54±6%) and seven healthy subjects (4 males, 3 females, 41±16 years, EF 60%) participated in the study.

The patients were recruited in the Netherlands through an article in a patient magazine. Fifty patients responded. Twenty patients were selected according to the selection criteria in table 1. Echocardiography was performed to evaluate the left ventricle ejection fraction and valvular function. A symptom-limited cardiopulmonary exercise test was performed to detect potential ischaemia. The subjects were informed about the possible risks and gave their voluntary consent in writing.

Study protocol
The tests were performed at sea level in the Isala Clinics, Zwolle, the Netherlands, in November 2006 and during the Dutch Heart Expedition on the Aconcagua in Argentina in March 2007.

All subjects underwent a maximum exercise test (3-minute increments) on a computer-controlled bicycle ergometer (Energy-Control-bike®) at sea level according to the guidelines described previously.[11,12] Maximal oxygen uptake (VO_2 max) and heart frequency were measured and the electrocardiogram (ECG) was analysed. All participants received a training schedule after the initial exercise test, to prepare themselves for the actual expedition.

The exercise test was repeated on a Cyclus 2® ergometer at base camp at an altitude of 4200 m, after ten days of acclimatisation. Heart frequency was measured with a Polar® heart rate monitor. Unfortunately, an ECG and measurement of VO_2 max at altitude could not be performed due to the circumstances. Troponin T was measured and a control echocardiography was performed after each exercise test. No palpitations were reported.

Before the expedition started, an emergency plan was written and, besides all the necessary medication, an Automatic External Defibrillator was also part of the equipment.

Statistical analyses
All data are expressed as mean and standard deviation. Data were analysed with SPSS statistical software. Standard paired t-test or Wilcoxon signed-rank test was used for comparison between data at sea level and base camp. Standard t-test or Mann-Whitney U test was used for comparison between the patient group and the controls. A value of $p<0.05$ was considered significant.

Table 1. Selection criteria.

Inclusion:	Documented myocardial infarction
	Age 18-65 years
Exclusion:	Severe hypertension
	Smoking
	Diabetes mellitus
	Ejection fraction <45%
	Ischaemia during exercise test at sea level
	Previous heart surgery
	Pacemaker
	Documented ventricular tachycardia
	Haemodynamically significant valve dysfunction
	History of cerebral disorders
	Anaemia
	History of pulmonary embolism
	Pulmonary pathology
	History of gastric disorders
	Nephrological disorder

Results

The baseline characteristics of the patient group and the healthy controls are described in table 2.

The echocardiography performed at sea level showed an ejection fraction of the left ventricle of >45% in all patients and a normal ejection fraction in the healthy controls. None of the subjects had a significant valvular dysfunction at sea level.

At sea level the maximum heart rate was 166±15 beats/min in the patient group and 181±13 beats/min in the control group ($p=0.050$). The maximum heart rate had decreased significantly within subjects with an average of 16% ($p<0.001$) in the patient group and 18% ($p<0.001$) in the control group at 4200 m compared with sea level. There was no significant difference in the decrease of the maximum heart rate between subject groups (table 3).

There was no significant difference in exercise capacity between patients and healthy controls at sea level and at 4200 m (table 3). Exercise capacity decreased at 4200 m compared with sea level. There was a significant difference in maximum wattage (amount of power on the ergometer) at base camp (4200 m) compared with sea level in both groups (patients: 251 W vs. 171 W, $p<0.001$

Table 2. Baseline characteristics.

Characteristics	Patients (n=8)	Controls (n=7)	P value
Age (year)	52±8	41±16	0.079
Male sex (%)	87	57	0.282
Weight (kg)	81±10	79±15	ns
Length (cm)	181±7	178±9	ns
BMI	24.8±1.9	25±4.7	ns
Previous MI (%)	100	0	<0.001
Previous PCI (%)	88	0	0.001
Medication			
- ASA (%)	88	0	0.001
- ACE inhibitor (%)	63	0	0.026
- Statin (%)	63	0	0.026
- β-blocker (%)	50	0	0.077
- Ca antagonist (%)	13	0	ns
- Diuretics (%)	0	14	ns

BMI=body mass index, MI=myocardial infarction, PCI=percutaneous coronary intervention, ASA=acetylsalicylic acid, ACE=angiotensin-converting enzyme, ca=calcium, ns=not significant.

Table 3. Exercise test.

		Patients	Controls	P value
Sea level	HR bpm (max)	166±15	181±13	0.050
	Wattage (max)	251±47	247±49	0.890
Base camp	HR bpm (max)	139±12	150±15	0.166
	Wattage (max)	171±33	174±39	0.872
BC vs. SL	Decrease HR (%)	16	18	0.669
BC vs. SL	Decrease wattage (%)	31	30	0.673

SL=sea level, BC=base camp, HR=heart rate, BPM=beats per minute.

and controls: 247 W vs. 174 W, p<0.001). At base camp, compared with sea level, maximum wattage decreased by 31% in the patient group compared with 30% in the control group (table 3).

Troponin levels did not exceed the normal range (<0.05 ng/ml) after all the exercise tests. Echocardiography after the exercise tests showed no wall motion abnormalities.

Discussion

Few studies describe the effect of high altitude on exercise level and maximum heart rate among patients after a myocardial infarction. To our knowledge this is the first study comparing patients with healthy controls at an altitude of 4200 m.

The current study showed a significant decrease in maximum heart rate and exercise capacity at high altitude compared with sea level in both the patient group and the control group. This was previously shown by Schmid et al.,[5] Hartley et al.[13] and more recently in a healthy group of mountaineers by Bhaumik et al.[14] However, the present study shows that this decrease in the patient group is comparable with the decrease found in healthy control subjects.

The maximum heart rate is lower in the patient group than in the control group at sea level and also at high altitude. This can be explained by the use of β-blockers by the majority of the patients, since β-blockers are known to decrease the heart rate both at rest and during exercise. The exact effect of β-blockers is unknown, because of the inter-individual dose-response variability.[15] The difference can also be explained by the younger age of the subjects in the control group. Maximum heart rate declines with age. The estimated maximum heart rate is 220-age with a considerable variance for any given age.[16]

The reason for the decrease in maximum heart rate at high altitude is not fully understood. Boushel et al.[17] suggested that there is an enhanced parasympathetic neural activity that could account for a lowering of heart rate during exercise at altitude. More research on this phenomenon is necessary.

Another possible explanation for the decrease in maximum heart rate and exercise capacity in healthy subjects might be a limitation in pulmonary function.[18-21] In the present study pulmonary function was not measured. However, the subjective reason to stop the exercise test was a sense of dyspnoea at high altitude compared with tired legs at sea level.

The study has certain limitations. The population was small because of practical and logistical reasons. The patient group only consisted of low-risk patients with percutaneous revascularised coronary artery disease, a left ventricular ejection fraction >45% and a normal exercise test at sea level. People, and specifically patients with a history of a myocardial infarction, with a mean exercise capacity of 251 watts are actually very fit. The reason to choose this group was the lack of any data concerning safe altitude exercise in high-risk patients. It is important to notice that the current data are not applicable to patients in a different risk category. Due to technical difficulties no ECG data could be obtained at high altitude. However, myocardial damage was excluded by measurement of troponin and echocardiography.

Conclusions

Our data showed a decrease in exercise tolerance and maximum heart rate at 4200 m compared with sea level. However, the decrease was similar in both the patient group and the healthy controls. This suggests that patients with a history of coronary artery disease with a low risk profile and sufficient exercise capacity do not respond differently from healthy controls. This implies that a selected group of patients will tolerate staying and exercising at high altitude. ■

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