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Which altitude is better? Under which artificial hypoxic conditions is training more effective for patients after a myocardial infarction?

Ph.D Agata Nowak-Lis, Prof. Zbigniew Nowak, Ph. D Dominika Grzybowska-Ganszczyk, Paweł Dudziński

Jerzy Kukuczka Academy of Physical Education, Department of Physiotherapy, Katowice, Poland

Introduction

Cardiac rehabilitation is a cornerstone of secondary prevention after myocardial infarction, aiming to restore exercise capacity, improve cardiovascular function, and enhance quality of life.

Introduction

While conventional training protocols in Poland include 22 training sessions in normoxic conditions, recent research has explored the potential benefits of integrating normobaric hypoxia simulating altitudes of 2000 to 3000 meters above sea level into endurance training.

Aim of the study

Assesment of the impact of 22 day endurance training under normobaric hypoxic conditions, while simulating altitudes of 2000m and 3000m, on excercise tolerance, cardiac function and selected hematological parameters in men after myocardial infarction

The following question was presented:

- Which hypoxic conditions (2000 or 3000 meters above sea level) during which interval training was performed on a cycle ergometer proved to be the most effective in terms of exercise test results and echocardiographic parameters of the heart?

Criteria for participation

- History of uncomplicated myocardial infarction, at least 4 weeks after the event
- Men aged 35–75 years
- Eligibility for cardiac rehabilitation according to model A (≥7 MET)
- Informed consent to participate in the study
- No active inflammatory diseases or other uncontrolled non-cardiac conditions

Methods

- Participants: 71 people
- Groups:
  - normoxia (control) 22 training sessions using an interval training on a cycloergometer
  - hypoxia (2000m)
  - hypoxia (3000m)

Methods

- Training program:
  - adaptation to the oxygen levels for 30 minutes before, and after training
  - resistance according to results of a stress test, then individually selected
  - 22 training sessions
  - general endurance and resistance training with cycle ergometer
  - based on Polish Society of Cardiology recommendations

Methods

- Assessment before and after the training program:

  - cardiopulmonary stress test CPET (75% HR_{max})

  - echocardiography

  - blood parameters test (morphology, fibrinogen, cythokine TNFα and interleukine IL 1β and IL10)

  - blood saturation

- All patients had a water bottle for rehydration
- Blood saturation and blood pressure were monitored before adaptation, after adaptation and after training

Researches took place in the laboratory of monitoring the physical effort and in a cabin of artificial hypoxia at the Academy of Physical Education in Katowice (Poland)

Results

Results of cardiopulmonary stress test (CPET)

Parameters		2000 m a.s.l			3000 m a.s.l	
Test time [min]	I	10,57±2,18	F=6,744	I	9,98±1,11	F=8,279
	II	11,23±2,30	P=0,012	II	11,34±1,61	P=0,007
Distance [m]	I	650,14±209,13	F=7,267	I	448,41±107,06	F=8,920
	II	714,16±226,47	P=0,009	II	546,66±116,16	P=0,005
MET [ml/kg/min]	I	7,84±1,32	F=0,482	I	8,02±0,87	F=7,878
	II	7,95±1,67	P=0,490	II	8,79±0,84	P=0,008
VE [l/min]	I	86,61±19,15	F=3,290	I	87,05±11,62	F=2,994
	II	92,78±18,25	P=0,074	II	90,41±9,64	P=0,093
VO_{2peak} [ml/min/kg]	I	27,34±4,67	F=0,251	I	28,45±2,74	F=2,218
	II	27,62±5,13	P=0,618	II	29,15±2,61	P=0,146
BF [l/min]	I	34,40±6,25	F=3,456	I	35,68±3,35	F=2,216
	II	35,43±6,33	P=0,079	II	36,52±3,35	P=0,146
RER	I	1,16±0,08	F=0,043	I	1,06±0,10	F=4,942
	II	1,15±0,34	P=0,837	II	0,98±0,09	P=0,033

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HR_{rest} [l/min]	I	70,85±8,94	F=0,639	I	70,41±7,23	F=0,000
	II	70,00±8,82	P=0,427	II	70,42±7,46	P=1,000
HR_{peak} [l/min]	I	136,30±15,79	F=1,458	I	141,91±5,28	F=0,143
	II	135,56±15,12	P=0,231	II	142,29±5,05	P=0,679
BPSrest [mmHg]	I	124,07±12,04	F=0,002	I	133,88±7,43	F=4,808
	II	124,03±11,21	P=0,961	II	128,24±7,28	P=0,035
BPDrest [mmHg]	I	70,71±8,22	F=0,083	I	70,52±5,15	F=6,297
	II	70,59±8,21	P=0,774	II	66,47±4,93	P=0,001
BPSmax [mmHg]	I	175,48±30,49	F=3,423	I	184,26±15,13	F=0,381
	II	182,11±33,41	P=0,069	II	185,56±12,11	P=0,541
BPDmax [mmHg]	I	76,71±12,27	F=1,617	I	74,71±4,89	F=0,258
	II	74,41±11,21	P=0,208	II	75,14±4,99	P=0,614

Results of blood tests

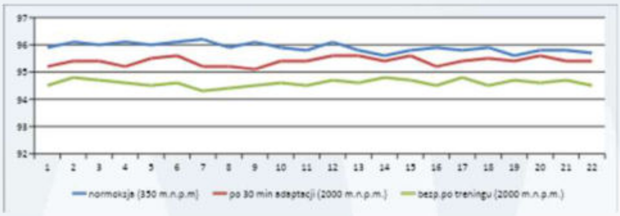
Parmeters		2000 m a.s.l			3000 m a.s.l	
WBC	I	6,36±1,32	F=0,984	I	7,10±1,12	F=0,005
	II	6,21±1,12	P=0,325	II	7,09±1,28	P=0,942
RBC	I	4,91±0,36	F=0,024	I	5,03±0,34	F=0,518
	II	4,92±0,35	P=0,877	II	5,09±0,38	P=0,476
HGB	I	14,99±1,01	F=0,051	I	15,41±1,04	F=0,660
	II	15,02±1,00	P=0,821	II	15,56±1,03	P=0,422
HCT	I	44,36±2,79	F=0,109	I	45,69±3,23	F=1,089
	II	44,26±2,21	P=0,742	II	46,29±2,79	P=0,304
PLT	I	212,91±52,40	F=0,071	I	213,64±38,85	F=0,407
	II	214,60±52,22	P=0,790	II	209,64±35,81	P=0,527
Fibryn.	I	3,35±0,71	F=0,042	I	3,17±0,58	F=0,747
	II	3,34±0,69	P=0,838	II	3,09±0,48	P=0,393
IL 1β	I	41,46±55,21	F=1,243	I	30,12±35,19	F=0,024
	II	48,81±69,82	P=0,269	II	31,09±35,36	P=0,876
IL 10	I	3,96±0,90	F=3,698	I	4,79±0,02	F=0,347
	II	3,76±0,87	P=0,059	II	4,77±0,03	P=0,559
TNF α	I	14,57±15,75	F=0,011	I	11,75±15,06	F=0,138
	II	14,39±17,45	P=0,917	II	10,78±11,02	P=0,712

Results of echocardiography

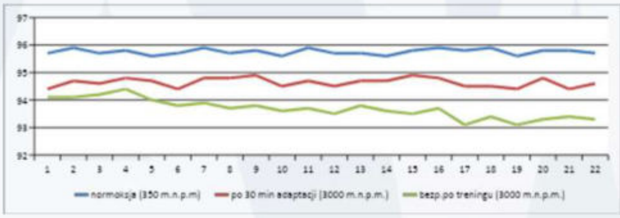
Parameters		2000 m n.p.m.			3000 m n.p.m.	
LVEDd	I	49,40±6,60	F=6,133	I	49,32±5,04	F=3,783
	II	45,51±7,52	P=0,016	II	47,71±4,73	P=0,060
LVESd	I	35,80±7,68	F=2,677	I	31,61±6,05	F=2,544
	II	37,29±8,73	P=0,106	II	33,24±5,40	P=0,120
LVESV	I	50,94±13,21	F=0,272	I	55,88±18,28	F=0,039
	II	50,11±12,86	P=0,604	II	55,24±17,20	P=0,844
LVEDV	I	107,24±24,05	F=0,312	I	104,70±29,78	F=1,543
	II	108,86±25,13	P=0,578	II	111,00±27,45	P=0,223
LVEF	I	51,34±7,73	F=2,643	I	50,47±6,38	F=0,025
	II	52,83±8,53	P=0,109	II	50,65±7,09	P=0,874
Fala E	I	0,66±0,17	F=0,650	I	0,64±0,14	F=4,912
	II	0,68±0,18	P=0,423	II	0,77±0,19	P=0,033
Fala A	I	0,64±0,18	F=0,175	I	0,68±0,22	F=0,293
	II	0,63±0,21	P=0,677	II	0,71±0,21	P=0,591

e' lateral	I	0,09±0,02	F=4,179	I	0,09±0,03	F=0,574
	II	0,10±0,02	P=0,045	II	0,09±0,03	P=0,453
e'septal	I	0,07±0,02	F=4,811	I	0,09±0,01	F=2,433
	II	0,09±0,02	P=0,032	II	0,09±0,02	P=0,128
E/E'	I	8,00±2,39	F=1,664	I	8,18±3,77	F=0,435
	II	7,64±1,94	P=0,201	II	8,64±3,46	P=0,514
E/A	I	1,11±0,44	F=1,914	I	1,11±0,48	F=0,570
	II	1,19±0,49	P=0,171	II	1,18±0,55	P=0,455
TAPSE	I	21,85±4,65	F=0,167	I	23,61±4,02	F=0,960
	II	22,09±5,27	P=0,684	II	22,94±3,86	P=0,334
MAPSE	I	15,11±3,69	F=2,911	I	16,32±3,16	F=0,842
	II	15,86±4,27	P=0,093	II	15,82±2,35	P=0,365

Blood saturation



2000m a.s.l.



3000m a.s.l.

Normoxia
After 30 minutes of adaptation
Right after training

Training under normobaric hypoxia leads to a **drop in blood oxygen saturation** - the higher the simulated altitude, the lower the saturation. Still, values remained within safe physiological limits.
The decline is still within a tolerable range, but shows greater stress on oxygen delivery.

Conclusions

- Comparing the effects of both hypoxic trainings, higher effectiveness was observed under conditions corresponding to an altitude of 3000 m a.s.l.
- The hemodynamic parameters of the heart muscle changed depending on the conditions in which the rehabilitation training was carried out.
- Rehabilitation training conducted in different environmental conditions over 22 days did not have a significant effect on changes in blood test results.

Summary

- Patients are tolerating hypoxia on 2000m a.s.l. much better than 3000m, which allows us to increase the resistance for more challenging training, leading to improvement in recovery.
- Increasing hypoxia level can be used as another training progressing tool.
- Trainings conducted were without any unexpected accidents, and were beneficial for patients on every altitude.

Thank you for your attention!