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Adding argon to low-oxygen training air: effects on fitness and tolerance to low oxygen

Submission date
18/07/2026

Recruitment status
No longer recruiting

Registration date
20/07/2026

Overall study status
Completed

Last Edited
20/07/2026

Condition category
Other

[_] Prospectively registered
[_] Protocol
[_] Statistical analysis plan
[_] Results
[_] Individual participant data
[X] Record updated in last year

Plain English summary of protocol

Background and study aims
Hypoxic (low-oxygen) training is commonly used to improve endurance performance, but reducing oxygen levels further to increase the training stimulus often causes greater discomfort and strain, limiting how hard athletes can train. This study examined whether adding argon, an inert gas, to the training air could allow a deeper level of low-oxygen exposure without extra physical strain, and whether this approach produced greater improvements in aerobic fitness and tolerance to low oxygen compared with standard low-oxygen training.

Who can participate?
Healthy men aged 19–35 years, with a body mass index of 21–28 kg/m², who exercised recreationally but were not competitive athletes

What does the study involve?
Participants were allocated to one of four groups, each completing 15 training sessions (4 hours each) that combined 2 hours of stationary cycling with 2 hours of rest, while breathing one of four different air mixtures: standard reduced-oxygen air, more strongly reduced-oxygen air, reduced-oxygen air enriched with argon, or normal air (control group). Aerobic fitness and tolerance to low oxygen were measured before training, 3 days after, and 3 weeks after training ended.

What are the possible benefits and risks of participating?
Participants may have benefited from improved aerobic fitness as a result of the training programme. Risks included typical symptoms of exercise under reduced-oxygen conditions, such as breathlessness, dizziness, headache, or fatigue, which were closely monitored throughout each session by supervising staff.

Where is the study run from?
Training and testing were conducted at a specialized adaptation-training complex in Saint Petersburg, Russia.

When is the study starting and how long is it expected to run for?
August 2025 to December 2025

Who is funding the study?
Investigator initiated and funded

Who is the main contact?
Dr Arseny Kuzmin, ars6786@gmail.com

Contact information

Type(s)
Public, Scientific, Principal investigator

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Study information

Scientific Title
Argon-enriched normobaric hypoxia enables deeper hypoxic exposure with comparable physiological cost and greater transfer effects

Acronym
AENH-T

Study objectives
1. To determine whether argon-enriched normobaric hypoxia allows exposure to deeper hypoxia with comparable acute physiological cost (ventilatory and cardiovascular) compared with conventional normobaric hypoxia during endurance training.
2. To compare the transfer effects of argon-enriched versus conventional normobaric hypoxic training on aerobic threshold, assessed under normoxic conditions.
3. To compare the transfer effects of argon-enriched versus conventional normobaric hypoxic training on hypoxic tolerance (Stange breath-hold test), assessed under normoxic conditions.
4. To assess the tolerability and feasibility of conventional normobaric hypoxia, deeper conventional hypoxia, and argon-enriched normobaric hypoxia across a 15-session training protocol.

Ethics approval required

Ethics approval required

Ethics approval(s)
Approved 19/06/2025, Ethics Committee of I.M. Sechenov First Moscow State Medical University (Sechenov University) (Trubetskaya str., 8, Moscow, 119991, Russian Federation; +7 (0) 4956229706; iec@staff.sechenov.ru), ref: No. 14–25

Primary study design
Interventional

Allocation
Randomized controlled trial

Masking
Open (masking not used)

Control
Active

Assignment
Parallel

Purpose
To evaluate the effects of modifying inspired gas composition (argon-enriched normobaric hypoxia versus conventional normobaric hypoxia) during endurance training on the acute physiological cost of hypoxic exercise and on transfer effects to aerobic performance and hypoxic tolerance under normoxic conditions

Study type(s)

Health condition(s) or problem(s) studied
Physiological adaptation to hypoxic endurance training in physically active but non-competitive men

Interventions
Participants are stratified by age, baseline functional capacity, anthropometric characteristics, and tolerance to hypoxic exposure, then allocated to one of four parallel groups using stratified randomization.

Group I (n = 14, conventional normobaric hypoxia): Participants complete 15 training sessions in which the fraction of inspired oxygen (FiO_2) is progressively reduced from 19% to 16–17% over the initial sessions and then maintained at 16–17% for the remainder of the protocol.

Group II (n = 14, deeper conventional normobaric hypoxia): Participants undergo the same protocol as Group I, but FiO_2 is further reduced to 14-15%.

Group III (n = 16, argon-enriched normobaric hypoxia): Participants are exposed to a fixed gas composition of 13-14% O_2 enriched with 33–35% argon throughout all 15 sessions.

Group IV (n = 14, normoxic control): Participants complete identical training under normoxic conditions (FiO_2 = 20.9%), without hypoxic exposure.

Each of the 15 training sessions lasts 4 hours and consists of 120 minutes of continuous cycling at 50-75% of maximal oxygen uptake (VO_2max), performed in the assigned gas environment, followed by 120 minutes of passive exposure while remaining in that gas environment. Exercise intensity is individually prescribed based on baseline VO_2max testing and adjusted as needed to maintain the target intensity range. Gas mixtures are prepared using medical-grade gases (O_2, N_2, Ar) and continuously monitored for O_2 concentration, CO_2 level, and pressure throughout each session.

Participants and investigators are not blinded to group assignment, as differing levels of inspired oxygen fraction across groups produce perceptible physiological symptoms of hypoxia (e.g., dyspnea, altered breathing effort) that cannot be masked, even though the gas delivery apparatus and chamber environment are standardized across groups.

Intervention Type
Other

Primary outcome(s)
1. Aerobic threshold measured using power output (W) during an incremental cycling test with stepwise increases starting at 50 W (25 W increments per stage), determined using combined ventilatory criteria (first disproportionate increase in VE/VO_2 without concomitant rise in VE/VCO_2, and changes in respiratory exchange ratio), assessed on an electronically braked cycle ergometer with breath-by-breath metabolic system (SCHILLER CARDIOVIT CS-200) at baseline (3 days before intervention), 3 days post-intervention and 3 weeks post-intervention

Key secondary outcome(s)
1. Hypoxic tolerance measured using breath-hold duration (s) during the Stange test (maximal breath hold at end-inspiration, seated position) at baseline (3 days before intervention), 3 days post-intervention and 3 weeks post-intervention

2. Ventilatory equivalent for oxygen measured using change in VE/VO_2 during standardized normobaric hypoxic exposure, assessed via breath-by-breath metabolic system (SCHILLER CARDIOVIT CS-200) at averaged across training sessions 1-15

3. Peripheral oxygen saturation measured using change in SpO_2 (%) during standardized normobaric hypoxic exposure, measured by pulse oximetry (MARG Microlux) at averaged across training sessions 1-15

4. Oxygen uptake measured using change in VO_2 ($L \cdot min^{1}$) during standardized normobaric hypoxic exposure, assessed via breath-by-breath metabolic system (SCHILLER CARDIOVIT CS-200) at averaged across training sessions 1-15

5. Cardiovascular cost during hypoxic exercise measured using change in heart rate (ΔHR, bpm) relative to normoxic resting values, recorded via wireless monitoring system (Polar) at training phases 1-5, 6-10, and 11-15

6. Tolerability measured using session completion rate, protocol modifications, and subjective symptom severity ratings; psychological well-being assessed using the SAN (Well-being-Activity-Mood) questionnaire at throughout the 15-session intervention

Completion date
22/12/2025

Eligibility

Key inclusion criteria
1. Healthy men aged 19–35 years
2. Body mass index (BMI) 21–28 kg/m²
3. Physically active but not competitive athletes, regularly engaged in recreational exercise (e.g., running, fitness training, swimming)
4. Written informed consent
5. Ability to maintain habitual physical activity throughout the study
6. Absence of cardiovascular, respiratory, metabolic, neurological, or psychiatric disease

Healthy volunteers allowed
Yes

Age group
Adult

Lower age limit
19 Years

Upper age limit
35 Years

Sex
Male

Total final enrolment
58

Key exclusion criteria
Any condition that could compromise safety, adherence, or physiological responses to hypoxia or exercise

Date of first enrolment
01/08/2025

Date of final enrolment
02/09/2025

Locations

Countries of recruitment
Russian Federation

Sponsor information

Organisation

Research Institute of Geroprotective Technologies, Saint Petersburg, Russia

Funder(s)

Funder type

Funder Name
Investigator initiated and funded

Results and Publications

Individual participant data (IPD) sharing plan

IPD sharing plan summary
Not expected to be made available