



Reference Values Of Gas Exchange Variables in A Cardiopulmonary Exercise Test At An Altitude Of 2640 m

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Rationale

As the altitude increases, the barometric, inspired and arterial pressures decrease. This modifies the breathing pattern and the arterial blood gases (ABG). Reference values for cardiopulmonary exercise testing (CPET) suggested by the American Thoracic Society (ATS) are based on studies at sea level, with a small number of subjects, including smokers and different racial groups. There are no reference values at the altitude of Bogota (2640 m).

Methods

Cross-sectional study in healthy non-smokers, non-obese adults with normal spirometry. A symptom-limited incremental exercise testing on a cycle ergometer with measurements of oxygen uptake and work rate. Gas exchange and ventilatory variables were analyzed breath by breath and the ABG at rest and peak exercise. We excluded athletes and subjects with a submaximal test. Analysis of group differences was tested using unpaired *t* test and ANOVA. 95% confidence limits were calculated.

Table 1. Variables at peak exercise (n=171)

	20-39 years (n=36)	40-60 years (n=84)	>60 years (n=51)
Work rate, %	101,8 ± 17,1	102,3 ± 15,3	103,3 ± 19,9
VO₂, mL/min	2200,9 ± 715,0	1791,8 ± 484,1	1622,1 ± 485,7
VO₂, %	96,4 ± 19,5	94,9 ± 14,3	98,1 ± 15,4
RQ	1,17 ± ,08	1,18 ± ,10	1,17 ± ,10
Heart rate, %	88,6 ± 5,4	88,7 ± 7,2	86,3 ± 6,9
VO₂/HR, %	109,1 ± 22,2	107,5 ± 16,9	114,1 ± 18,5
VE, L	89,9 ± 22,6	77,9 ± 21,8	69,8 ± 22,0
VT, mL	2182,0 ± 563,2	2081,9 ± 574,1	1800,5 ± 468,8
RR, breaths/min	41,8 ± 6,7	38,1 ± 7,6	38,9 ± 7,5
MVV - VE	58,8 ± 26,3	56,0 ± 21,5	44,7 ± 19,6

Values: mean ± SD. VO₂: oxygen uptake; VT: tidal volume; RR: respiratory rate; MVV: maximal voluntary ventilation

Table 2. Arterial blood gases values at rest and at exercise by age

Age Years	PaCO ₂ , mmHg		PaO ₂ , mmHg		P(A-a)O ₂ , mmHg		VD/VT	
	Rest	Exercise*	Rest*	Exercise*	Rest*	Exercise*	Rest*	Exercise*
20-39	30,0±2,3	27,0±2,5	68,7±4,5	80,0±3,6	5,5±3,8	5,4±2,9	,23±,08	,06±,04
40-60	30,9±2,4	27,2±2,4	66,7±4,3	79,3±4,7	6,4±4,5	5,8±3,7	,29±,08	,08±,06
>60	31,0±2,4	28,1±2,8	65,0±4,5	74,5±6,0	8,0±3,8	9,8±5,3	,31±,07	,11±,07

Values: mean ± SD. *P<0.05 differences by age groups

Table 3. Upper or lower 95% confidence limits at peak exercise

Age	PaO ₂	PaCO ₂	P(A-a)O ₂	VE/VCO ₂ *	VD/VT	P(a-et)CO ₂
20-39	>72	<32	<12	<39	<0,16	<0
40-60	>69	<32	<14	<41	<0,22	<0
>60	>62	<34	<21	<42	<0,24	<1

*at the anaerobic threshold

Results

We included 171 healthy adults, 53% men. Values at peak exercise by age are shown in table 1. At the anaerobic threshold the ventilatory equivalents (VE/VCO₂) increased as the age increased: 33.0 3.0, 34.0 3.0 and 35.0 3.0. In exercise in all subjects, there was a decrease of pH, PaCO₂ and VD/VT and an increase in PaO₂. In older subjects at rest and during exercise, the PaO₂ was lower and PaCO₂ and the VD/VT higher than the in younger subjects (table 2). The upper or lower 95% confidence limits in exercise are shown in table 3.

Conclusions

This is the first study with a large sample of adults of both genders and different ages which establishes reference values of the arterial blood gas and gas exchange variables in exercise in Bogotá, a city located at a high altitude. As expected, the PaO₂ and the PaCO₂ at rest and exercise were lower than at sea level. The limits of normality of the P(A-a)O₂, VD/VT and VE/VCO₂ were lower than those suggested by the ATS. These results are useful for the interpretation of the CPET in Bogotá and other cities at a similar altitude.