Acta Andina (1996) 5:19-22

Vol. 5. N°.1
Printed in Perú

PHYSIOLOGICAL CHANGES RELATED TO RAPID ALTITUDE SHIFTS IN LA PAZ, BOLIVIA

TRIPLETT, JC., ZUBIETA-CALLEJA, L., ZUBIETA-CASTILLO, G., AND ZUBIETA-CALLEJA, GR.

High Altitude Pathology Institute (IPPA). La Paz, Bolivia

ABSTRACT

Due to the bowl shaped topography of La Paz, Bolivia ,the residents of the city are constantly changing altitude from 3100 meters, in a common residential area to 4100 m at El Alto, an upper industrial city and airport area. In order to access cardio-respiratory alterations occurring with rapid altitude changes, 15 soldiers [average age = 19 years, Weight = 59.07 Kg., Height = 165 cm], residents of El Alto (4000 m), were examined in a mobil unit equipped with a computerized cardio-ventilatory apparatus. Following calibration of the ventilatory apparatus, and after 15 minutes of rest, over the next 6 hours, subjects were connected via mouthpiece to a one way flow valve for 15 minutes. Expired gas was collected in Douglas bags. The electrocardiogram was monitored with 3 standard chest leads. Finger oximetry was recorded. Blood was drawn for arterial gases analysis. These were analyzed at 3600m with a Radiometer Blood Gas MK2 pH. The same procedure was repeated the next day on descent to the forest of Aranjuez (3100 m). Saturation rose from 87.8 ± 2.83% to 91.47 ± 1.40% ($p < .001$). Heart rate changed from 72.5 ± 10.2 to 68.3 ± 7.9 ($p < .05$) beats per minute. Alveolar ventilation (BTPS) diminished from 7,117 ± 1,232 ml to 6,197 ± 844 ml ($p < .05$). Oxygen consumption greatly increased from 172 ± 30 to 300 ± 42 ml/min ($p < .001$). Carbon dioxide production did not change significantly 266 ± 43.23 to 245 ± 32 ml/min. The respiratory Quotient diminished from 1.5 to 0.8 Arterial partial oxygen tension (PaO_2) increased from 54 ± 2.79 to 64 ± 6.33 mmHg ($p < .001$). $PaCO_2$ changed from 33 ± 2.2 to 34 ± 1.57 ($p < .05$). The pH decreased from 7.434 ± 0.026 to 7.381 ±0.335 ($p < .001$). This research demonstrates that when patients are analyzed in a cardio-pulmonary laboratory after they descend or ascend to it, the change in altitude must be considered in interpretation of results. Rapid altitude shifts in La Paz, force residents to constantly adapt, producing respiaratory acidosis on descent within the city. **(Acta Andina 1996, 5:19-22)**

RESUMEN

Debido a la topografía montañosa de la ciudad de La Paz, Bolivia, sus residentes están constantemente cambiando de altura trasladándose entre los 3100 m de la zona residencial a los 4100 m en el Alto y el aeropuerto. Para valorar las alteraciones cardio-respiratorias que ocurren debido a estos cambios, 15 soldados (edad promedio = 19 años, peso = 59.07 Kg., Talla = 165 cm), residents de El Alto (4000 m), se examinaron en una unidad móvil equipada con aparatos computarizados. Después de la calibración del equipo respiratorio, los sujetos previo reposo de 15 minutos fueron conectados mediante una válvula bucal unidireccional durante 15 minutos, cada uno. El gas expirado fue recolectado en bolsas de Douglas y el electrocardiograma fue monitorizado con 3 derivaciones precordiales standard. Fue registrada la oximetría de dedo y se tomaron muestras de gases en sangre arterial, éstas fueron analizadas en nuestro laboratorio a 3600 m con un Radiometer Blood MK2 pH. El mismo procedimiento fue repetido al día siguiente inmediatamente despúes del descenso al bosque de Aranjuez (3100 m). La saturación de oxígeno se elevó de 87.8 ± 2.83 a 91.47 ± 1.40 ($p < .001$). La frecuencia cardiaca cambió de 72.5 ± 10.2 a 68.3 ± 7.9 ($p < .05$). La ventilación alveolar (BTPS) disminuyó de 7,117 ± 1,232 ml a 6,197 ± 844 ml ($p < .5$). El consumo de oxígeno se incrementó significativamente de 172 ±30 a 300 ± 42 ml/min ($p < .001$). La producción de anhidrido carbónico no cambió significativamente de 266 ± 43.23 a 245 ± 32 ml/min. El cociente respiratorio disminuyó de 1.5 a 0.8. La presión parcial arterial de oxígeno (PaO_2) aumentó de 54 ± 2.79 a 64 ± 6.33 mm Hg ($p < .001$). La $PaCO_2$ cambió de 33 ± 2.2 a 34 ± 1.57 ($p < .05$). El pH disminuyó de 7.434 ± 0.026 a 7.381 ± 0.335 ($p < .001$). Esta investigación demuestra que cuando los pacientes son analizados en un laboratorio cardio-pulmonar despúes de descender o ascender a la misma altura, el cambio de altura debe tomarse en cuenta en la interpretación de los resultados. Los cambios de altura bruscos y constantes en la ciudad de La paz, obliga a sus residentes a adaptarse constantemente, produciendo acidosis respiratoria al descender. **(Acta Andina 1996, 5:19-22)**

There are related to acute exposure to hypoxia of high altitude many study published in the literature [6,5,2]. Studies at fixed points of altitude of permanent high altitude residents have also been performed [3,4]. However, high altitude shifts of normal highland residents have not been studied. Nearly to 1 million inhabitants of high altitude in the city of La Paz (3600 m), have adapted to the altitude and varying topography constructing their residences and places of work at altitudes varying from 3100 to 4100 m. Some live in the residential areas in the lower part of the city and work in the higher part of the city then, they experience up to 1000m of altitude shifts daily and sometimes four times a day since the habit of going home for lunch persists. In order to observe the physiological changes that constant altitude shifts at high altitude impose on healthy humans, cardio-respiartory studies were performed at both altitudes.

Corresponding author:
John C. Triplett IPPA La Clinica del Instituto de Patologia en la Altura Av. Saavedra 2302 Casilla 2852 La Paz, Bolivia
Tel: 591-2-430251
Fax: 591-2-357159
E-mail: zubieta@oxygen.bo

Methods and Materials

A mobil camper-truck was equipped with computerized cardio-respiratory equipment. A Puritan-Bennett model REMAC adapted through an analog digital converter to a PC was used to measure ventilation during 15 minutes, through a mouthpiece one-way flow valve constructed in our laboratory with a noseclip. After 1/2 hour warm-up, calibration was made with a 3 liter syringe. Barometric pressure was taken from the military airport located at the First Brigade of the Bolivian Air Force in the Alto at 4005 m. with a barometric pressure (PB) of 478 mmHg. Fifteen soldiers with age (19 years ± 1.55 S.D), height of 165 cm ± 6.46 and weight 59.07 Kg. ± 7.42, were observed following 15 minutes of rest. Expired gas was collected during 15 minutes of ventilation in Douglas bags and later after being appropriately mixed by flushing a disposable 60 cc plastic syringe, a sample was collected in this syringe. We had previously checked that these syringes were able to adequately store expired samples for days. Simultaneously; ECG monitoring was completed with 3 standard chest leads hooked-up to the same computer. Earlobe oximetry was performed with a portable NONIN oximeter Model 8500. Arterial blood samples were taken from either the radial or humeral artery while the subjects were lying down. The observations were done during a 6 hour span. Blood gases and expired gases were analyzed in our laboratory at 3500 m in the PhmK2 Acid-Base analyzer of Radiometer, properly calibrated according to manufacturer`s recommendations. The following day the same procedure was repeated in the same group of soldiers on descent to the bosque of Aranjuez (3100 m).

Statistical analyses was performed calculating averages and standard deviations in a PC with the software statpro and probability was calculated using paired and non-paired student's test.

Results

Table 1 shows the average and standard deviation of heart rate, blood pressure and ventilation values at both altitudes.

Alveolar ventilation (VA) was calculated from $VA = VCO_2/PACO_2 * 0.863$, where VCO_2 = Carbon dioxide production. Tidal Volume (Vt) from VE/RR where VE = Expired ventilation/min and RR = respiratory rate. Dead space volume (VDS) was derived from Bohr's equation. Fifteen soldiers were observed and any observation with systematicerrors were left out and hence the number of observations (n) varies.

		HR	BP Syst	BP Diast	RR	VE	VA	Vt	VDS
		/min	mmHg	mmHg	/min	ml/min	ml/min	ml	ml
EL ALTO	n =	15	15	15	15	15	14	15	14
4005 m	X =	72.47	106.0	66.4	18.9	12944.8	7117.6	689.6	309.8
Pb = 471 mmHg	SD =	10.18	13.55	9.64	3.73	2607.08	1323.53	97.03	58.77
ARANJUEZ	n =	15	15	15	15	15	11	11	11
3140 m	X =	68.33	103.5	66.8	17.2	13031.7	6192.8	771.6	416.8
Pb = 524 mmHg	SD =	7.90	9.87	6.87	3.49	2116.72	885.33	110.12	56.17
	p	<.05	NS	NS	<.05	NS	<.1	<.01	NS

Table 1. Heart rate, blood pressure and ventilation changes in both altitudes. HR = heart rate, BP Syst = systolic blood pressure, BP Diast = diastolic blood pressure, RR=Respiratory rate, VE=Expired ventilation (BTPS), VA=Alveolar ventilation (BTPS), Vt=Tidal volume, VDS=Deadspace.

								STPD		
		SAT	pH	PaCO2	PaO2	PEO2	PECO2	VO2	VCO2	RQ
		%		mmHg	mmHg	mmHg	mmHg	ml/min	ml/min	
EL ALTO	n =	15	14	14	14	15	15	14	14	14
4005 m	X =	87.8	7.434	32.5	54	77	17.9	172.5	266.2	1.56
Pb = 471 mmHg	SD =	2.83	0.026	2.20	2.79	2.25	1.95	30.59	43.23	0.16
ARANJUEZ	n =	15	11	11	11	14	14	11	11	11
3140 m	X =	91.5	7.382	34.2	64	79	16.4	300.7	245.4	0.82
Pb = 524 mmHg	SD =	1.41	0.034	1.57	6.33	2.94	1.76	42.22	32.52	0.06
	p	<.001	<.001	<.05	<.001	NS	NS	<.001	NS	<.001

Table 2. Ventilatory and blood gases changes in both altitudes. SAT= Oxygen saturation, PaCO2 =Arterial carbon dioxide partial pressure, PaO2 Arterial oxygen partial pressure, PEO2 = Expired gas oxygen partial pressure, PECO2 = Expired gas carbon dioxide partial pressure, VO2 = Oxygen consumption, VCO2 = Carbon dioxide production, RQ=respiratory quotient.

Table 2 shows the average and standard deviation of the respiratory parameters and blood gases. Carbon dioxide production (VCO_2) was calculated from VE * $FECO_2$, where $FECO_2$ = Fractional expired carbon dioxide. Oxygen consumtion on (VO_2) was derived from the classic oxygenconsumption equation.

Discussion

Previous studies of normal values of residents in La Paz, have been made considering the city of LaPaz as one point and relating its values to sea level or mountain regions near La Paz [1]. To our knowledge, no studies have been made in normal residents within the same city acutely exposed to altitude shifts. La Paz residents are constantly adapting and shifting to a relative environment of hyperoxia or hypoxia. The city's paved roads permit the ascent of close to 1000 m in 1/2 hour. The airport is located at the higher part of the city at 4050 m.

We found that the heart rate change from 72 to 68 was significant at the .05 level. VE,VA and VDS did not change, however changes in Vt and RR were significant at the .01 and .05 level, respectively. Arterial oxygen tension (PaO_2) and carbon dioxide tension ($PaCO_2$) and Oxygen saturation (%SAT) increased significantly, as expected. The decrease in ventilation upon going lower was confirmed. However the most important observation in our study dealt with VO_2. It is striking to observe a low

Air Force base (4005 m) altitude for these soldiers, and correspondingly the respiratory quotient was quite high (1.56). It seems that at this permanent altitude people consume less oxygen. Their physical capabilities, were not measured in this report, but are known to be excellent because as a military group they are constantly involved in conditioning exercise. On descent, their VO_2 increased significantly ($p < .001$) to 300 ml/min, although their VA diminished, and they maintained a similar VCO_2 and therefore lowered the RQ to 0.82. Finally the pH diminished significantly from 7.434 to 7.382 ($p < .001$). This is the opposite reaction for man on rapid ascent, where respiratory alkalosis develops because respiratory adaptationis inmediate but metabolic adaptation takes several days.

The same phenomenon is observed in this study, although inverse i.e. respiratory acidosis is produced by going down 1000 meters. This implies that the inhabitants of La Paz are permanently changing from respiratory alkalosis to respiratory acidosis, and viceversa. It is surprising to many visitors, that such a large population could have settled at this altitude. This observation should be taken into consideration when we draw blood for gas analysis in patients if they happen to come from the higher or lower parts of the city. Although they should adapt to the PO_2 of the altitude of the lab, the pH value may tend towards a respiratory acidosis or alkalosis.

References

1.-**Cudkcowicz L., Spielvogel H. and Zubieta G.** (1972) Respiratory studies in women at high altitude (3,600 m or 12,200 ft and 5,200 m or 17,200 ft). Respiration; 29: 393-426.

2.-**Kayser B.**(1994) Factors Limiting Exercise Performance in man at high altitude. Ph. D. Thesis. University de Geneve Press.

3.-**Leon-Velarde F. y Arregui A.**(1993) Hipoxia:Investigaciones Basicas y Clinicas. IFEA-UPCH, Lima, Peru.

4.-**Medicina de la Altura**. Actas del quinto congreso nacional de medicina de la altura. (1992). Consejo Nacional de Ciencia y Tecnologia, Lima, Peru.

5.-**Ward, M.P., Milledge J.S. and West J.B.**(1989) High Altitude Medicine and Physiology. University of Pennsylvania Press.

6.-**West J.B.**(1984) High living: lessons from extreme altitude.Am.Rev.Respir.Dis; 130: 917-923.