

Effects of Altitude on Anthropometric and Physiological Patterns in Aymara and Non-Aymara Population Between 18 and 65 Years in the Province of Parinacota Chile (3.700 masl)

Efectos de la Altura Sobre Patrones Antropométricos y Fisiológicos en Población Aymará y no Aymará entre 18 y 65 Años de la Provincia de Parinacota, Chile (3.700 msnm)

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ESPINOZA-NAVARRO, O.; DIAZ, J.; RODRÍGUEZ, H. & MORENO, A. Effects of altitude on anthropometric and physiological patterns in Aymara and non-Aymara population between 18 and 65 years in the province of Parinacota Chile (3700 m). *Int. J. Morphol.*, 29(1):34-40, 2011.

SUMMARY: The aim of the study was to compare anthropometric and physiological patterns in a sample of 522 Aymara and non-Aymara individuals from Parinacota, Chile (3.700m). After signing voluntary informed consent forms, the residents were separated in two age groups. Groups A: 18 to 35 years, and Group B: 36 to 65 years, by sex and Aymara and non-Aymara ethnicity. The results of this study determined that anthropometric anteroposterior diameter (DAP) are higher in Aymara population. Biacromial diameter (DBA) is significantly lower in the Aymara population. Aymara males between 18 and 35 years are smaller than non-Aymara males. Aymara women had significantly lower heart rates. The respiratory rate is significantly lower in Aymara males and females from 18 to 35 years. Partial oxygen saturation (SaO₂) is higher in Aymara women, compared with non-Aymara women. The body mass index (BMI) did not differ within each group according to age, however, in comparison between groups, older individuals independent of sex and ethnicity have index of overweight and obesity. In forced vital capacity (FVC), there is no difference in ages however, while comparing between ages, older populations independent of sex and ethnicity presented significant decreases in this parameter. This may reflect mechanisms of adaptation to the high altitude of Aymara native populations living in the Andes.

KEY WORDS: Aymara; Altitude; Anthropometry; Physiological patterns.

INTRODUCTION

The altitude environment is usually associated to extreme climates of very low temperatures, scarce relative humidity, high levels of radiation and hypoxia, common of low atmospheric pressure. Nearly 30 million people live above 2.500 meter above sea level (masl) in the Cordillera de los Andes, of these 5,5 million correspond to the Aymara ethnic group with their own language and culture, and who live in the high planes of Bolivia, Peru and North of Chile in altitudes of up to 4.400 (masl) (Stuber & Scherrer, 2010).

Age and genetics are important to determine the survival and quality of life at high altitude. For approximately 12,000 years this population has lived in the Andes allowing sufficient time for the adaptation to altitude (Gonzales, 2007).

The Chilean Aymara population concentrates in the Northern area of the foothills and highlands belt with a population density of 48,477 individuals. The Parinacota Province encompasses a total extension of 8146 km² and a total population of 3156 inhabitants, 60% corresponds to the Aymara population (National Institute for Statistics, INE, 2005).

In the Andean populations the mapping common to these areas are an added stressor to the altitude condition determining the isolation of the population.

Studies show that the anthropological characteristics of these populations are related to the adaptation process to extreme environments. Specifically, low birth weight are

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Financed by Universidad de Tarapacá, Chile, Grant UTA N° 4710-11

reported, as well as slow and prolonged growth which translates to lower height at an adult age (Lomaglio *et al.*, 2005; Espinoza-Navarro *et al.*, 2009; Julian *et al.*, 2009).

Some authors determine that hypoxia would be directly responsible for these changes, while others attribute this to energetic-nutritional factors (Harris *et al.*, 2001; Moreno *et al.*, 2006).

A study of the Chilean Aymara population realized by Dittmar (1997), found that anthropometry of these Aymara is characterized the large corporal mass in relation to height, with relatively short inferior member with respect to the trunk. This population presents good nutrition and is apparently healthy. While comparing this population with population at sea level, shows they have less weight and height, but are larger and heavier than other Aymara populations of the study. These inter ethnic differences in linear growth could be attributed to improved nutritional factors.

Pawson *et al.* (2001), in comparing Peruvian population height of different socio-economic levels, found that bad nutrition is a key factor in the anthropometric changes in weight, size, body mass index and thorax diameter. The studies of Harris *et al.* (2001), determine that the growth retardation is not associated with altitude, rather with nutritional factors.

Other alterations common to height refer to the changes in physiological patterns. Acute hypoxic ventilatory response is another adaptation mechanism of hypoxia. Individuals who live in altitudes have a substantial advantage in better use of the availability of oxygen for an increase in residual volume, and increase in vital capacity (Rupert & Hochachka, 2001; Terblanche *et al.*, 2005).

Other studies determine that the development, genetic and intra-individual factors would influence in a successful adaptation of height of the cardio-respiratory components (Greksa, 2006).

The aim of this study was to compare anthropometric and physiological patterns in a sample of 522 Aymara and non-Aymara individuals, separated in two age groups of 18 to 35 years, and 36 to 65 years, in the Parinacota Province who live at 3700 (masl).

MATERIAL AND METHOD

The sample population was of 535 individuals, of

which 13 subject were excluded for showing tobacco addiction and a history of chronic respiratory illnesses.

The criteria used to include 522 residents having lived in the Province for at least five years. This study was approved by the Committee on Ethics of the Universidad de Tarapacá. After signing the informed voluntary consent form, participants were separated in two age groups, according to age, ethnicity and sex. Group A: young individuals from 18 to 35 years of age; Group B: adults of 36 to 65 years of age.

Constituting part of the Aymara ethnicity was determined by the use of last names, widely used in genetic populations (Schull & Rothhammer, 1977).

Measure and anthropometric variables registration. Measure of weight and size was carried out with a stadiometer with incorporate bascule (fitness, model D-339.2; USA).

The biacromial diameter and anteroposterior diameter of the thorax was obtained using anthropometric kit (FAGA-SRL; USA).

Body mass index was calculated by the formula of weight divided by square height (P/A^2), classifying them in: emaciated, normal, overweight and obese (WHO, 1999).

Measure and registration of physiological variables. Cardiac frequency and partial oxygen saturation, were measured with a pulse oxymeter (Masimo RAD-V5; UK). The sensor was placed on the distal extreme of the annularis digitus.

Measure of physiological patterns. Respiratory frequency was registered in direct form by observation of the evaluator, expressed in terms of breaths per minute.

The forced vital capacity expressed in liters per minute, was realized through the electronic spirometer (Vitalograph – 6800; US) according recommendations by Meyer *et al.* (2003).

The results obtained were registered and analyzed statistically, inside the groups by ages, for the purpose analysis of variance and post-hoc test of Tukey ($p \leq 0.05$), was used, while between ages confidence intervals were constructed ($p \leq 0.05$) for comparison by age pairs in relation to the variable to be compared. The SPSS 14.0 (2006), program was used with a significance value of $p \leq 0.05$.

RESULTS

The results observed in Tables I, II (within ages) and Table III (between ages).

Table I demonstrates results in the age group A: between 18 and 35 years of age (n=315). It is observed that the anteroposterior diameter of the thorax, in Aymara females as well as males are significantly higher than in non-Aymara females and males. The biacromial diameter is significantly less only in Aymara men. The Aymara men are additionally significantly smaller in corporal height than the non-Aymara men 1.57m and 1.63m respectively ($p \leq 0.05$). The women do not demonstrate size difference. The body mass index shows no significant differences between the male population in the study, with slight overweight index. The Aymara women present normal index (24.1) and the non-Aymara slight overweight (25,0).

The cardiac frequency is significantly less in Aymara women (85 beats/min) with respect to the non-Aymara (94 beats/min). Respiratory frequency in the Aymara ethnicity is significantly lower with respect to the non Aymara population. The partial oxygen saturation, presents no significance between the male Aymara population and the non Aymara. However in the Aymara women the values are significantly higher with respect to non Aymara women (89.9 and 85.9 respectively). The forced vital capacity does not

show significance according to ethnicity and sex in this population in the study.

Table II shows the results of group B: the ages from 36 to 65 years (n=207). It is observed that the anteroposterior diameter of the thorax in Aymara women as well as men present a significant increase with respect to non Aymara population at high altitude. With respect to the biacromial diameter the men present a significant decrease with respect to non Aymara men. The women do not present significant differences between each other. The Aymara men present a significantly lower height within relation to the non Aymara men (1.56 m and 1.63 m respectively, ($p \leq 0.05$)). The body mass index does not present significant differences between the population in the study, according to ethnicity and sex. However they all presented indexes of overweight, furthermore the Aymara women of this age group, presented levels of obesity.

Cardiac frequency is significantly lower in Aymara women, no significant difference was observed in men. The respiratory frequency in these women also presents a significant decrease (18/min and 21/min respectively).

The partial oxygen saturation is significantly greater in the Aymara women in comparison to non Aymara women. The total population in the study in this age group does not present differences as far as Forced Vital Capacity.

Table I. Changes in morphological and physiological patterns according to sex and ethnicity, in subjects between 18 and 35 years of age (group A).

Age Group A	18-35 years			
	Aymara		Non-Aymara	
Origin	Male	Female	Male	Female
Sex				
N	92	94	58	71
Total	315			
Anthropometry				
ADT (cm)	19.6*	14.6*	16.4	13.2
BAD (cm)	33.5*	20.5	36.5	20.9
Size (m)	1.57*	1.54	1.63	1.56
Weight (kg)	62.9	57	67.7	60.8
BMI (k/m ²)	25.5	24.1	25.5	25
Physiological				
CF (x/min)	81	85*	86	94
RF (x/min)	19*	19*	21	23
O ₂ sa (%)	88.6	89.9*	87.4	85.9
FVC (l/min)	3.1	3.3	2.9	3.3

Table II. Changes in morphological and physiological patterns according to sex and ethnicity, in subjects between 36 and 65 years of age (group B).

Age Group B	36-65 years			
	Aymara		Non-Aymara	
Origin	Male	Female	Male	Female
Sex				
N	58	66	46	37
Total	207			
Anthropometry				
ADT (cm)	19.8*	15.6*	16.4	13.7
BAD (cm)	35.2*	21.3	38.4	21.1
Size (m)	1.56*	1.5	1.63	1.56
Weight (kg)	72.4	68.1	71.1	67
BMI (k/m ²)	27.3	30.3	29.2	27.5
Physiological				
CF (x/min)	76	81*	76	91
RF (x/min)	18*	18*	18	21
O ₂ Sa (%)	87.8	88.1*	87.8	85.4
FVC (l/min)	2.6	2.8	2.6	2.6

Table III indicates the differentials obtained between both age groups in the study. In the anthropometric patterns it is observed that the anteroposterior diameter of the thorax of Aymara women in the group between 36 to 65 years, present an increase with respect to the first group of younger women, with a differential of 1.1 ($p \leq 0.05$). The biacromial diameter in the older age group in women as well as men of the Aymara ethnicity presented a significant differential increase. While in the non Aymara population no changes were observed between the two age groups.

There are no significant differences found between

both populations with respect to size of individuals. The differentials according to corporal weight show a significant increase in the older age individuals, in Aymara and non Aymara women as well as men. This is expressed in an increase of body mass index and are classified as overweight and obese (25 – 29,9 and ≥ 30 respectively).

In physiological patterns, cardiac frequency presents a decrease in the older age group, being significant in Aymara as well as non Aymara men (differentials of 5.13 and 10.0 respectively). The respiratory frequency shows a decrease in all individuals in group B, according to ethnicity and sex.

Table III. Differences obtained in both populations in the study according to age, sex.

Origin	Aymara		Non-Aymara	
	Male	Female	Male	Female
Sex				
N	522	160	104	108
Anthropometry				
ADT (cm)	0.16	1.1*	0	0.43
BAD (cm)	1.75*	0.84*	1.92	0.24
Size (m)	0.01	0.05	0	0
Weight (kg)	9.58	11.07*	337	6.22*
Physiological				
CF (x/min)	5.13	3.78	10.0*	30
RF (x/min)	1.0*	1.1*	29*	2.10*
O ₂ Sa (%)	0.85	1.75*	0.38	0.46
FVC (l/min)	0.48	0.52	0.3	0.67

The older age Aymara women present a significant decrease in the partial saturation of oxygen, with a differential of 1,75 ($p \leq 0.05$). The forced vital capacity presents significant differentials that are lower in the older age groups, indicating that at an older age the vital capacity decreases independent of sex and ethnicity.

DISCUSSION

This study was carried out in the Province of Parinacota, compares the results obtained from these residents by suggesting possible human adaptations, morphological and physiological in Aymara and non Aymara populations that live at high altitude and inhabit the Chilean Andean high planes (Dittmar, 1997; Gonzales, 2007; Espinoza-Navarro *et al.*, 2009; Stuber & Scherrer, 2010).

Anthropometric variables. The results obtained for weight and size, show that these indexes are reduced in the Aymara population with respect to their non Aymara peers ($p \leq 0.05$), similar to findings by other authors, who determined that these differences could be influenced by nutritional conditions and low temperatures common to high elevation regions (Greksa, 2006; Moreno *et al.*, 2006; Julian *et al.*, 2009). These differences are not reflected in the BMI, in which the total population in the study, Aymara and non Aymara is at overweight levels, excepting the Aymara women from 18 to 35 years, who present normal weight indexes.

In reference to the thoracic morphology the Aymara present a significant increase of the anteroposterior diameter of the thorax, with respect to non Aymara residents ($p \leq 0.05$). It has been suggested that this characteristics one of the main adaptations of the populations at high altitudes (Hurtado, 1932; Fiori *et al.*, 2000; Harris *et al.*, 2001). The biacromial diameter presents a significant decrease only in the Aymara male population of both age groups.

Physiological Variables. The Aymara population in the study present significantly lower cardiac frequency and respiratory frequency, significantly less in comparison to non Aymara residents in both study groups.

The partial oxygen saturation shows a tendency of being greater in the Aymara population. However, this is only significant in the Aymara women in comparison with non Aymara women in both age groups. The forced vital capacity, does not show significant differences within each of the study groups by sex and Aymara ethnicity. These

values could reflect an adaptive mechanism of the cardio respiratory system in the Aymara population and other populations living at high altitudes related with the historical occupation of the highlands (Frisancho, 1999; Kapoor & Kapoor, 2005; Greksa, 2006; Aldenderfer, 2006).

In comparing the anthropometric differentials between both groups in the study (Table III), it is noted that there are no great variations in the size of the thorax, excepting the Aymara older age women who present a significant increase of anteroposterior diameter of the thorax. The diacromial diameter presents a significant increase in the older age Aymara population, noting no changes in the non Aymara population. The size of individuals does not indicate changes between the two study groups by ethnicity and sex, however, body weight presents a significant increase in the total population of the study, which causes the older age population to be classified with a body mass index of overweight and obesity. The physiological differences (Table III), shows that cardiac frequency and respiratory frequency tend to decrease in the older age groups, particularly in men of both populations. These results are similar to those found by Greksa (2006) and Beall (2007), who determine that development, the genetic and time of colonization are influential factors in the components of cardiorespiratory adaptation at high altitude although the relative importance of each is still not clear.

The partial oxygen saturation presents a significant increase in Aymara women in relation to the non Aymara women in both study groups. However the Aymara women in the group between 18 to 35 years, present percentages of partial oxygen saturation that are more elevated with respect to the older age Aymara women. This could possibly be a genetic adaptive mechanism, by which the descent of great altitude protects fetal growth and greater survival of the offspring (Beall, 2007; Julian *et al.*, 2009).

The forced vital capacity indicates a significant decrease in the Aymara and non Aymara older age populations. These anthropometric and physiological differentials note that high altitude populations have a substantial advantage in taking better advantage of the oxygen and the development, genetic, nutrition and intra individual factors are influential for an improved adaptation of the altitude condition, whether it is in the Aymara or the non Aymara population. However the Aymara population in view of its history and endurance at high altitudes is more adapted to a better quality of life in altitudes with respect to the non Aymara population (Rupert & Hochachka, 2001); Greksa, 2006; Gonzales, 2007).

CONCLUSIONS

The results obtained in both study groups allow the conclusion that the individuals of Aymara origin present a greater anteroposterior diameter of the thorax than the non Aymara population. The Aymara men regardless of age, are of smaller size than the non Aymara men. The body mass index does not present difference within each group according to age, however, between groups, older age individuals regardless of sex and ethnicity present indexes of overweight and obesity.

The cardiac frequency and respiratory frequency present a tendency to decrease within the Aymara population

in each group. Among the study groups, this decrease is very significant in the older age group, independent of ethnicity and sex.

The Aymara women present a greater partial oxygen saturation within the ages with respect to the non Aymara female population.

The forced vital capacity does not present differences within the ages, however, between ages, the older age populations independent of ethnicity and sex, present a significant decrease in this parameter.

ESPINOZA-NAVARRO, O.; DIAZ, J.; RODRÍGUEZ, H. & MORENO, A. Efectos de la altura sobre patrones antropométricos y fisiológicos en población Aymará y no Aymará entre 18 y 65 años de la Provincia de Parinacota, Chile (3.700 msnm). *Int. J. Morphol.*, 29(1):34-40, 2011.

RESUMEN: El objetivo de este estudio fue comparar patrones antropométricos y fisiológicos en una muestra de 522 individuos aymará y no aymará de la Provincia de Parinacota (3.700 msnm). Luego de la firma del consentimiento informado por los residentes se procedió a separar a los individuos en dos grupos etáreos: población de 18 a 35 años y de 36 a 65 años, según sexo y etnia aymará y no aymará. Los resultados de este estudio determinan que los patrones antropométricos de diámetro antero posterior del tórax son mayores en la población aymará. El diámetro biacromial, es significativamente menor en la población aymará. Los varones aymará de entre 18 a 35 años son de menor tamaño que los varones no aymará. Las mujeres aymará presentan una disminución significativa de la frecuencia cardiaca. La frecuencia respiratoria es significativamente menor en damas y varones aymará de 18 a 35 años. La saturación parcial del oxígeno es mayor en las damas aymará, respecto a mujeres no aymará. El índice de masa corporal no presenta diferencia dentro de cada grupo según edades, pero al comparar entre los grupos, los individuos de mayor edad independiente del sexo y la etnia presentan índice de sobrepeso y obesidad. La capacidad vital forzada, no presenta diferencias dentro de las edades, sin embargo al comparar entre las edades, las poblaciones de mayor edad independiente de la etnia y el sexo presentan disminuciones significativas de este parámetro. Esto posiblemente reflejaría mecanismos de adaptación a la altura de las poblaciones nativas aymará, que viven en los Andes.

KEY WORDS: Aymará; Altura; Antropometría; Patrones fisiológicos.

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Received: 22-10-2010
Accepted: 29-11-2010