HUMAN ADAPTABILITY IN A QUECHUA POPULATION OF THE PERUVIAN CENTRAL ANDES (HUANCAVELICA, 3680 m). RELATIONSHIPS BETWEEN FORCED VITAL CAPACITY, CHEST DIMENSIONS AND HEMOGLOBIN CONCENTRATION.

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RESUMEN: Adaptabilidad Humana en una Población Quechua de los Andes Peruanos Centrales (Huancavelica, 3680 m). Relaciones Entre Capacidad Vital Forzada, Dimensiones Torícicas y Concentración de Hemoqlobina

El estudio intenta brindar datos originales de una población Quechua de un área poco estudiada, los Andes Peruanos Centrales, y busca investigar las relaciones entre variables implicadas en la adaptabilidad humana a la altura. Se examinó una muestra de 77 varones adultos sanos no emparentados, nativos de la provincia de Huancavelica (3680 m). Se investigó las siguientes variables somatométricas y fisiométricas: talla, talla en posición sentada, ancho torácico, espesor torácico, circunferencias torácicas máxima, mínima y normal, capacidad vital forzada (FVC) y concentración de hemoglobina (Hb). Los valores de las variables examinadas son comparables a los de estudios previos de poblaciones Andinas de altura. La Hb y la edad no estuvieron correlacionadas. Para evaluar las relaciones entre las variables, se realizó análisis de regresión múltiple secuencial de la FVC y de las otras variables. Los resultados sugieren que la edad y la mecánica respiratoria, pero no las dimensiones torácicas, están fuertemente asociadas con la funcionalidad pulmonar.

Palabras claves: Adaptabilidad a la altura, Andes, Quechuas, Capacidad vital forzada, Hemoglobina, Antronometría

RÉSUMÉ: Adaptabilité humaine d'une population quechua des Andes centrales péruviennes (Huancavelica, 3 680 m). Relations entre la capacité vitale forcée, les dimensions thoraciques et la concentration d'hémoglobine.

Ce travail tente de fournir des données originales sur une population Quechua d'une région peu étudiée, les Andes centrales péruviennes, et recherche les relations entre les variables impliquées dans l'adaptabilité humaine à la haute altitude. Les 77 sujets d'un échantillon d'adultes masculins, sains et non apparentés, natifs de la province de Huancavelica (3 680 m) ont été examinés. Les variables somatométriques et physiométriques suivantes ont été mesurées : taille, taille en position assise, largeur et épaisseur du thorax, circonférences maximales, minimales et normales du thorax, capacité vitale forcée (FVC) et concentration d'hémoglobine. Les valeurs des variables examinées sont comparables à celles d'études préalables sur des populations andines de haute altitude. Il n'y a pas de corrélation entre l'hémoglobine et l'âge. Afin d'évaluer les relations entre les variables, une analyse de régression multiple séquentielle de la FVC sur les autres variables a été effectuée. Les résultats suggèrent que l'âge et la mécanique respiratoire, mais non les dimensions thoraciques, sont fortement associés à la fonctionnalité pulmonaire.

Mots-clés : Adaptabilité à la haute altitude, Andes, Quechuas, Capacité vitale forcée, Hémoglobine, Anthropométrie.

SUMMARY: The study aims to provide original data on a Quechua population from a less studied area, the Peruvian Central Andes, and to investigate the relationships between variables involved in human adaptability to high altitude. A sample of 77 healthy unrelated adult males, natives of the Province of Huancave}ica (3680 m), was examined. The following somatometric and physiometric variables were investigated: height, sitting height, weight, chest breadth, chest depth, maximum, minimum and normal chest circumferences, forced vital capacity (FVC) and hemoglobin concentration (Hb). Values of the examined variables are comparable to those from previous studies of Andean high altitude populations. Hb and age are not correlated. In order to evaluate the relationships between the variables, stepwise multiple regression analysis of FVC on the other variables was performed. Results suggest that age and respiratory mechanics, but not chest dimensions, are strongly associated with lung functionality.

Keywords: high altitude adaptability, Andes, Quechuas, forced vital capacity, hemoglobin, anthropometry

INTRODUCTION

Since Hurtado began the first systematic research on adaptations to high altitude at the population level (1,2), several studies have reported and analysed the differences between high and low altitude populations (3-20). These differences mainly regard anthropometric and physiometric variations concerning the uptake and transport of oxygen. Indeed these functions are the basis of adaptation to the hypoxic environment. The multiple factors that could explain the variability among high and low altitude populations are the subject of an active field of research for anthropologists and a prolific source of theoretical questions in adaptive biology. In the first studies, the differences between high and low altitude populations were attributed to an adaptive genetic component resulting from natural selection (1,18). Starting from the '70s, an alternative hypothesis based on biological plasticity replaced the predominant point of view. This hypothesis gives greater importance to the possibility of modelling adaptation during growth (6-8). Recent research has tried to quantify the genetic and developmental components of the adaptation to an hypoxic environment and has revealed the importance of both factors (21,22). Other studies have assessed the role of work activity (21,23) and of socio-econornic conditions in the determination of the detected variability among high altitude populations (2426).

Adaptation to high altitude implies the interaction of systems involved in the uptake, transport and delivery of oxygen. Thus it is appropriate to study the interactions between variables that are reliable indicators of the functionality of those systems. This approach is important because Frisancho et al. (5) have shown that particular stresses associated with environments such as high altitude or circumpolar areas could modify the relationships between morphometric and physiometric variables.

This study is part of a joint research program of the University of Bologna and Cayetano Heredia University of Lima, Peru. Besides human adaptability to high altitude, the research aims to study body composition and genetic variability, using surnames, classical markers and DNA polymorphisms, in the populations of the province of Huancavelica (3680 m), in the Peruvian Central Andes. A parallel collaboration with the Academy of Sciences of Kazakhstan will allow comparison of the results obtained in the Andean populations with those obtained in high altitude groups from Central Asia (19, 27-30).

In this paper, we present the first anthropometric and physiometric data obtained in the Quechua population from Huancavelica. The results are compared with those available for other Andean high altitude populations. The study aims to provide original data on a Quechua population from a less studied area, the Peruvian Central Andes. The relationships between lung function measured by forced vital capacity (FVC) and the other variables studied have also been analysed using stepwise multiple linear regression.

MATERIALS AND METHODS

The sample examined

The sample is composed of 77 healthy unrelated adult males, natives of the Province of Huancavelica. All the subjects belong to the Quechua ethnic group and are permanently resident in the area around the city of Huancavelica (3680 m), which is characterised by low rates of admixture with non-indigenous populations. 73% of the subjects are manual labourers (mainly farmers). The age distribution of the sample is shown in figure 1.

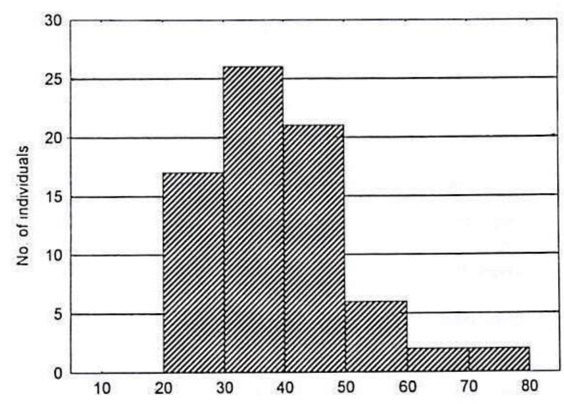

Figure 1 Age distribution ofthe Quechua sample from Huancavelica (3680m).

Variables considered in the study

Each subject was interviewed in order to assess his ethnic origin and his permanent residence in the high altitude environment. The following anthropometric and physiometric variables were measured: height, sitting height, weight, chest breadth, chest depth, maximum, minimum and normal chest circumferences, forced vital capacity (FVC), hemoglobin concentration (Hb). All the somatometric parameters were measured by the same investigator in October 1994 (E. T.S.), according to the recommendations of Weiner and Lourie (31) and Lohman et al. (32). The forced vital capacity (FVC) was measured with a Vitalograph-ALPHA spirometer. Every subject repeated the test twice and the best performance was recorded. The hemoglobin concentration was measured from a capillary blood sample with a portable Hemo-Flash Menarini spectrophotometer. Three readings of hemoglobin concentration were made and the mean value was recorded.

Statistical analysis

The following basic statistics were calculated for each variable: mean, standard deviation, coefficient of variation and Pearson's correlation coefficient with age and its level of significance. Means and standard deviations for subsamples (i.e. ten-year age classes) were also calculated. Stepwise multiple linear regression was used to analyse the relationships between FVC, a reliable indicator of lung functionality, and the anthropometric and physiometric measurements.

RESULTS AND DISCUSSION

Table 1 reports the basic statistical data for the considered variables. Figure 2 shows that the sitting height and weight of the Huancavelica Quechuas are similar to those reported for other Andean populations, while the mean height is lower. Indeed only the mean height of the 20-30 years class is similar to the values of other Andean populations.

	Total sample					20-29 years			30-39 years			40-49 years			>49 years		
	N	Mean	S.D.	r	p	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.	N	Mean	S.D.
Height (cm)	77	157.90	5.56	-0.30	0.010	17	160.19	6.58	26	157.50	5.07	·21	157.44	5.65	10	155.27	3.41
Sitting height (cm)	77	84.52	3.41	-0.30	0.010	17	85.01	4.04	26	84.80	3.38	21	84.52	2.73	10	82.47	3.43
Weight (K)	72	60.00	6.63	0.10	0.400	14	60.90	6.30	25	56.80	5.70	20	62.80	0.66	10	61.40	6.20
Chest breadth (cm)	77	26.07	1.72	0.12	0.300	17	20.15	1.05	26	19.80	1.17	21	21.07	1.11	10	22.24	1.98
Chest depth (cm)	77	20.52	1.53	0.47	<0.001	17	25.66	1.81	26	25.77	1.36	21	27.21	1.63	10	25.36	1.88
Max. chest circ. (cm)	77	96.23	4.15	0.12	0.310	17	96.18	4.39	26	94.66	3.36	21	98.54	3.79	10	96.19	4.92
Min. chest circ. (cm)	77	90.38	4.20	0.25	0.030	17	89.74	4.95	26	88.57	3.38	21	92.84	3.59	10	91.41	4.06
Normal chest. circ. (cm)	77	93.38	4.18	0.17	0.150	17	92.26	4.35	26	90.50	3.48	21	94.88	3.87	10	92.73	4.47
Forced vital capacity (FVC) (l)	77	4.82	0.91	-0.40	<0.001	17	5.12	0.83	26	5.04	0.79	21	4.66	0.87	10	4.02	0.91
Hemoglobin conc.(Hb) (g/dl)	77	17.53	1.93	-0.01	0.917	17	18.18	1.53	26	17.23	1.74	21	17.28	1.72	10	17.85	3.23

Table 1. Sample size (N), means and standard deviations (SD) in the total sample and in the four ageclasses. Pearson's correlation coefficients (r) with age and their significance levels (p) are reported for the total Quechua sample from Huancavelica (3680 m).

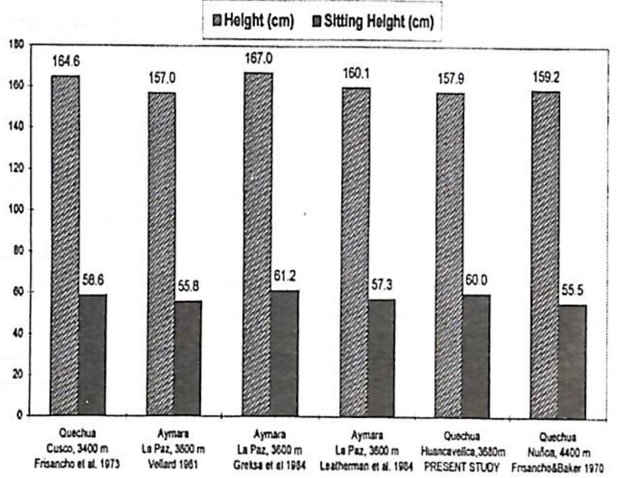

Figure 2 Mean values of height and sitting height in selected Andean populations.

In the Huancavelica sample, there are significant negative correlations with age of height and sitting height (table 1). These correlations could be explained either by the anatomical effects of ageing or by secular trend processes. Gonzales et al. (33) have reported a secular increase in stature in populations of the Peruvian Central Andes between 1937 and 1980, mainly displayed by a relative increase in lower limb length. This differential increase of body segment lengths should imply the diminution of the corrnic index with time and a positive correlation between cornnic index and age in a transversal sample. However neither feature is present in the Huancavelicans examined (r = -0.06, p= 0.618), which suggests the absence of secular trend in Huancavelica during the last few decades. Thus the negative correlation between age and height (r-0.30) could be a result of ageing processes. The negative correlation between age and sitting height (r=-0.30) strengthens this hypothesis since this variable is affected by two typical aging phenomena: the reduction of intervertebral spaces and the curvature of the vertebral column. The general worsening of socio-economic conditions in this area of Peru in recent decades is in accordance with the hypothesised absence of secular trend. The non-significance of the decrease in mean height with age reported in table 1 (p>0.10) is probably due to the small sample size.

Chest dimensions and FVC values of the Quechua population from Huancavelica are similar to those reported for other Andean native populations (figure 3 and 4). However, comparisons should be performed with caution and taking into account possible bias due to age composition, ethnicity and sample size. As concerns the age composition, our data can be compared with results obtained by Muller et al. (15) in Aymara populations from Northern Chile (fig. 5). FVC for each age class is higher in the Quechua sample from Huancavelica if compared with Aymara populations from Costa, Sierra (2500-3500 m) and Altiplano (4000-4500 m) (figure 3). The differences between the Peruvian Quechuas and the Chilean Aymaras are probably due to the high level of Caucasian admixture in the Aymara samples, rather than to the different altitude. In fact, in the Altiplano about 30% of the subjects are non Aymara (15) and the percentage of non Aymara individuals increases with decreasing altitude. As recently suggested by Greksa (22), a portion of variance of FVC values in Andean populations is due to a genetic component. This interpretation is consistent with the slight differences in lung volumes between Quechuas and Aymaras obtained by Greksa. (34)..

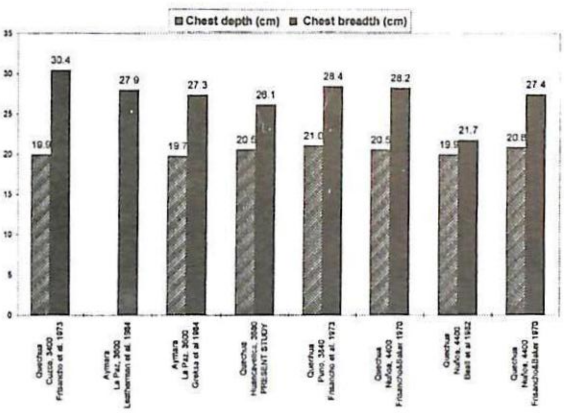

Figure 3 Mean values of chest depth and chest breadth.

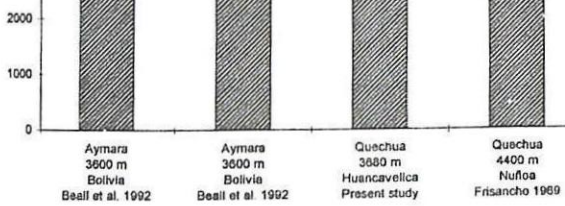

Figure 4 Forced vital capacity (FVC) in selected Andean populations.

The hematological response to high altitude in the Huancavelica sample was measured by hemoglobin concentration. The mean values are close to the values reported for rural Andean populations of comparable altitude (35-39) (Figure 6). There is no correlation between hemoglobin concentration and age, in agreement with results obtained in other rural high altitude populations (37,38,40).

Figure 6 illustrates the results of stepwise multiple linear regression of FVC on the other variables considered in this research. The maximum and minimum chest circumferences and age are the most important explanatory parameters of the lung function variability, as measured by FVC. The high values of the regression coefficient beta associated with maximum and minimum chest circumferences are expected (0.990 i 0.416, p=0.021 and -0.719 i 0.347, p=0.043 respectively). However, not all the chest dimensions are involved in the deterrnination of FVC: normal chest circumference and chest diameters show a low correlation with lung functionality (figure 5). This suggests that, in an adult sample, the parameters of respiratory mechanics, and not chest dimensions, are associated with the forced vital capacity. Frisancho (3) and Mueller et al. (15) have observed that, during growth, chest dimensions and age show the highest correlations with lung functionality, as measured by lung volumes. This relationship has been interpreted as an adaptive mechanism deterrnined by both genetic and developmental components. However, our data suggest that this relationship is not present during adulthood, when the variability of FVC is strongly associated with the ageing process and respiratory mechanics. but not with chest dimensions.

It is interesting to observe that hemoglobin concentration is negatively correlated with FVC. Beall and Goldstein (41) and Pettener et al. (19, 30) have found a similar relationship in Central Asian populations. Since hemoglobin concentration is neither negatively nor positively correlated with age in our sample, it is possible that the negative association with FVC is independent of the are in; process. Multivariate analysis applied to our data corroborates this.

In conclusion, the Quechua sample from Huancavelica is characterised by values for somatometric and physiometric variables that are comparable to those previously reported for Andean high altitude populations. The interactions of physiometric responses implicated in the adaptation to the hypoxic environment have been investigated. A clear negative association between FVC and age has been found, while there was no correlation between hemoglobin concentration and age. Finally, the negative correlation between FVC and hemoglobin concentration, which should be confirmed by further analyses, seems to be independent of age.

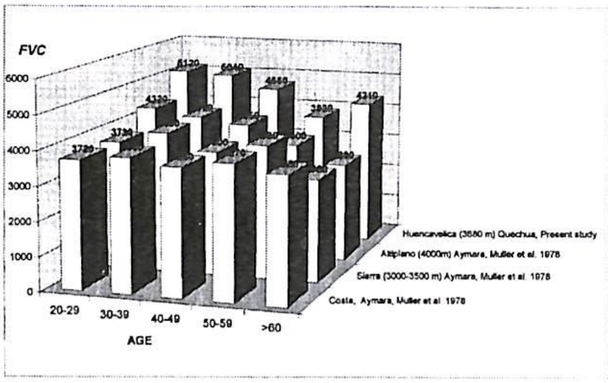

Figure 5 Forced vital capacity (FVC) by age classes in the Quechua sample from Huancavelica and in Aymara populations from Northern Chile.

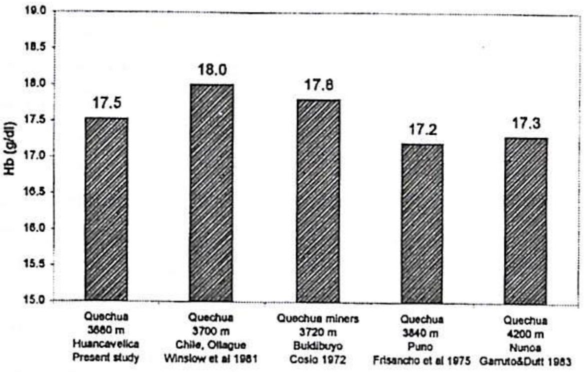

Figure 6 Hemoglobin concentration in selected rural Andean populations.

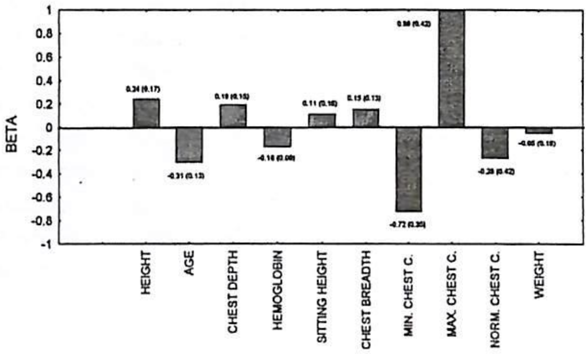

Figure 7 Stepwise multiple linear regression of FVC on the other exam~ined variables: standardised regression coefficients (beta) with standard errors in the Quechua population from Huancavelica.

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