



Original Article

Characteristics of age-related changes in blood pressure, oxyhemoglobin saturation, and physique in Bolivians residing at different altitudes: presentation of basic data for health promotion

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Abstract. [Purpose] To present basic data for a health promotion plan tailored to the body function of Bolivians residing in different municipalities and altitudes by investigating their blood pressure and oxyhemoglobin saturation. [Participants and Methods] The participants were 589 Bolivians residing in different altitudes who voluntarily participated in health promotion activities. We measured the blood pressure, peripheral capillary oxygen saturation, height, and weight, and calculated the body mass index. We divided the participants into two groups based on the altitude (valley and lowland) and the participants of each altitude group into six age brackets (every 10 years) to investigate the effect of age on each value. [Results] The altitude affected the systolic and diastolic blood pressure, oxyhemoglobin saturation, and height. All average values in the valley group were lower than those in the lowland group. There were significant effects in all variables based on age. The body mass index values were significantly higher in participants aged 45–64 years compared to those aged 18–34 years; the average value was 29. [Conclusion] An anti-obesity initiative for health promotion is needed to reduce the risk of health impairment in Bolivians, especially lifestyle-related diseases, such as type 2 diabetes mellitus, cardiovascular diseases, and stroke.

Key words: Altitude, Obesity, Bolivia

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INTRODUCTION

The Plurinational State of Bolivia is a landlocked country in South America surrounded by Peru, Brazil, Argentina, Paraguay, and Chile. Its land area is 1,098,600 km² and the total population is approximately 11.05 million¹⁾. Based on geographical features and altitude, Bolivia is divided into highlands (altitude 3,500 m or more), valleys (1,000–3,000 m), and plains (1,000 m or less). Approximately 40% of the total population lives in the highlands and about 30% in the valleys²⁾. Previous studies have shown that people who settle in valleys and highlands above 2,500 m in altitude are subject to various physical functions such as increased blood hemoglobin concentration, elevated hematocrit level, and decreased percutaneous arterial blood oxygen saturation due to the hypobaric and hypoxic environment³⁾. It has been reported that 10–15% of residents born and raised in the highlands may develop adaptive disorders such as high pulmonary hypertension and chronic high altitude sickness due to prolonged hypoxic exposure⁴⁾. Therefore, health management using indicators to evaluate the cardiovascular system is necessary. Owing to Bolivia's geographical diversity, it is important to plan prevention policies that account for the

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possible health problems in each region.

According to World Health Organization (WHO) data⁵, cardiovascular disease, cancers, and other non-communicable diseases account for an estimated 23%, 21%, and 21% of deaths, respectively. In recent years, the proportions of people developing heart disease, malignant tumors, diabetes, and so on owing to lifestyle habits are increasing. An increase in the obesity rate accompanying economic development has been reported in South American countries⁶. Therefore, weight control is important.

Looking at the current state of health and medical care in Bolivia, especially in rural areas, there are multiple problems such as a shortage of amenities and human resources at health care centers, poor-quality medical services, and the inaccessibility of facilities. Therefore, people consult a primary medical institution only once their symptoms have become glaring. A health and medical policy that enables citizens to receive regular annual medical checkups has not yet been instituted.

In summary, in order to develop preventive health interventions adapted to Bolivia's diverse geography, the physical functions and characteristics of local residents should be clarified.

The purpose of this study, therefore, is to present basic data for health promotion plans tailored for the body function of Bolivians living in municipalities at different altitudes by investigating blood pressure, oxyhemoglobin saturation (SpO₂), and physique.

PARTICIPANTS AND METHODS

The participants were 589 Bolivians (average age 46 years, SD ± 18 years, 209 males and 380 females) who voluntarily participated in health promotion events in Bolivia. Table 1 shows the number of participants, average age, and standard deviation for each location where the health promotion events were conducted. These health promotion events were organized by a medical subcommittee formed by Japan International Cooperation Agency volunteers who were assigned to Bolivia in the health, medical care, and welfare fields. Their purpose was to improve the health awareness and health education of local residents. Anyone in the area could participate in this activity for free. About public awareness to local residents, we called for participation using street posters, radio, and news from local TV stations about one week before the implementation date. The events were held in Colonia Okinawa (Warnes county, department of Santa Cruz de la Sierra), Punata (Punata county, department of Cochabamba), San Juan (Ichilo county, department of Santa Cruz), and Tupiza (Sud Chichas county, department of Potosí). The basic information for each region is depicted in Table 2. These regions are at a fair distance from urban districts (one to six hours by land), where prefectural government offices are located, but are accessible by automobile or bus. Also, public transport, such as taxis and minibuses, is available in each area. The supply of electricity, water, and gas is stable.

Blood pressure was measured with a digital sphygmomanometer (HEM-7113, OMRON Co., Ltd., Kyoto, Japan) and oxyhemoglobin saturation (SpO₂) was measured with a percutaneous arterial oxygen saturation measuring device (HM-OXYVISIONI, Hillusa Co., Ltd., Miami, USA and H100B, EDAN Co., Ltd., Shenzhen China) with the participant seated relaxed in a chair with a backrest. Height was measured with an original height meter made by attaching tape to a pillar placed perpendicular to the ground. Body weight was measured with a digital scale (WS-50, Microlife USA Inc., Florida, USA) while the clothed participant stood barefoot.

Table 1. Number of participants in each region, average age, and standard deviation

	Male	Female	Total	Average age ± SD
Okinawa	37	68	105	41 ± 16
Punata	53	103	156	39 ± 18
San Juan	41	63	104	53 ± 17
Tupiza	78	146	224	51 ± 16
Total	209	380	589	46 ± 18

Table 2. Outline of the regions where health promotion events were held

	Altitude (m)	Population	Average temperature (degrees Celsius)
Okinawa	252	12,482	24.1
Punata	2,750	28,887	16.0
San Juan	250	9,192	24.3
Tupiza	2,850	44,814	15.3

This table was created based on statistical data published by Instituto Nacional de Estadística¹⁸.

Okinawa, at an altitude of 252 m, and San Juan, at an altitude of 250 m, were classified into the lowland group. Punata, at an altitude of 2,750 m, and Tupiza, at an altitude of 2,850 m, were classified as the valley group. This was done to examine the influence of altitude. Furthermore, in order to investigate the effect of age on each value, the participants of each altitude group were divided into six age brackets: 18–24 (20s group), 25–34 (30s group), 35–44 (40s group), 45–55 (50s group), 55–64 (60s group), and over 65 (70s group). The overall data were analyzed by a two-way analysis of variance with systolic blood pressure (SBP), diastolic blood pressure (DBP), SpO₂, and body mass index (BMI) as dependent variables and altitude (lowland and valley) as the independent variable. Bonferroni correction was used for a post hoc test between levels for each factor. To investigate the relationship between BMI, SBP, DBP, and SpO₂, partial correlation coefficients of BMI and each value adjusted by age, sex, and altitude were calculated. IBM SPSS Statistics 23 (IBM Inc., USA) was used for all statistical analysis. Results were considered statistically significant if the p value was less than 0.05.

All study procedures were approved by the concerned institutional review board (approval number: 14-Io-161).

RESULTS

Table 3 shows all values (average and standard deviation) for each altitude and age bracket. A main effect of altitude was observed on SBP (F=15.5, p<0.05), DBP (F=19.0, p<0.05), SpO₂ (F=690.6, p<0.05), and height (F=12.3, p<0.05). All average values in the valley group were lower than that in the lowland group. In addition, another main effect of age bracket was observed on all values (SBP; F=17.3, DBP; F=19.0, SpO₂; F=12.0, height; F=3.8, body weight; F=6.3, BMI; F=11.2, p<0.05). As a result of comparing the differences between age brackets in each altitude group, in the valleys, the 60s and 70s age brackets showed significantly higher than the 20s age bracket. In the lowland group, the SBP values in the 60s and 70s age brackets were significantly higher than in the 20s and 30s age brackets.

A main effect of age bracket on BMI was observed (F=11.2, p<0.05) while no main effect of altitude was observed (F=0.04, p=0.83). Tables 4 and 5 show comparison of values among all age brackets in both valley and lowland groups. When comparing differences among age brackets in each altitude group, the BMI values of the 40s and 50s brackets were significantly higher than the 20s bracket in the lowlands. The BMI values of the 30s, 40s, 50s, and 60s brackets were significantly higher than the 20s bracket in the valleys.

The value of partial correlation coefficients between BMI and SBP adjusted by age, gender, and altitude was r=0.19 (p<0.05), showing a significant positive correlation.

DISCUSSION

The results of the statistical analysis demonstrated that the blood pressure value of the valley group was significantly lower than that of the lowland group, attributable to the altitude of residence. In this study, the blood pressure value was defined as a cardiovascular index that reflects arteriosclerosis. According to the results of the latest systematic review and meta-analysis investigating blood pressure values for adults aged 18 and older at altitudes more than 2,400 m, the SBP and DBP of the Andean population decline as altitude rises⁷. The cause of this result is hypothesized to be the relaxation of vascular smooth muscle by long-term hypoxic exposure, development of collateral circulation, development of peripheral vascular network^{8–10}, and a decreased cardiac output¹¹.

Table 3. Comparison between the lowland group and the valley group in each age bracket

Age brackets		All	20s	30s	40s	50s	60s	70s
Age (years)		All	18–24	25–34	35–44	45–54	55–64	65≤
SBP (mmHg)	Lowland	128.0 ± 22.5	112.3 ± 13.3	117.9 ± 20.4	128.0 ± 20.2	125.4 ± 14.6	133.0 ± 22.5	144.3 ± 24.4
	Valley	121.0 ± 16.0	116.3 ± 14.1	115.9 ± 15.7	118.2 ± 12.1	122.6 ± 16.5	125.9 ± 16.0	125.4 ± 17.7
DBP (mmHg)	Lowland	74.2 ± 11.4	66.9 ± 7.0	75.9 ± 10.7	75.9 ± 10.7	75.1 ± 10.0	76.3 ± 11.0	76.5 ± 12.9
	Valley	69.6 ± 10.3	66.2 ± 8.3	71.6 ± 8.6	71.6 ± 8.6	71.4 ± 11.5	71.4 ± 10.1	69.0 ± 11.1
SpO ₂ (%)	Lowland	96.5 ± 2.2	97.5 ± 1.4	97.4 ± 2.1	96.7 ± 2.1	96.5 ± 2.0	95.8 ± 2.4	95.2 ± 2.1
	Valley	91.7 ± 2.1	92.6 ± 1.9	92.2 ± 2.1	91.7 ± 1.8	91.4 ± 1.8	91.4 ± 2.4	91.0 ± 2.0
Height (cm)	Lowland	157.5 ± 8.6	159.0 ± 8.4	159.4 ± 7.4	158.2 ± 10.2	156.3 ± 7.4	153.9 ± 8.3	157.3 ± 9.5
	Valley	154.9 ± 8.0	158.0 ± 7.3	155.2 ± 7.7	155.0 ± 7.9	154.9 ± 7.4	152.6 ± 7.6	153.3 ± 8.8
Body mass (kg)	Lowland	69.0 ± 14.6	63.4 ± 16.2	70.1 ± 13.0	73.4 ± 15.1	71.2 ± 15.0	65.9 ± 14.4	67.1 ± 14.3
	Valley	66.1 ± 12.8	59.6 ± 10.5	64.3 ± 10.3	69.8 ± 12.8	71.6 ± 13.4	67.6 ± 14.5	65.3 ± 11.0
BMI (kg/m ²)	Lowland	27.8 ± 5.3	24.9 ± 4.7	27.6 ± 4.8	29.3 ± 5.5	29.3 ± 6.7	27.6 ± 4.1	27.0 ± 4.5
	Valley	27.6 ± 5.2	23.8 ± 3.4	26.6 ± 3.4	29.0 ± 4.6	29.9 ± 5.6	29.0 ± 5.7	27.9 ± 4.7

*Significant when comparing the lowlands with the valleys (Bonferroni method, p<0.05).

SBP: systolic blood pressure; DBP: diastolic blood pressure; SpO₂: oxyhemoglobin saturation; BMI: body mass index.

Table 4. Values in the lowland group

Group No.	Age brackets							Comparison among age brackets
	1	2	3	4	5	6		
Categorized age (years)	All	18–24	25–34	35–44	45–54	55–64	≥65	
n	209	20	45	34	39	25	46	
Age (years)	47 ± 18	21 ± 2	28 ± 3	40 ± 3	49 ± 5	59 ± 3	71 ± 5	
SBP (mmHg)	128.0 ± 22.5	112.3 ± 13.3	117.9 ± 20.4	128.0 ± 20.2	125.4 ± 14.6	133.0 ± 22.5	144.3 ± 24.4	1<3,5,6* 2<5,6* 3<6 4<6*
DBP (mmHg)	74.2 ± 11.4	66.9 ± 7.0	75.9 ± 10.7	75.9 ± 10.7	75.1 ± 10.0	76.3 ± 11.0	76.5 ± 12.9	1<3, 5,6*
SpO ₂ (%)	96.5 ± 2.2	97.5 ± 1.4	97.4 ± 2.1	96.7 ± 2.1	96.5 ± 2.0	95.8 ± 2.4	95.2 ± 2.1	1,2,3,4>6* 2>5*
Height (cm)	157.5 ± 8.6	159.0 ± 8.4	159.4 ± 7.4	158.2 ± 10.2	156.3 ± 7.4	153.9 ± 8.3	157.3 ± 9.5	
Body mass (kg)	69.0 ± 14.6	63.4 ± 16.2	70.1 ± 13.0	73.4 ± 15.1	71.2 ± 15.0	65.9 ± 14.4	67.1 ± 14.3	
BMI (kg/m ²)	27.8 ± 5.3	24.9 ± 4.7	27.6 ± 4.8	29.3 ± 5.5	29.3 ± 6.7	27.6 ± 4.1	27.0 ± 4.5	1<3,4*

Date are the mean ± SD. *Significant when compared among the age brackets (Bonferroni method, p<0.05).

SBP: systolic blood pressure; DBP: diastolic blood pressure; SpO₂: oxyhemoglobin saturation; BMI: body mass index.

Table 5. Values in the valley group

Group No.	Age brackets							Comparison among age brackets
	1	2	3	4	5	6		
Categorized age (years)	All	18–24	25–34	35–44	45–54	55–64	≥65	
n	380	79	47	50	65	69	70	
Age (years)	46 ± 18	22 ± 2	29 ± 3	40 ± 3	50 ± 3	59 ± 3	71 ± 5	
SBP (mmHg)	121.0 ± 16.0	116.3 ± 14.1	115.9 ± 15.7	118.2 ± 12.1	122.6 ± 16.5	125.9 ± 16.0	125.4 ± 17.7	1<5,6* 2<5*
DBP (mmHg)	69.6 ± 10.3	66.2 ± 8.3	71.6 ± 8.6	71.6 ± 8.6	71.4 ± 11.5	71.4 ± 10.1	69.0 ± 11.1	1<5*
SpO ₂ (%)	91.7 ± 2.1	92.6 ± 1.9	92.2 ± 2.1	91.7 ± 1.8	91.4 ± 1.8	91.4 ± 2.4	91.0 ± 2.0	1>4,5,6* 2>6*
Height (cm)	154.9 ± 8.0	158.0 ± 7.3	155.2 ± 7.7	155.0 ± 7.9	154.9 ± 7.4	152.6 ± 7.6	153.3 ± 8.8	1>5,6*
Body mass (kg)	66.1 ± 12.8	59.6 ± 10.5	64.3 ± 10.3	69.8 ± 12.8	71.6 ± 13.4	67.6 ± 14.5	65.3 ± 11.0	1<3,4,5*
BMI (kg/m ²)	27.6 ± 5.2	23.8 ± 3.4	26.6 ± 3.4	29.0 ± 4.6	29.9 ± 5.6	29.0 ± 5.7	27.9 ± 4.7	1<2,3,4,5,6* 2<4*

Date are the mean ± SD. *Significant when compared among the age brackets (Bonferroni method, p<0.05).

SBP: systolic blood pressure; DBP: diastolic blood pressure; SpO₂: oxyhemoglobin saturation; BMI: body mass index.

It is known that the Andean highland populations adapt to the environment via increased blood hemoglobin concentration³). An increase in hematocrit value can be interpreted as a state in which blood viscosity is increased. In addition, it can be thought that the decrease in circulating blood volume decreases the preload and stroke volume.

In summary, since the Bolivians who live in the valleys at altitudes of around 2,800 m belong to the Andean group, the changes in bodily and physiological functions during the process of adapting to the high-altitude environment are the same as in previous studies.

SBP in the highland group was found to be lower than the lowland group overall, but SBP in the 60s and 70s brackets was significantly higher than in the 20s bracket. The average SBP value in the 70s bracket was significantly higher than in the 30s bracket. This result is in agreement with that of a previous study¹²) reporting age-related changes in blood pressure in highland populations. Although the average blood pressure value in the valley group seemed low, it increased with age. This can be interpreted as being indicative of age-related arterial changes. In the valley group, although the mean blood pressure value was low, an age-related change was observed; therefore, it is necessary to carefully observe blood pressure after late middle age. Further study is required to clarify other factors related to the rise in blood pressure, such as lifestyles, industry, food, and modernization of the research field.

Similar to the highland group, the blood pressure values of the lowland group increased with age. When comparing the average blood pressure values between the age brackets, the value of the 60s bracket was significantly higher than that of the 20s bracket, and the value of the 70s bracket was significantly higher than those of the 20s, 30s, and 40s brackets. In addition, the standard deviation of the 60s and 70s brackets was higher than that of the other age brackets. The data variance of the 70s

bracket was significantly higher and homoscedasticity was confirmed. From these results, it can be thought that the lowland group's 70s bracket had many individual differences in SBP, and that there were many people with high blood pressure. For those living in the lowlands, it is considered that management strategies such as carrying out blood pressure measurement before late middle age, when blood pressure values increase, is necessary to reduce the prevalence of hypertension in those over 65 years old.

A main effect of altitude on SpO₂ was observed. The average values (standard deviation) of each altitude group were 96.5% (2.2) in the lowlands and 91.7% (2.1) in the highlands, respectively. The average SpO₂ in the highland group was lower in all age brackets, making it evident that those in the highland group were clearly affected by the hypothetical environment. Furthermore, since the SpO₂ in the 60s and 70s brackets was significantly lower than in the 20s bracket, aging appears to have an influence. It seems that elderly people have a risk of hypoxemia. Andean residents adapt via increased hemoglobin concentration in order to efficiently transport oxygen to the tissues against a low-oxygen environment, and it is considered that the viscosity of the blood increases³). It is reported that when this happens, the risk of developing secondary diabetes is high because oxygen transportation becomes disadvantageous and exhibits hypoxic condition in the body¹³).

Although altitude did not have a main effect on BMI, the average BMI in both highland and lowland groups was more than 25, which demonstrates overweight in all age brackets except the 20s. The average BMI value increased with age. Moreover, the average BMI of the 40s and 50s brackets was 29. The WHO reported that the proportion of obese women with BMI greater than or equal to 30 in 1994 was 9.7% in urban areas and 5.1% in rural areas, but in the same survey in 2008, it increased to 19.1% and 13.9%, respectively⁵). However, the causes of increasing obesity were not investigated in this survey. Obesity in developing countries in South America has been reported to be affected by changes in socioeconomic situation and dietary habits, and decreased amounts of physical activity⁶). However, we did not investigate nutrition and activity levels to clarify the causes of obesity. Further studies must investigate factors related to the increase in obesity rate.

Recently, Itoh¹⁴) proposed the concept of the "metabolic domino," according to which risk factors are superimposed as obesity as the underlying pathology. Obesity, an accumulation of visceral fat, occurs because of lifestyle fluctuations such as diversion of eating habits and lack of exercise. Insulin resistance is caused by visceral fat accumulation and abnormal adipocytokine secretion. In addition, visceral fat accumulation and insulin resistance cause chronic inflammatory reactions and increased sympathetic nervous system activity. Then, hypertension, hyperglycemia, and lipid metabolism abnormalities occur, causing arteriosclerosis and the development of ischemic heart disease, cerebrovascular disorder, and the like. Therefore, in order to prevent the onset and progression of arteriosclerotic diseases, it is important not to individually treat risk factors but to reduce multiple risks through reduction of visceral fat, which is a common cause.

In the present study, the partial correlation coefficient demonstrated a significant positive correlation between BMI and blood pressure value. However, the correlation was weak owing to the large variation of the data. It is conceivable that there are many other factors that affect blood pressure values. However, there are several reports that BMI is the best predictor of blood pressure values of the altitude population¹⁵⁻¹⁷). In order to prevent hypertension, it is necessary to review personal lifestyle and reduce obesity.

This study had several limitations. First, the number of participants was small. Second, being a cross-sectional survey, it was unable to clarify how the physical function of the same participants changed with age. Third, the existence of selective bias cannot be denied. As the participants of this study voluntarily participated in health promotion activities, it is likely that they were already concerned about their health. With regard to the evaluation items, we were able to collect lifestyle-related data such as diet, socioeconomic background, and amount of physical activity, which influence blood pressure and BMI. Longitudinal epidemiological studies including these factors are necessary in the future.

We clarified the aging-related physical characteristics of Bolivians and differences caused by residential altitude. Presenting the results of this study as basic data on the physical functions of people living at different altitudes and showing the agendas related to health promotion support will be beneficial for determining the future course of health and medical policy in Bolivia.

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Conflict of interests

None declared.

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