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ORIGINAL CONTRIBUTION

High Altitude and Blood Pressure in Children

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We aimed to evaluate the blood pressure of children who had similar demographic characteristics but lived at different altitudes. Blood pressure of the children attending primary schools in Izmir (sea level: n = 425) and Van (altitude: 1725 m, n = 291) were measured by mercurial sphygmomanometer for this study. They were similar with respect to age, sex, weight, height, and BMI. Mean age of the children was 10.51 ± 0.87 years (range: 9 to 12 years), and 358 (50 percent) of them were female. Mean systolic blood pressure was significantly higher in the children living in Van than in the children living in Izmir (104.72 ± 11.2 vs. 97.96 ± 25.5 mmHg, respectively, p < .001). Similarly mean diastolic blood pressure was significantly higher in the children living in Van than in the children living in Izmir (63.98 ± 9.3 vs. 59.91 ± 10.0 mmHg, respectively, p < .001). When blood pressure was evaluated with regard to height percentile, the number of children with a blood pressure over 90 percentile were 19 (4.5 percent) and 48 (16.5 percent) for systolic blood pressure, and 25 (5.9 percent) and 37 (12.7 percent) for diastolic blood pressure among the children living in Izmir and Van, respectively (p < .001). Systolic and diastolic blood pressures were found to increase in parallel to the increase in body mass index in children living in Van (r = 0.358, p < .001 and r = 0.235, p < .001, respectively). However, blood pressures were not correlated to body mass index in children living in Izmir. A difference of 1700 m in altitude was associated with higher systolic and diastolic blood pressure levels in children with similar demographic characteristics, and at this altitude, body mass index and blood pressure showed a positive correlation.

INTRODUCTION

Blood pressure (BP)[d] increases acutely in proportion to height above sea level in mountain climbers as they climb to high altitudes in short-time periods [1]. This elevation in BP has been attributed to increased sympathetic activity secondary to hypoxia [2, 3]. Hypoxia stimulates the adrenal release of epinephrine, which modulates peripheral vascular tone and cardiac function [3]. However, this is true only for short-lasting hypoxia. More prolonged hypoxia of several days increases systemic pressure gradually, especially mean arterial BP and diastolic BP, in parallel with increases in plasma concentrations of norepinephrine [3].

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[d] Abbreviations: BP, blood pressure; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure.

Table 1. Anthropometric values and mean systolic and diastolic blood pressures of the children.

City	Gender n (%) Boy	Girl	Age (year)	Weight (kg)	Height (cm)	BMI	Systolic BP	Diastolic BP
Van	143 (49.1)	148 (50.9)	10.46±1.0	33.99±7.9	139.95±9.2	17.18±2.7	104.72±11.2	63.98±9.3
Izmir	215 (50.5)	210 (49.5)	10.54±0.7	32.63±9.5	139.82±6.5	16.64±3.2	97.96±25.5	59.91±10.0
p	.05	>.05	>.05	>.05	>.05	>.05	<.001	<.001

The effect of altitude on BP in childhood has not been studied extensively. In one study, it has been reported that systolic BP of the children living in areas of high altitude (Peruvian children) is lower with respect to age, but similar when corrected for body weight and height compared to their peers living at sea level (Dutch children) [4]. In that study, socio-economic characteristics are probably different in two groups of children. In this study, we aimed to evaluate the BP of children with similar demographic characteristics, but living at different altitudes.

MATERIAL AND METHODS

Children attending two primary schools in Izmir (sea level, n = 425) and Van (altitude: 1725 m, n = 291) were evaluated for this study. They were similar with respect to age, sex, weight, height and body mass index (BMI) (Table 1). The majority of the children's families from Izmir had moved to the area from Van and surrounding regions. Salt intake and nutritional habits of the families in Van and Izmir were similar.

Heights of the children with shoes off and weights with least possible clothing were measured at the children's classrooms by two physicians in two cities. The BMI of all children, defined as weight/stature square (in kg/m^2), were calculated.

Systolic and diastolic BP (SBP and DBP) were measured by a mercurial sphygmomanometer with proper-sized cuff (9 to 12.5 cm according to the body size) using right arms at sitting position at 10.00 to 11.00 a.m. in all of the children. Korotkoff sounds 1 and 5 were used to determine SBP and DBP, respectively [5]. Measurements were performed in the classrooms of the children and after a resting period of 30 minutes. Three measurements were obtained from each child, and the mean value was accepted as the blood pressure of that child. In the two study populations, the same protocol for blood pressure measurement was used by observers who showed no significant differences in average blood pressure readings during training sessions.

Height percentiles and BP percentiles with respect to height percentiles were determined for each child. Those children with a BP lower than 90 percentile, between 90 to 95 percentiles and over 95 percentile were regarded as having normal BP, high-normal BP and high BP, respectively [5].

Statistical analysis was performed by student's t test for differences of two independent samples, chi-square and Fisher's exact tests for comparison of the proportions, and Pearson's correlation analysis for correlation of variables.

RESULTS

Mean age of whole children was 10.51 ± 0.87 years (range: 9 to 12 years), and 358 (50 percent) of them were female. Mean ages of those living in Izmir and Van

Table 2. Comparison of the ratio of children with systolic and diastolic blood pressures <90, 90 to 95 and >95 percentiles living in Izmir (sea level) and Van (altitude: 1725 m).

City	Blood pressure percentiles (for height)					
	Systolic			Diastolic		
	<90 p (%)	90-95 p (%)	>95p (%)	<90 p (%)	90-95 p (%)	>95 p (%)
Van	243 (83.5)	22 (7.6)	26 (8.9)	254 (87.3)	17 (5.9)	20 (6.8)
Izmir	406 (95.5)	7 (1.7)	12 (2.8)	400 (94.1)	13 (3.1)	12 (2.8)
p	<.001	<.001	<.001	<.001	>.05	<.05

were 10.54 ± 0.7 and 10.46 ± 1.0 years, respectively (p > .05).

Mean SBP was significantly higher in the children living in Van than in the children living in Izmir (104.72 ± 11.2 vs. 97.96 ± 25.5 mmHg, respectively, p < .001) Similarly, mean DBP was significantly higher in the children living in Van than in the children living in Izmir (63.98 ± 9.3 vs. 59.91 ± 10.0 mmHg, respectively, p < .001). When BP was evaluated with regard to height percentile, the number of children with a BP over 90th percentile were 19 (4.5 percent) and 48 (16.5 percent) for SBP and 25 (5.9 percent) and 37 (12.7 percent) for DBP among the children living in Izmir and Van, respectively (p < .001). In accordance with this finding, the number of children with SBP and DBP within normal ranges (less than 90 percent) was significantly higher in Izmir (p < .001, Table 2). On the other hand, the number of children with BP value over 90 percent was significantly higher among those living in Van except the children having DBP in 90 to 95 percent for their heights (Table 2).

SBP and DBP were found to increase in parallel to the increase in BMI in children living in Van (r = 0.358, p < .001 and r = 0.235, p < .001, respectively). However, SBP and DBP were not correlated to BMI in children living in Izmir.

DISCUSSION

Some adaptive changes develop in the bodies of persons living in high altitudes in order to make them to live a life as comfortable as those living at sea level. Among these changes are respiratory volume, erythrocyte number, hemoglobin, and cardiac output [6]. In addition, as the altitude rises, some vascular changes develop to improve tissue hypoxia. Increase in capillary diameter and tortuosity, blood volume, blood viscosity — due to high erythrocyte number — and cardiac output results in increased BP.

However, it has been reported that arterial BP is kept at normal ranges by enhanced vascularization resulting in decreased total peripheric resistance in adults living in mountains for a long period [6]. In our study, on the other hand, BP of the children living in high altitude was found to be higher than those living at sea level. This might result from the insufficient vascular adaptive changes at this age group.

On the other hand, a study performed in adults in Russia demonstrated that SBP and DBP increased significantly in males and females living at 2540 m altitude in comparison to those living at sea level in all age groups [7]. As such, in a study performed in Arabia, it was found that BP of the people living at high altitudes was higher, and this was attributed to higher BMI and polycythemia of those people [8]. Likewise, hypertension has been reported to be frequent in Tibetans [9]. This was attributed to over-consumption of salt and yak butter, since obesity and smoking were uncommon among Tibetans [2, 9]. In our study, BMIs of the two groups were not different.

Our study shows that there is a positive relationship between the BP and altitude in childhood age group. In addition, as the BMI of the children living in Van (1725 m altitude) increased, both SBP and DBP of these children increased significantly. Such an association was not present among the children living in Izmir (sea level). It is known that when BMI increases to obesity levels hypertension develops [10]. However Bhadra M et al. [11], found no correlation between the BMI and SBP in young women, in their study. Moreover, in a large study, 24-hr SBP measurements were not correlated with BMI in postpubertal children [12]. Similarly, many studies found weak or no correlation between DBP and BMI [12, 13]. In another study performed by Naumann D et al. [14], found no correlation between the body weight and the blood pressure in normotensive and borderline hypertensive adults. The finding of correlation between BMI and BP at high altitude in our study could be explained by the previously mentioned mechanism. Thus, high altitude did not result in hypertension in adults [6]. Our results indicate that high altitude was associated with hypertension in children and this is positively correlated to BMI. Preservation of normal BP in adults living at high altitudes is explained by the normalization of total peripheral resistance by enhanced neovascularisation [6]. In children, development of a similar vascularization could be insufficient due to their small ages. In addition, as BMI of the children increase, the required tissue needed to develop vascularization to keep BP at normal ranges also increase. Thus, BP of these children could be affected more by BMI in comparison to those children living at sea level.

In conclusion, a difference of 1700 m altitude was associated with higher SBP and DBP levels in children with similar demographic characteristics, and at this altitude, BMI and BP showed a positive correlation.

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