Effects of gender and altitude on short-term heart rate variability in children

Çocuklarda rakım ve cinsiyetin kalp atım hızı değişkenliği üzerine etkileri

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ABSTRACT

Objective: We aimed to study short-term heart rate variability (HRV) in 113 apparently healthy children permanent residents of moderate altitudes, the effects of gender and altitude.

Methods: Children were assigned into 3 groups according with altitude of residence: Group 1 - 1650 m/a/s/l (n=38), Group 2 - 1740 m/a/s/l (n=36) and Group 3 - 2030 m/a/s/l (n=39). All children underwent short-term electrocardiographic recordings with spectral analysis of HRV at rest and during standing. Statistical analysis was performed using multivariate ANOVA analysis.

Results: Heart rate variability analysis showed significant increase in SDNN, high frequency and total powers in parallel with increase of the altitude of residence ($p<0.0001$, $p<0.03$ and $p<0.01$, respectively). The magnitude of the HRV response to posture did not differ between groups except index of sympathetic modulation, LFNU, which rose to a significantly lesser degree ($F=3.45$, $p<0.03$) in Group 3, as compared with Group 1 and 2. Girls had lower HRV as compared with boys.

Conclusion: Thus, in apparently healthy children, residents of moderate altitudes, increase in altitude levels is accompanied by higher overall variability and parasympathetic modulation of the sinus node and lower sympathetic response to posture. Heart rate variability in children, residents of moderate altitudes is also dependent of gender, resembling similar relationship in inhabitants of sea level. *(Anadolu Kardiyol Derg 2006; 6: 335-9)*

Key words: Heart rate variability, children, altitude, gender, posture

ÖZET

Amaç: Bu çalışmada, orta rakımda devamlı yaşayan 113 sağlıklı çocukta cinsiyet ve yüksekliğin kalp atım hızı değişkenliği (KAHD) üzerine etkilerini araştırmayı amaçladık.

Yöntemler: İkamet edilen deniz seviyesi yüksekliğine göre tüm çocuklar 3 gruba ayrıldı: Grup 1 - 1650 m/d/s (n=38), Grup 2 - 1740 m/d/s (n=36) ve Grup 3 - 2030 m/d/s (n=39). Tüm bireylerde yatarken ve ayakta kısa süreli elektrokardiyogram çekildi ve KAHD spektral analizi yapıldı. İstatistiksel analiz çok yönlü ANOVA testi ile uygulandı.

Bulgular: Yapılan KAHD analizi, SDNN, yüksek frekanslı ve total güçlerin deniz seviyesi yüksekliği ile paralel olarak arttıklarını (sırası ile $p<0.0001$, $p<0.03$ ve $p<0.01$) göstermiştir. Vücut duruşunun değişikliğine KAHD'nın cevabı incelendiğinde gruplar arası belirgin bir fark bulunmadı. Sadece LFNU- sempatik modülasyon indeksinin artışı Grup 3'te diğer gruplara (Grup 1 ve 2) göre anlamlı olarak daha düşük seviyede bulundu ($F=3.45$, $p<0.03$). Kızlarda KAHD erkeklere göre daha düşüktü.

Sonuç: Orta rakımda devamlı yaşayan sağlıklı çocukta, deniz seviyesi yüksekliğin artışı KAHD ve sinüs düğümünün parasempatik modülasyonunun artmasına ve duruş değişikliğine sempatik cevabının azalmasına neden olmaktadır. Bu çocuklarda, deniz seviyesinde yaşayan bireylerin ilişkilerine benzer olarak KAHD cinsiyete bağlı bulunmuştur. *(Anadolu Kardiyol Derg 2006; 6: 335-9)*

Anahtar kelimeler: Kalp atım hızı değişkenliği, çocuk, rakım, cinsiyet, duruş

Introduction

Heart rate variability (HRV), representing the beat-to-beat variation in cardiac cycle, is thought to reflect autonomic modulation of the sinus node, namely parasympathetic and sympathetic modulations, and sympathovagal interaction when analyzed by spectral techniques (1, 26, 29, 36, 37). Heart rate variability is reduced in children with cardiac diseases and it has been recognized to correlate with the functional deterioration and life-threatening arrhythmias in children with congenital heart anomalies before and after their surgical correction (7, 12, 18, 19, 25).

High altitudes are known to modify autonomic responses with higher parasympathetic activity in native inhabitants of highlands (5, 23, 27, 42) and enhanced sympathetic modulation during acute ascent in low lands inhabitants (28, 33).

At the same time, high altitudes through chronic exposure to hypoxia and other environmental factors (29, 34) could increase the incidence of congenital heart diseases, especially patent duc-

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tus arteriozus, atrial septal defect, tetralogy of Fallot in children permanent residents of moderate and high altitudes (4, 8, 14, 22).

Notwithstanding, the physiological and clinical significance of HRV and autonomic modulation of heart rate in children residing at moderate and high altitudes, healthy or those with cardiac diseases are not studied broadly.

We aimed to investigate short-term heart rate variability in children permanent inhabitants of moderate altitudes, the effects of gender, altitude and response to posture.

Material and Methods

Overall 113 apparently healthy children (58 girls and 55 boys, age range 9-10 years), of 150 permanent residents of three counties situated at 1650, 1740, and 2030 meters above the sea level underwent general health examinations with eligible electrocardiographic recordings, were included into the study.

Children were assigned into three groups according with the altitude of residence - Group 1 - 1650 m above the sea level (n=38), Group 2 - 1740 m above the sea level (n=36) and Group 3 - 2030 m (n=39) above the sea level.

All children underwent general health evaluation and short-term ECG recordings at rest and during posture in the ambulatory polyclinics situated at the same level of permanent residency of children (1650, 1740 and 2030 meters above the sea level). ECG recordings were further analyzed by spectral analysis of HRV (fast Fourier transformation) with specially developed software according with standard requirements for HRV processing and evaluation of short-term recordings (36).

The following measures of HRV were calculated: standard deviation of RR intervals (SDNN), low frequency (LF. 0.04-0.15 Hz) and high frequency (HF, 0.15-0.40 Hz) spectral powers, total power under the spectral curve (TP, 0.0-0.40 Hz), LF/HF ratio and the LF normalized power (LFNU) calculated as the LFNU=(absolute LF power /TP)x100 .

Statistical analysis was performed using SPSS for Windows 10.0, Chicago IL, USA software by Kolmogorov-Smirnov test for assessment of normality of data distribution, unpaired t test for comparison of gender specified groups, paired Students t tests for evaluation of the intra-group changes during posture, ANOVA for assessment of differences for altitude specified groups and multivariate analysis of variance (MANOVA) to assess the relationship of HRV changes with altitude, gender and posture.

Results

Heart rate variability analysis showed significant increase in SDNN, HF and TP in parallel with increase of the altitude of residence ($p<0.0001$, $p<0.03$ and $p<0.01$, respectively) of children (Table 1). These differences in HRV between groups in regard to altitude were also preserved in the posture position ($p<0.04$ for SDNN, $p<0.02$ for Log HF and $p<0.05$ for Log TP).

Evaluation of the HRV changes during posture (Table 1 and Fig. 1) according with altitude levels revealed uniform significant

Table 1. HRV parameters in healthy children in supine and posture changes according with the altitude of residence

	Group 1 1650m (n=38)	Group 2 1740 m (n=36)	Group 3 2030 m (n=39)	F	p
RR, ms					
Supine	823.3±75.6	812.9±110.3*	865.1±78.9	3.6	0.03
Posture	708.8±78.5♦♦♦	695.1±71.9♦♦♦	722.9±67.3♦♦♦	1.3	NS
SDNN, ms					
Supine	55.7±16.5***	59.0±20.1**	74.6±23.8	9.2	0.0001
Posture	50.9±17.6	50.6±13.6♦	59.9±22.1♦♦	3.2	0.04
Log LF					
Supine	2.30±0.35*	2.40±0.41	2.52±0.39	0.72	NS
Posture	2.35±0.37	2.45±0.35	2.43±0.38	2.9	0.054
Log HF					
Supine	2.44±0.27*	2.51±0.29	2.61±0.29	3.3	0.03
Posture	2.20±0.38♦♦*	2.31±0.39♦♦	2.46±0.45	3.9	0.02
Log TP					
Supine	2.71±0.25**	2.80±0.29	2.90±0.28	4.3	0.01
Posture	2.62±0.33*	2.73±0.32	2.80±0.34	3.02	0.053
LF/HF ratio					
Supine	1.02±0.95	1.11±1.08	1.06±0.75	0.08	NS
Posture	1.84±1.22♦♦	2.08±2.3♦	1.56±1.80	0.76	NS
LFNU, %					
Supine	42.9±18.2	44.3±18.7	45.8±16.9	0.24	NS
Posture	57.9±18.0♦♦	56.7±19.6♦♦	48.3±22.2	2.6	0.07

*- p<0,05, **- p<0,01, ***- p<0,0001 Scheffe F test differences are significant as compared with altitude of residence at 2030 m above the sea level

♦- p<0,01, ♦♦- p<0,001, ♦♦♦- p<0,0001 Student paired t test differences are significant as compared with supine position

HF- frequency power, HRV- heart rate variability, LF- low frequency power, LFNU- LF power expressed in normalized units, NS- nonsignificant, SDNN- standard deviation of the normal-to-normal RR intervals duration, TP- total power under the spectral curve

(all p<0.0001) reduction of mean RR interval in all groups and marked decrease in SDNN value in Groups 2 and 3 (p<0.01 and p<0.001, respectively). Children of Group 1 and 2 had an uniform reduction in Log HF (p<0.001 and p<0.001, respectively), with concomitant increase in LF/ HF ratio (p<0.001 and p<0.01) and LFNU (p<0.001 for all), while changes in the former parameters in the Group 3 did not reach statistical significance.

Multivariate analysis (Fig. 1) of the response to posture according with altitude of residence showed no difference in the magnitude of HRV changes between groups except LFNU, index of sympathetic modulation of heart rate, which rose to a significantly lesser degree (F=3.45, p<0.03) in Group 3, as compared with Group 1 and 2.

Gender-related differences in HRV (Table 2) were characterized by shorter RR interval (p<0.02), lower SDNN (p<0.01), Log LF (p<0.016) and Log TP (p<0.057) in girls as compared with boys.

Assessment of the gender-specific response to posture (Fig. 2) showed that boys had more profound reduction in SDNN (F=5.42, p<0.02) and Log TP (F=3.32, p<0.07). The main feature was different response in Log LF in girls as compared with boys, which increased (p<0.01) during posture changes in girls and reduced in boys (F=6.17, p<0.01). When these responses were analyzed with adjustment for altitude of residence, the similar pattern was observed.

Discussion

Our study demonstrated, that in apparently healthy children permanent inhabitants of moderate altitudes increase in levels of altitude of residence is accompanied by higher overall variability (SDNN and TP) and parasympathetic modulation (high frequency variability) of the sinus node with lower sympathetic (LFNU) response to posture, as assessed by short-term HRV analysis.

Gender-related differences in children residing at middle altitudes are characterized by lesser values of HRV in girls in comparison with boys and different responses to posture of overall HRV index and LF component.

Heart rate variability analysis studies in children showed that HRV gradually increases from neonatal period to adolescent period accordingly with reduction of heart rate (30). The autonomic maturation is especially should be regarded to HF component of HRV with its fairly discernible peak in neonates and its further increase in adolescents due to increase in myelination of vagal fibers and decrease in heart rate (9). The lower frequency of LF peak in children was explained by lower transmission rate of the signal and immature autonomic nervous system (15). The age-related increase in short and medium-term HRV and changes in autonomic nervous system continues up to age of 8-10 (2, 3), after what only the changes in long-term HRV (SDANN) were noticed (32, 37). We included in the study only the children/preadolescents at age of 9-10 years, assuming the stabilization in sympathetic and parasympathetic limbs reactivity (32).

Our findings on gradual increase in HF with increase in altitude in children inhabitants of moderate altitudes are in concert with previous findings on increase of parasympathetic modulation of heart rate with increase of altitude reported in adults (5, 27). The increase in parasympathetic modulation of heart rate has been reported also in young Tibetians (42) and in newborns at

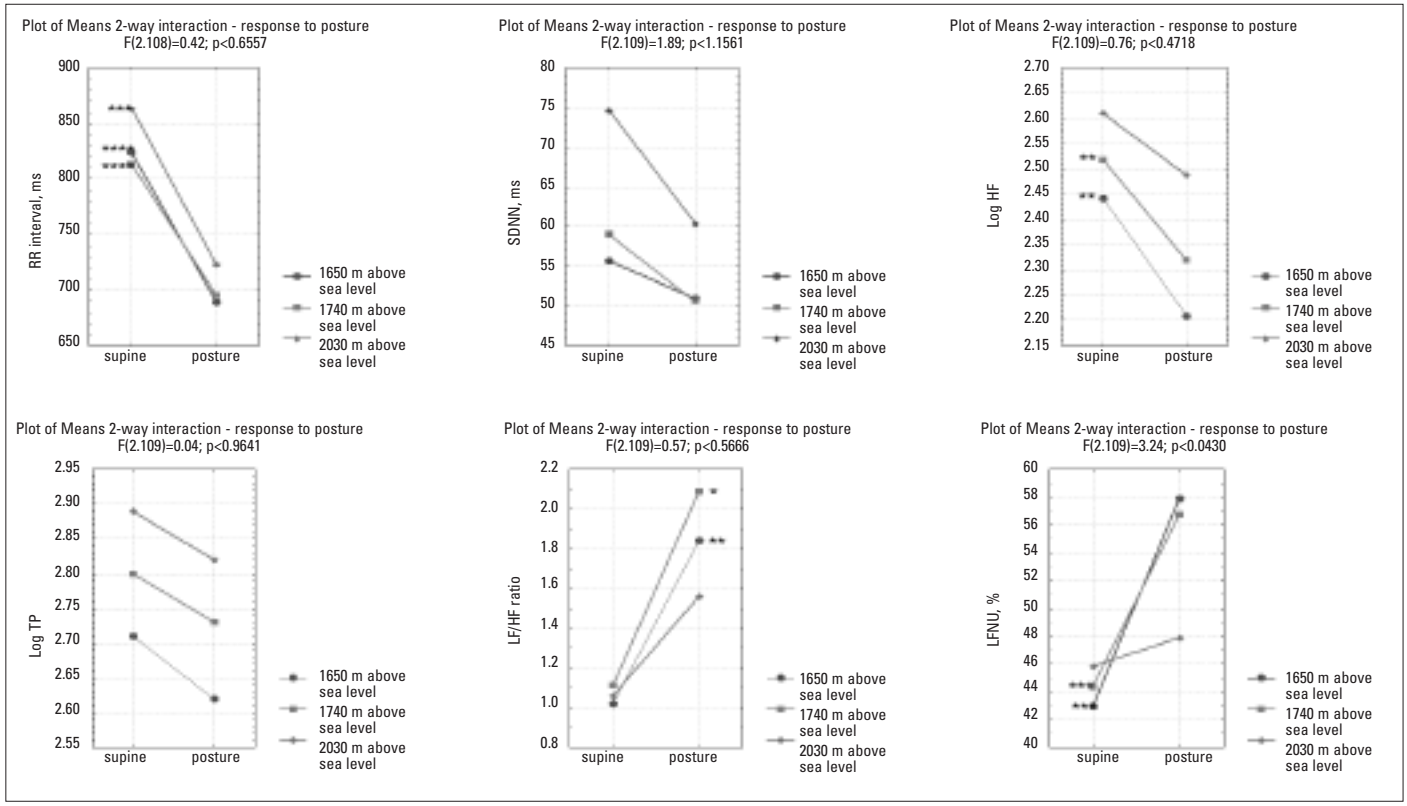

Figure 1. MANOVA analysis curves for HRV response to posture according with altitude of residence

*-p<0.05, **-p<0.001, ***-p<0.0001 differences are significant as compared with supine position
HF- high frequency power, LF- low frequency power, LF/HF - LF/HF ratio, LFNU - LF normalized power, Log - logarithmic value, SDNN - standard deviation of normal-to-normal RR intervals, TP- total power

Table 2. Gender related differences in HRV of healthy children, residents of moderate altitudes

Parameters	Boys (n=38)	Girls (n=36)	p
RR, ms			
Supine	854.5±95.3	816.1±84.1	0.02
Posture	722.5±81.4***	697.1±62.4***	NS
SDNN, ms			
Supine	68.4±24.5	58.1±17.7	0.01
Posture	54.5±19.7***	53.4±17.5	NS
Log LF			
Supine	2.50±0.35	2.32±0.41	0.016
Posture	2.40+0.37	2.42±0.36*	NS
Log HF			
Supine	2.55±0.33	2.49±0.24	NS
Posture	2.33±0.47**	2.33±0.36**	NS
Log TP			
Supine	2.85±0.29	2.75±0.27	0.057
Posture	2.72±0.37**	2.73±0.3	NS
LF/HF, ratio			
Supine	1.19±1.02	0.93±0.81	NS
Posture	1.78±1.73*	1.87±1.91**	NS
LFNU, %			
Supine	47.4±17.1	41.4±18.1	NS
Posture	53.3±20.5	55.1±20.3***	NS

*-p<0.01, **-p<0.001, ***-p<0.0001 Student paired t test differences are significant as compared with supine position

HF- frequency power, HRV- heart rate variability, LF- low frequency power, LFNU- LF power expressed in normalized units, NS- nonsignificant, SDNN- standard deviation of the normal-to-normal RR intervals duration, TP- total power under the spectral curve

high altitudes (23). These changes in autonomic regulation in native inhabitants of high altitudes were attributed to effects of hypoxia and hypobaria (31). Since hypoxia is also observed at middle altitudes (40) we can assume that they also could influence the altitude differences of HRV in our children.

We also showed in multivariate analysis that children residing at higher altitudes had lower response of sympathetic modulation of heart rate as compared with those living at lower altitudes. The lower response of sympathetic modulation of HR at higher altitudes may be also attributed to inhibiting effects of hypoxia on β-adrenergic responsiveness (16, 17, 20).

Gender related differences have been reported (11) for higher HRV in boys than in girls of 3-15 years old, though others (6, 35) described no differences at all. Our findings on gender-related changes in HRV of children inhabitants of moderate altitudes are in concert with previous studies on HRV extracted from 24-hour ECG recordings (10, 13, 37, 38). Silvetti et al. (29) found higher SDNN for boys and no differences in parasympathetic (pNN50, RMSSD) modulation between genders. Similarly, we showed that SDNN was markedly lower in girls that in boys, however we also found differences in slow fluctuations (LF) and accordingly TP, which were lower in girls than in boys, inhabitants of moderate altitudes. These differences in LF component have already been described for adult women as compared with middle-aged men by Huikuri et al (13). Faulkner et al. (10) attributed the differences in overall HRV in children of this age to the start of secondary sexual characteristics in circadian patterns. Though it is not well explained, similar can be speculated for gender differences in HRV in children inhabitants of moderate altitudes (35, 41).

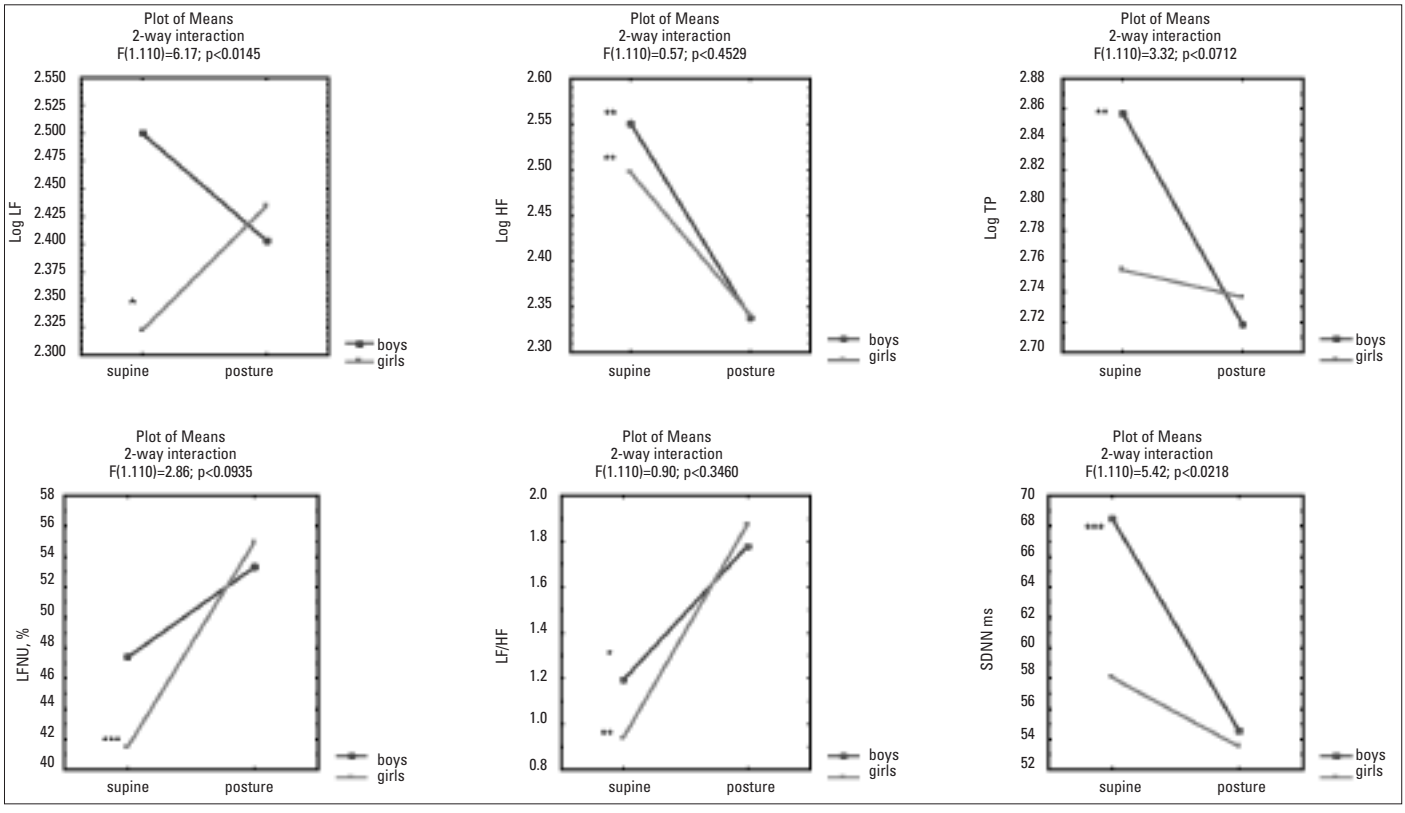

Figure 2. MANOVA analysis curves for HRV response to posture according with gender

*-p<0.01, **-p<0.001, ***-p<0.0001 differences are significant as compared with supine position

HF- high frequency power, LF- low frequency power, LF/HF - LF/HF ratio, LFNU - LF normalized power, Log - logarithmic value, SDNN - standard deviation of normal-to-normal RR intervals, TP- total power

The main limitation of our study is the absence of control group of children permanently residing at sea level (50-100 m above the sea level) and narrow age limits. Further studies should be addressed to elucidate effects of altitudes on heart rate variability and autonomic modulation in children residing at high altitudes, as well the relationship of HRV and cardiovascular diseases in residents of moderate and high altitudes.

Conclusion

Thus, in apparently healthy children, residents of moderate altitudes, increase in altitude levels is accompanied by higher overall variability and parasympathetic modulation of the sinus node and lower sympathetic response to posture. HRV in children, residents of moderate altitudes is also dependent of gender, resembling similar relationship in inhabitants of sea level.

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