Habitual Physical Activity in 10- to 12-Year-Old Bolivian Boys

The Relation Between Altitude and Socioeconomic Status

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Abstract

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This study describes habitual physical activity (HPA) of Bolivian boys living at different altitudes and from different socioeconomic status. The boys were living at high altitude (HA) in La Paz (4000 m) and at low altitude (LA) in Santa Cruz (400 m). At both altitudes samples of 10- to 12-year-old boys were chosen from a relatively low socioeconomic status (LSES) and a relatively high socioeconomic status (HSES). At HA 19 boys from LSES and 10 boys from HSES were measured and at LA 14 boys from LSES and 13 boys from HSES.

HPA was measured by 24-h heart rate (HR) monitoring. Also an interview was completed to recall the HPA. By comparing the registered HR data with the time they were asleep the mean HR during sleep was calculated (HRsleep). The maximal HR (HRmax) was measured from a maximal exercise test on a bicycle ergometer. Heart rate reserve (HRR = HRmax − HRsleep) was used to measure the mean level of physical activity of the subjects. The results show that HRsleep (= HRrest) in HA boys with 70 (±6) beats/min was significantly lower ($p < 0.05$) than in LA boys with 77 (±10) beats/min. HRmax was also significantly lower ($p < 0.05$) in HA boys (187 ± 12 beats/min) compared to LA boys (195 ± 8 beats/min). Because HA influences HRsleep and HRmax in the same way, HRR is not significantly different between boys of HA and LA.

The mean heart rate over 24 h (HRmean) in HA boys (87 ± 7 beats/min) was significantly lower than in LA boys (93 ± 8 beats/min). There was no SES effect and also no interaction between SES and altitude. If the mean 24-h HR is expressed as a percentage of HRR (HRR%) there were no significant differences between the four groups, neither between altitudes nor between SES.

However, LSES boys spent significantly ($p < 0.05$) more time at 50 %, 60 %, 70 % and 80 % HRR than HSES boys. The same holds for LA boys compared to HA boys at 50 % and 60 % HRR.

It can be concluded that when 24-h HR is expressed in the time they spent above the aerobic training threshold of 50 % HRR, LSES and LA boys were physically more active than HSES and HA boys.

Key words

High altitude, prepubescent boys, heart rate monitoring, heart rate reserve, physical activity

Introduction

It is now well-established that monitoring the heart rate for a prolonged period (24 h) can give valuable information about the daily physical activity of man (13,26). Because of technological advances over the last 10 years, daily heart rate (HR) monitoring has also become a practical indicator of physical activity among children (12). Usually those individuals who spend longer periods of time in higher heart rate ranges are generally more active than those children whose heart rates are lower (12). Because the association between HR and oxygen uptake in children is weak (9), physical activity in this study will be expressed as percentages of heart rate reserve (HRR), being the difference between maximal (HRmax) and resting heart rate (HRrest).

A percentage of the HRR is assumed to be related with the same percentage of maximum oxygen uptake ($\dot{V}O_2max$). Consequently, the American College of Sports Medicine (ACSM) proposed to use 50 %–85 % of HRR as the exercise training intensity range (2). There is little information available on 24-h physical activity in prepubescent boys at high altitude. Post et al. (1992) used a retrospective activity questionnaire (24 h), grouped activities in four different intensities and converted them to energy in kilocalories. There was no difference in energy output between boys living at high altitude (HA) and boys from low altitude (LA). However, if socioeconomic status (SES) was taken into account, boys of a low SES had significantly higher energy output than boys from high SES.

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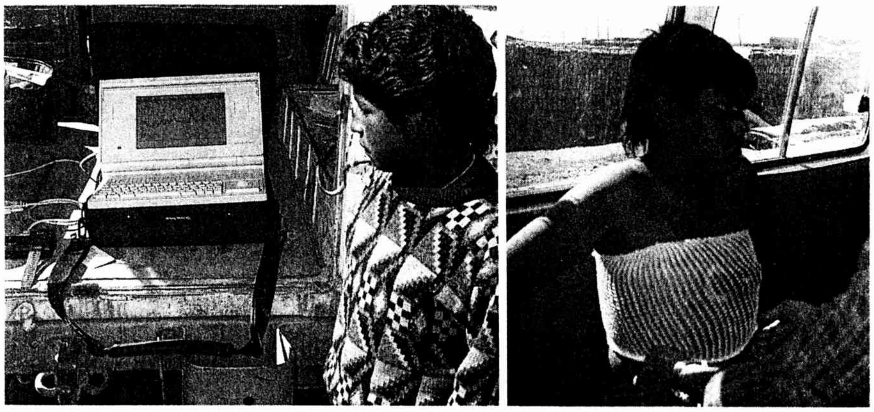

Fig. 1 Heart rate monitoring of boys with the sporttester system.
Left: Discharging of heart rate on portable computer.
Right: Attachment of electrodes and transmitter.

The aim of this study is to compare the 24-h HR data of boys living at HA with those of boys living at LA. Physical activity at both altitudes was studied and expressed in time boys spent at different levels of percentage of HRR.

Subjects and Methods

Subjects

From the total number of 143 boys in this study 56 healthy 10- to 12-year-old Bolivian schoolboys were selected at random at two altitudes and from two socioeconomic levels.

Heart rate monitoring

Heart rate was monitored over a period of 24 h with a cardiofrequency device (Polar Sporttester Heart Rate Monitor, Polar Electro, Kempele, Finland). This system consists of an electrode belt transmitter and wrist microcomputer receiver that stores the pulse in a memory. In this study the chest band was deputized for two disposable electrodes (3M) on which the transmitter was attached directly. To prevent the transmitter from becoming loose and losing information, the electrodes on the boys' chests were covered with elastic medical gauze (Fig. **1**). The receiver on the wrist was covered with tape in order to prevent subjects from being influenced by the monitor or from tampering with the monitor.

Heart rate was recorded at 1-min intervals up to a maximum recording time of 33 h and 40 min. At the end of the recording period, the heart rate memories were discharged into a portable computer (Apple Macintosh) through a computer interface (Polar, Finland) and the data were stored on diskette. Data quality control was performed by checking the following criteria: (a) mean heart rates (per min) were accepted in the range of 30–240 beats/min, (b) more than 20 h had to be registered, and (c) the data were accepted, if the missed HR did not exceed 2.5 % of the time during which the HR was recorded. Figure **2** shows the 24-h heart rate profile of an 11-year-old boy of low SES living at HA during a normal school day in August 1990.

Assessment of individual rest and maximal heart rate

All the subjects in this study were also involved in the study of Post et al. (1992). In this study food consumption and physical activity were measured with a 24-h recall method.

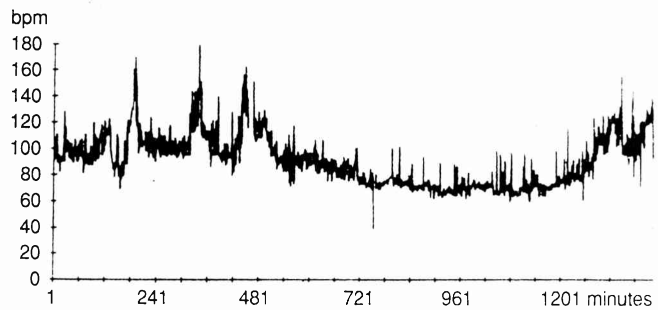

Fig. 2 Twenty-four heart rate profile of an 11-year-old boy from low SES living at high altitude (Kemper 1991). (y axis: heart rate in beats/min (bmp) and x axis: time base (min).

With a retrospective activity questionnaire information was gathered about all the physical activities over the last 24 h. From this information, time of retiring for the night and total sleep time was used in the present study. Mean HR over the period of 1 h after retiring and 1 h before waking up was determined and was assumed to be representative for the HRsleep of the boys.

Maximal HRs of the boys were determined in a maximal exercise test on a cycle ergometer (Brue) in the study of Obert et al. (1992). In this study maximal oxygen uptake was determined by the direct method. The seat height, the handlebars, and pedal crank were adjusted to child size. The pedaling frequency was maintained at 70 rpm and HR was recorded on an electrocardiogram. The highest HR during this exercise was assumed to be representative for the HRmax.

Assessment of physical activity

Mean HR during the 24 h was calculated. The relative load on the boys was calculated by relating this mean to the heart rate reserve (HRR) of the boys (expressed as a % of HRR). HRR was calculated as the difference between HRmax and HRsleep. To determine the intensity of the physical activity of the boys, physical activity was expressed as the time and percent of 24 h that the boys spent on an intensity range of 50 %–85 % of HRR. This range is the exercise training intensity range prescribed by the American College of Sports Medicine (2).

Table 1 Mean and standard deviation (SD) of physical characteristics of the four groups of schoolboys.

	High altitude		Low altitude		Effects		
Subjects	Low SES (n = 19)	High SES (n = 10)	Low SES (n = 14)	High SES (n = 13)	Altitude	SES	Alt × SES
Age (yrs)	10.9 (1.0)	10.8 (0.9)	10.6 (0.8)	10.5 (0.7)	NS	NS	NS
Height (cm)	134.8 (6.1)	142.6 (8.7)	132.7 (7.6)	142.0 (6.9)	NS	*	NS
Weight (kg)	32.6 (4.7)	37.7 (11.4)	30.6 (4.8)	38.6 (8.0)	NS	*	NS
Sum of 4 skinfolds (mm)	28.7 (5.7)	41.9 (21.8)	31.1 (8.2)	53.1 (25.1)	NS	*	NS

* Statistically different ($p < 0.05$); NS = not significant, SES = socioeconomic status

Table 2 Mean and standard deviation (SD) of heart rate during sleep (HRsleep), maximal heart rate (HRmax), mean heart rate (HRmean), and heart rate reserve (HRR) of the four groups of schoolboys.

	High altitude		Low altitude		Effects		
Subjects	Low SES (n = 19)	High SES (n = 10)	Low SES (n = 14)	High SES (n = 13)	Altitude	SES	Alt × SES
HRrest	71.1 (6.0)	69.4 (6.8)	80.6 (12.7)	73.6 (7.2)	*	NS	NS
HRmax	183.8 (13.5)	193.7 (6.7)#	191.0 (8.3)	198.3 (6.0)	*	*	NS
HRR	112.7 (13.8)	125.2 (8.1)#	110.4 (17.2)	124.7 (9.4)	NS	*	NS
HRmean	87.6 (6.0)	85.0 (9.2)	94.1 (8.3)	91.4 (8.1)	*	NS	NS

* Statistically different ($p < 0.05$); # n = 9; NS = not significant; SES = socioeconomic status

Statistical analysis

Anthropometric and heart rate variables are presented as mean and standard deviations. Data were analyzed using analysis of variance (ANOVA with two factors: altitude and SES and the interaction between altitude and SES). The level of significance used was $p < 0.05$.

Results

Anthropometry

The physical characteristics (33) of the four groups of schoolboys are presented in Table **1**. There was no difference between the groups in altitude (A) or in socio-economic status (SES) in the mean age. The HSES boys were significantly taller ($p < 0.05$), heavier ($p < 0.05$), and fatter ($p < 0.05$) than the LSES boys irrespective of altitude.

Heart rate

Table **2** shows the results of HRsleep, HRmax, mean HR during 24 h (HRmean) and HRR of the schoolboys. HRsleep, HRmax, and HRmean were significantly lower ($p < 0.05$) in HA boys than in LA boys. HRmax and HRR were significantly ($p < 0.05$) higher in HSES boys than in LSES boys.

Physical activity

Figure **3** shows the 24-h heart rate of the schoolboys as a percentage of HRR (HRR%). The HRR% varied between the groups from 12.5 % to 15 % and there were neither significant differences in altitudes nor in SES between the groups.

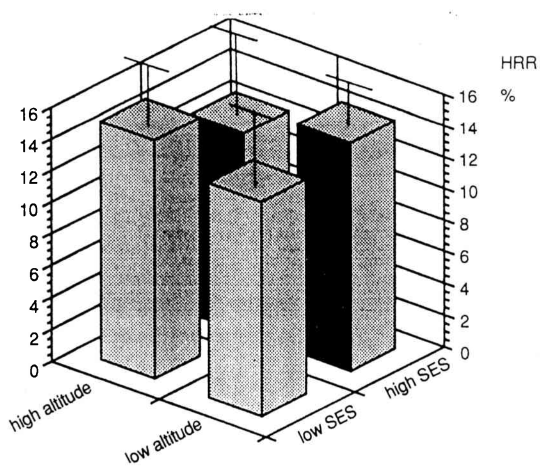

Fig. 3 Mean and standard deviation of the 24-h heart rate of the four groups expressed as a percentage of HRR (HRR %).

Table **3** shows the intensity range of 50 %–85 % of HRR and the time (min) the boys spent at and above a specific level of this range. Boys at LA spent significantly ($p < 0.05$) more time than HA boys at 50 % and 60 % of HRR. LSES boys spent significantly ($p < 0.05$) more time at 50 %, 60 %, 70 %, and 80 % of HRR than HSES boys.

In Table **4** the time which boys spent at different levels of HRR is related to 24 h and expressed as a percentage of 24 h (24 h%). Boys at LA spent a significantly ($p < 0.05$) higher percentage at 50 % and 60 % of HRR than HA boys.

Table 3 Mean and standard deviation (SD) of the time (in min) at different levels in the range between 50 %–85 % of heart rate reserve (% HRR) of the four groups.

Subjects	High altitude Low SES (n = 19)	High altitude High SES (n = 9)	Low altitude Low SES (n = 14)	Low altitude High SES (n = 13)	Effects Altitude	Effects SES	Effects Alt × SES
% HRR							
50	65.6 (58.3)	16.7 (14.6)	82.9 (53.2)	71.1 (39.6)	*	*	NS
60	39.2 (40.5)	8.1 (8.1)	52.7 (35.9)	40.5 (23.4)	*	*	NS
70	24.0 (29.4)	3.9 (5.7)	33.4 (26.2)	17.2 (11.0	NS	*	NS
80	15.4 (25.1)	3.0 (4.9)	19.8 (18.6)	12.1 (9.0)	NS	*	NS
85	12.6 (24.1)	2.7 (4.5)	14.8 (15.3)	9.9 (8.3)	NS	NS	NS

* Statistically different ($p < 0.05$); NS = not significant; SES = socioeconomic status

Table 4 Mean and standard deviation (SD) of the percentage of 24 h (%) the boys spent at different levels of heart rate reserve (% HRR).

Subjects	High altitude Low SES (n = 19)	High altitude High SES (n = 9)	Low altitude Low SES (n = 14)	Low altitude High SES (n = 13)	Effects Altitude	Effects SES	Effects Alt × SES
% HRR							
50	4.7 (4.3)	1.1 (0.9)	5.6 (3.5)	5.1 (2.7)	*	*	NS
60	2.8 (2.9)	0.6 (0.8)	3.6 (2.4)	2.9 (1.6)	*	*	NS
70	1.7 (2.1)	0.2 (0.4)	2.3 (1.7)	1.2 (0.8)	NS	*	NS
80	1.1 (1.8)	0.2 (0.3)	1.3 (1.2)	0.9 (0.6)	NS	NS	NS
85	0.9 (1.7)	0.2 (0.3)	1.0 (1.0)	0.7 (0.6)	NS	NS	NS

* Statistically different ($p < 0.05$); NS = not significant; SES = socioeconomic status

Table 5 Mean and standard deviation (SD) of transformed heart rate (beats/min), i.e., percentage of HRR (beats/min) plus the resting HR (beats/min).

Subjects	High altitude Low SES (n = 19)	High altitude High SES (n = 9)	Low altitude Low SES (n = 14)	Low altitude High SES (n = 13)	Effects Altitude	Effects SES	Effects Alt × SES
% HRR							
50	127.4 (7.9)	131.1 (5.2)	135.8 (6.4)	127.0 (4.5)	NS	NS	*
60	138.7 (8.9)	143.6 (5.3)	146.8 (5.9)	137.7 (4.4)	NS	NS	*
70	150.0 (9.9)	156.1 (5.5)	157.9 (5.9)	160.9 (4.7)	*	*	NS
80	161.2 (11.1)	168.6 (5.8)	168.9 (6.3)	173.4 (5.0)	*	*	NS
85	167.4 (11.7)	174.9 (6.0)	174.4 (6.7)	179.3 (5.1)	*	*	NS

* Statistically different ($p < 0.05$); NS = not significant; SES = socioeconomic status

LSES boys spent a significantly ($p < 0.05$) higher percentage at 50 %, 60 %, and 70 % of HRR than HSES boys.

In Table **5** mean percentage of HRR (beats/min) plus the resting HR (beats/min) is shown. This is called the transformed HR. This transformation makes it possible to compare the results of this study with other studies on 24-h physical activity. LAHSES boys had a significantly ($p < 0.05$) lower transformed HR (50 % and 60 %) than HAHSES. LALSES boys had a significantly ($p < 0.05$) higher transformed HR (50 % and 60 %) than HALSES. HA boys had a significantly ($p < 0.05$) lower transformed HR (70 %, 80 %, and 85 %) than LA boys. HSES boys had a significantly ($p < 0.05$) higher transformed HR (70 %, 80 %, and 85 %) than LSES boys.

Discussion

Heart rate

Although heart rate can be influenced by numerous factors such as emotional stress, environmental temperature, and type of exercise (arm, leg, dynamic, static etc.), Saris (28) and Freedson (15) recommended 24-h heart rate monitoring as a valid and practical measure of children's physical activity. This is based on the assumption that, even when considering the influence of extraneous factors (as in this study: altitude) on heart rate, children who spend longer periods of time in the higher heart rate ranges are generally more active than children whose heart rates are lower (12).

HRrest was determined during sleep. Because of this, HRrest in this study will be lower compared to other studies and it is likely that HRrest values are not influenced by extraneous factors such as emotional stress and type of exercise. Assessing HRrest in this way and the assessment of HRmax in a maximal exercise on a cycle ergometer seemed to be the most valid way of determining HRR.

However, it is likely that such extraneous factors can make it impossible to compare different groups living at different altitudes. Because HRrest and HRmax are significantly lower at HA with a mean value of 7–8 beats/min, expressing physical activity as the time the boys spent for example at 160 beats/min or higher would have resulted in totally different values for both altitudes, values which are not representative for the actual intensity of physical activity. This validates the use of time spent at different levels of a percentage of HRR (HRR%) and the expressing of HRmean as a percentage of HRR (HRR%) in this study. Maximal heart rate in this study was about 185 beats/min at HA and 195 beats/min at LA. The first value is similar to that found in some other studies at altitude (3,17); the second is similar to the values of Andersen and Ghesquire (4) and Seliger et al. (29). The HA value is lower than the normal range of 195–205 beats/min for young, untrained boys (5,11,30,25). The significantly higher HRmax values of HSES boys (both altitudes) compared to the LSES boys (both altitudes) might partially be explained by the fact that HSES boys (both altitudes) are used to riding a bicycle and consequently were able to perform a maximal exercise test. Most of the LSES boys had no experience with bicycles, so it must have been difficult for them to perform maximally. It is difficult to compare the HRrest and HRmean data with results of other studies.

The data in this study provide evidence for the fact that even in prepubescent boys, HRrest, HRmax, and HRmean (24 h) are significantly lower at HA than at LA. This phenomenon might partially be explained in the autonomic regulation of heart rate as a result of adaptation to high altitude. Farinelli et al. (14) described the changed strategy of autonomic regulation of heart rate after acclimatization to high altitude. After acclimatization, a reduced sensitivity of the heart to sympathetic drive is reported and the hypothesis of an increase in parasympathetic activity is mentioned. The hypothesis is that man living at HA intrinsically has a reduced sensitivity to sympathetic drive. This hypothesis partially explains the lower resting and maximal heart rate in the HA boys compared to the LA boys.

Physical activity

The relation between % of maximal HRR and % of $\dot{V}O_2max$ was recently investigated by Brennan et al. (10), Woodard et al. (35), and Wier and Jackson (34). They concluded that with fit subjects, 70 % maximum heart rate reserve represents 70 % $\dot{V}O_2max$. However, the heart rate model underestimates % $\dot{V}O_2max$ at heart rates below 70 % and overestimates % $\dot{V}O_2max$ above 70 %. These data showed that % max HRR and % $\dot{V}O_2max$ do not represent equivalent indices of exercise intensity. The time which boys spent in this study at or above the intensity of 70 % HRR is equal to time at or above 70 % $\dot{V}O_2$, but at the extremes (85 % HRR) % $\dot{V}O_2max$ is only 75 % (10).

It is recommended for adults to participate at least 3–5 times per week in physical activities with an intensity of 50 %–85 % of their $\dot{V}O_2max$, sustained for a period of 20–60 min depending on the intensity, to maintain a reasonable level of physical fitness (2). The threshold intensity of exercise appropriate to training of the prepubescent child remains uncertain, but it is probably higher in a young child than in an adult (2,32), in part because the child has a higher peak heart rate (32). The intensity of 70 % $\dot{V}O_2max$ (68.6 %) is the anaerobic threshold intensity of exercise described by Kanaley and Boileau (18) appropriate to training of prepubescent children. This anaerobic threshold would correspond to a heart rate of 150–160 beats/min. Shephard et al. (31) observed an aerobic training response with a physical education program that developed telemetrically recorded heart rates of 150 to 160 beats/min. Atomi et al. (7) found that 9- to 10-year-old boys spent only 18 min/day at the lactate threshold, and 34 min/day at 60 % of $\dot{V}O_2max$.

In the present study heart rates between 150 to 161 beats/min correspond with the intensity of 70 % HRR. Assuming 70 % HRR is equal to 70 % $\dot{V}O_2max$ and representive for the anaerobic threshold, HSES boys in this study spent 3.9 (HA) and 17.2 (LA) min/day at this threshold. They do not differ in (intensity of) physical activity from the subjects in the study of Atomi et al. (7). However, the LSES boys spent more time at this threshold. They spent 24.0 (HA) and 33.4 (LA) min at this level, respectively. Based on adult standards, a target heart rate of at least 60 % of the heart rate reserve for a duration of 30 min is usually needed to promote cardiovascular fitness (16). If the same standards can be applied to the boys in this study, this target heart rate would be at least ± 140 beats/min. The present data provide evidence, assuming the target heart rate is a good intensity threshold, that the voluntary activity patterns of at least the LSES boys may be adequate, in terms of duration and intensity, to promote cardiovascular health. At the intensity level of 70 % HRR (see Tables **3** and **4**) LSES boys spent significantly ($p < 0.05$) more time than HSES boys at this level. Although not statistically different ($p = 0.08$), there was a tendency that LA boys spent more time at this level than HA boys.

It is known that because of the lack of water supply in their houses low SES boys (both altitudes) participate in some household activities (carrying water in jerrycans) and that the low SES boys at high altitude have to climb up and down to and from home and school in the slopes of La Paz (24). These factors might explain the longer time at higher intensities of physical activity of the low SES boys at both altitudes.

Conclusions

It appears that prepubescent boys living at high altitude have a significantly lower HRmax, HRrest, and HRmean than boys living at low altitude. Boys of HSES have a significantly higher HRmax and HRR than boys of LSES. If the mean 24-h heart rate is expressed as a percentage of HRR (HRR%), there are no significant differences between altitudes or between SES. Boys of LSES and boys of LA spent more time above 50 % HRR.

In conclusion, boys of LSES and boys of LA experience physical activity of a higher intensity for a longer duration than their counterparts.

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