INFLUENCE OF DIFFERENT-TYPE PHYSICAL LOADS ON ADOLESCENTS' AUTONOMIC HEART RATE CONTROL

by

Algimantas Kepeženas, Audronius Vilkas[1], Giedrius Varoneckas

Autonomic heart rate control and its peculiarities are factors determining reactions of the cardiovascular system to physical loads. Therefore, while evaluating physical conditioning of an individual, it is purposeful to perform physical load tests in order to determine the functional possibility reserve of that individual's cardiovascular system and the level of autonomic heart rate (HR) control, which reflects such a reserve.

The aim of the research is to investigate 14-16-year-old boys and girls' autonomic heart rate control peculiarities under different kinds of physical loads (anaerobic or aerobic ones).

Following a literary review, we determined physical developmental peculiarities of 14-16-year-old adolescents under different physical biological development conditions, which depend on external and internal factors. We also determined the extent and nature of their physical exercising. The rhythmography method was used to distinguish the data of the involved sportsmen's heart rates (RR_V), heart rate dispersion ($s\,RR_1$) and the amplitude of breathing arrhythmia (BA) while at rest in the lying position. We also measured the results of reflective heart rate reaction to muscle tension (RR_V) during standing up sampled in active orthostasis as well as maximal rate increase (RR_B) and the index of heart adaptation to physical loads according to the Rouffier method (IR).

The research results show that only results of heart rate and heart adaptation to physical loads show reliable statistical differences in girl groups. Heart rate is lower and Rouffier index results are better for girls practicing aerobic sport disciplines. For boys, as well as for girls, heart rate values are lower and Rouffier index is better in aerobic endurance groups. Representatives of this group also have statistically better basic data of active orthostatic sampling (RR_V and RR_B). In the gender-related aspect, the data has little differences between females and males.

Physiological investigations of autonomic HR indicate that girls, when compared with boys of the same age, have greater influence of adrenergetic-humoral and parasympathetic nervous systems on HR control.

[1]Faculty of Natural Sciences, Vilnius Pedagogical University, Studentu 39, Lt – 2034, a.vilkas@vpu.lt

Key words: autonomic heart rate, Poincare plots, spectral heart rate analysis.

Introduction

In a human life, the adolescence period has a significant position. It is not only a period of active development, but also the time of versatile personality formation. The adolescence period is complex in various aspects, as representatives of different scientific spheres use different criteria as a basis while researching it. Psychologists treat the main activity type as an important criterion, while educators bring forward possibilities of knowledge acquisition, biologists and doctors see importance in the tempo of physical growth and development. As a child develops and grows, changes occur that help him or her become a complex and precisely perfect mature organism. As the body develops and grows, huge somatic changes take place. Motor functions also increase the development tempo. Therefore, it is important to investigate separately the ontogenesis of somatic-functional systems and motor ontogenesis, despite the fact that their interrelations are genetically and mutually determined. In the development process of the organism, qualitative, quantitative and differential integral changes take place, which embrace morphological, functional and motor development (Gailiuniene and Kontvainis 1994).

In the recent decades, child physical development and puberty processes have accelerated. Various hypotheses are used to explain the reasons of this phenomenon. One of the possible reasons is improving living conditions, the impact of the external environment, the lifestyle and active physical activities that accelerate organism growth and development (Vilkas 2002). The adolescence period results in functional physiological movement maturity (Žukauskiene 1998). During the organism maturation process, various functions undergo changes. Therefore, in determination and evaluation of physical preparedness, it is also necessary to determine at that period (by using physical load tests) functional cardiovascular system capacity and the level of autonomic heart rate control that reflects it (Eckberg and Sleight 1992, Sayers 1973, Žemaityte 1997). Such determining allows a more precise distinction of the functional capacity development level of adolescents' organisms. This level reflects organism reactions to physical loads while testing (Ewing et al. 1976, 1980; Kepeženas 1990, Kepeženas and Žemaityte 1998).

The aim of the research was to investigate and evaluate the peculiarities of autonomic heart rate control of 14-16-year-old adolescents' trained for physical loads of different nature (anaerobic and aerobic).

Material and Methods

144 adolescents aged 14-16 (including 62 girls and 82 boys) took part in the research and their training loads were investigated. The rhythmography method was used to determine the participating sportsmen's data of heart rates (RR_1), heart rate dispersion (s RR_1) and the amplitude of breathing arrhythmia (BA) at rest in the lying position as well as indicators of active orthostatic sampling – the indicator of reflective reaction to muscle tension while standing up (RR_V), maximal heart rate increase (RR_B) and the index of heart adaptation to physical loads according to the Rouffier method (IR). All the adolescents took part in active orthostatic sampling by uninterrupted rhythmographic registration and inputting RR interval sequences into a computer. The data was analyzed by using a computerized system of heart rate analysis. Heart rate characteristics reflecting the level of autonomic control were analyzed using spectral analysis and Poincare plots. Average level (RR) was counted while at rest in lying position, and spectral analysis was carried out. Heart rate dispersion (s RR) as well as very low (VLFC), low (LFC) and high (HFC) frequency components with absolute (ms) and relative (%) values were analyzed (Žemaityte et al. 1986). We also determined maximal heart rate reaction while standing up from the lying position (? RR_B, ms and ? RR_B, %).

Poincare plots. RR interval value sequences were used to construct Poincare plots (see fig. 1): RR interval values (RR_i) were marked on the x-axis, and the value of every next RR interval (RR_{i+1}) was marked on the y-axis. We received a dot cloud reflecting heart rate values while in the horizontal position, while standing up and in the vertical position. After having removed ectopic rates and noise values and having performed interpolation, the area of the heart rate plot reflecting sine rate in the Poincare plot (see the outlined area) was analyzed thus deriving the following values: the minimal RR sequence interval value (RR_{min}) reflecting the maximal heart rate; the maximal RR sequence interval value (RR_{max}) reflecting the minimal heart rate; heart rate variability (? RR_t) interpreted as the maximal difference between diagram points; the distance between (? RR_r) in the Poincare plot, which reflects maximal heart rate reaction during particular tests as well as the total area of the Poincare plot (P, ms^2) (Žemaityte et al. 2001).

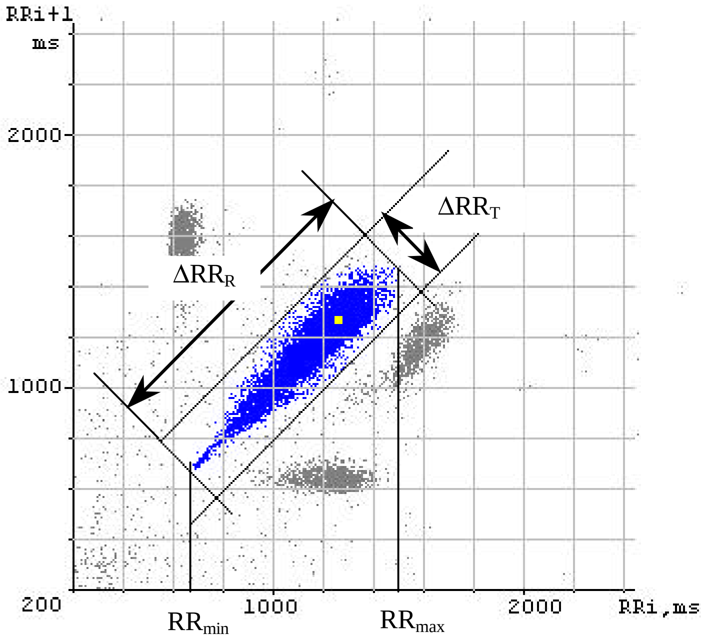

Fig. 1. Scheme of RR interval Poincare plot analysis

Results and discussion

While analyzing the results acquired through using the rhythmography method, we compared the results of heart rate and adaptation to physical loads for boys and girls in different sports activities (Table 1).

Table 1. Heart rate and physical load parameters (Me±SE) of 14-16-year-old girls and boys practising sports related to different physical loads

Parameters Experimental groups	RR_1 (ms)	sRR_1 (ms)	BA_1 (ms)	RR_B (ms)	RR_V (ms)	IR (s. units)
1. Girls' (n = 31) anaerobic loads of speed and power	880.2 ±23.1	58.20 ±4.42	91.12 ±8.40	582.6 ±12.8	718.4 ±16.6	6.40 ±0.52
2. Girls' (n = 31) aerobic endurance loads	945.3 ±20.9	58.91 ±2.59	93.80 ±5.21	610.8 ±11.9	755.7 ±12.9	4.60 ±0.43
* (p < 0.05) 1:2	*					*
3. Boys' (n = 30) anaerobic loads of speed and power	864.3 ±14.4	61.02 ±3.13	89.84 ±5.70	536.4 ±7.4	695.9 ±9.0	6.10 ±0.42
4. Boys' (n = 52) aerobic endurance physical loads	974.9 ±16.3	57.40 ±3.06	83.30 ±5.28	606.9 ±9.1	758.8 ±9.3	2.90 ±0.30
* (p < 0.05) 3:4	*			*	*	*
* (p < 0.05) 1:3				*		
* (p < 0.05) 2:4						*

The comparison of different girl group data indicates that only heart rate values while at rest and adaptation while in orthostasis show statistically reliable differences. Representatives of the aerobic sports group have lower heart rates and better Rouffier index results (lower absolute values). In boy groups, more of the registered values show reliable statistical differences between different groups. Heart rates and Rouffier index results were better, as well as among the girls, for the representatives of the aerobic group. The aerobic group also has statistically higher mean values (RR_V and RR_B) taken in active orthostasis. From the gender point of view, there are little statistically reliable differences between male and female groups.

Spectral analysis of heart rate while at rest in the lying position shows the data to be statistically similar for boys and girls, but heart rate dispersion was higher for girls (see table 2). A greater heart rate variability of girls, in comparison with that of boys of the same age, is determined by greater absolute values of VLFC ($p < 0.05$) and HFC. This also indicates dominance of more prominent adrenergetic-humoral and parasympathetic heart rate control among girls. An analysis of interrelation between parasympathetic and sympathetic control shows that boys have reliably higher relative LFC in the heart rate spectre, which reflects sympathetic control. This can also explain statistical unreliability of higher heart rates observed in boy groups while at rest. Higher absolute HFC values ($p > 0.05$) observed in the girl group reflect the level of parasympathetic control. It clearly determines higher maximal heart rate reaction measured in orthostasis (? RR_B).

Table 2. Heart rate characteristics in horizontal position, heart rate reactions to orthostasis and Rouffier index in boy and girl groups

	Boys	Girls
N	63	37
RR, ms	800.7 ± 14.88	837.0 ± 20.98
s RR, ms	50.6 ± 2.39	61.2 ± 3.13*
s VLFC, ms	22.3 ± 0.99	30.6 ± 2.32*
s LFC, ms	23.1 ± .65	23.9 ± 2.01
s HFC, ms	36.9 ± 2.18	43.5 ± 2.88
NVLFC, %	24.1 ± 1.65	29.1 ± 3.16
NLFC, %	23.2 ± 1.73	17.1 ± 1.91*
NHFC, %	52.7 ± 2.47	53.9 ± 3.54
? RR_B, ms	251.7 ± 9.78	285.9 ± 15.34
? RR_B, %	31.1 ± 0.76	33.3 ± 1.10
ROUFFIER	7.2 ± 0.35	7.2 ± 0.52

*$p < 0.5$

With the help of Poincare plots, heart rate analysis performed in orthostasis allows evaluating the peculiarities of autonomic control and the reserve of cardiovascular adaptation to physical loads (Kamen et al. 1996). Results and a graphical representation of heart rate analysis in orthostasis are presented in table 3 and figure 2. The cloud diagram composed of dots reflecting RR interval relation is larger for girls (fig. 2 B) in comparison with boys' results (fig. 2 A). Higher maximal heart rate reactions during the test and higher variability of heart rate indicate better cardiovascular system reactions and adaptation possibilities. The process takes place due to expressed level of parasympathetic control, as the maximal RR value (RR_{max}) is higher in the girl group. An analysis of Poincare plot characteristics in boy and girl groups indicates that maximal heart rate variability (? RR_t) indicating the status of autonomic control and the maximal heart rate reaction measured in orthostasis (? RR_r), which reflects adaptation possibilities, are better in the girl group.

Table 3. Heart rate characteristics during the entire orthostasis based on Poincare plot analysis male and female groups

	Boys	Girls
N	63	37
RR, ms	714.6 ± 9.90	739.2 ± 16.81
RR_{min}, ms	53.6 ± 7.12	545.3 ± 9.03
RR_{max}, ms	925.8 ± 17.68	991.2 ± 24.59*
? RR_r, ms	387.1 ± 15.05	445.8 ± 9.08*
? RR_t, %	157.9 ± 8.19	177.2 ± 9.80
P, ms^2	28133.4 ± 1416	33180.2 ± 2035*

*$p < 0.5$

A B

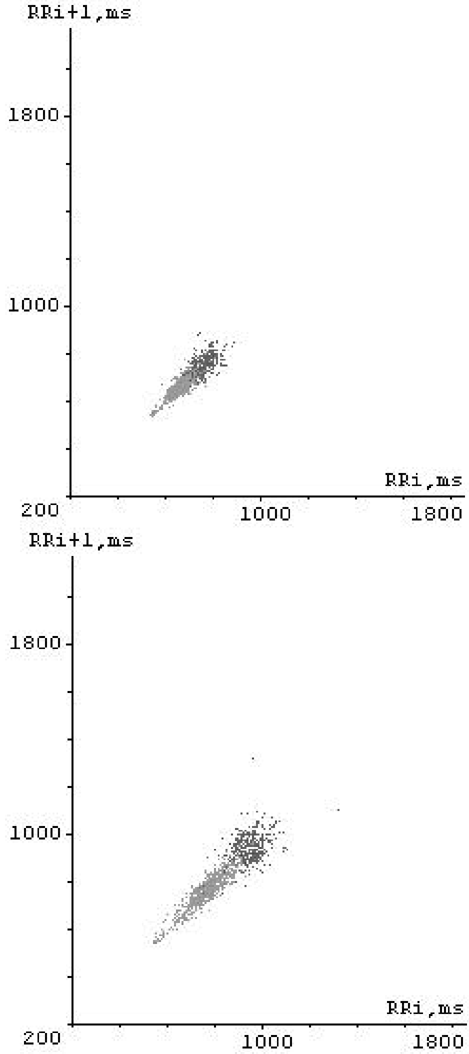

Fig. 2. Poincare plot examples for boys (A) and girls (B) registered in orthostasis

Physiological investigation of autonomic heart rate control indicates that girls, in comparison with boys of the same age, have higher-expressed influence of adrenergetic-humoral and parasympathetic systems on heart rate control, and this determines the tendency for higher heart rate reaction in orthostasis. Such differences can be explained by earlier puberty of girls.

Evaluation of autonomic heart rate control allows distinguishing the functional cardiovascular system reserve and obtaining data on particular cardiovascular system adaptation mechanisms that function during adaptation to physical loads while exercising or in real life situations.

Conclusions

1. Heart rate periodical structure results of 14-16-year-old adolescents are similar. Statistically reliable differences are only observed for heart rate results and adaptation to physical loads.
2. When compared in the gender aspect, there are little differences among 14-16-year-old female and male results of heart rates and adaptation to physical loads provided that they are in groups practicing same-typed physical activities.
3. Physiological research of autonomic heart rate control indicates that girls, when compared to boys of the same age, have a more prominently expressed impact of adrenergetic-humoral and parasympathetic systems on heart rate control, which determines the tendency of higher heart rate reaction in orthostasis (under equal physical load conditions).

REFERENCES

Ewing D.J., Kerr F., Leggett R., Murray A, 1976. Interaction Between Cardiovascular Responses to Sustained Handgrip and Valsalva Manoeuvre, British Heart Journal **38**, 483-490.

Ewing D.J., Hum L., Campbell I.W. et al., 1980. Autonomic Mechanisms in the Initial Heart Rate Response to Standing, Journal of Applied Physiology 49 , 809-814.

Eckberg DL, Sleight P. 1992. Human Baroreflexes in Health and Disease. Oxford, England: Clarendon Press; 572.

Gailiuniene A., Kontvainis V., 1994. Physicals Features of children Adolescents and Youth Kaunas, 39 (in Lithuanian).

Kamen P.W., Krum H., Tonkin A.M., 1996. Poincare Plot of Heart Rate Variability allows Quantitative Display of Parasympathetic Nervous Activity in Humans, Clinical Science 91, 201-208.

Katinas M., Vilkas A., 2002. Efficiency of Methods Related, to Developing 12 – 13 year – old Girls Coordination Abilities in classes of Physical Education, Sport science, 2, 59-62 (in Lithuanian).

Kepženas A., 1990. Evaluation of Sportsmen's Heart Adaptation to Physical Loads Using the Rhytmography Method (in Lithuanian).

Kepeženas A., Žemaityte D., 1998. Heart Rate Variability in Physical Training Control. Lithuanian Journal of Cardiology, p. 81.

Sayers B.M., 1973. Analysis of Heart Rate Variability, *Ergonomic* 16 , 17-37.

Zhemaitite D., Kepezhenas A., Martinkenas A., Podlipskite A., Varonetskas G., Zhilyukas G., 1998. Age-related Relationship of Cardiac Rhythm and Blood Flow Parameters in Healthy Subjects and Patients with Cardiovascular Diseases. Human Physiology, 6 (24), 701. Translated from Fiziologiya Cheloveka, 1998, 6 (24), 56-65.

Žemaityte D., Varoneckas G., Plauška K., Kaukenas J., 1986. Components of the Heart Rhythm Power Spectrum in Wakefulness and Individual Sleep Stages. Int. J. Physiology, 2 (4), 129-141.

Žemaityte D., Varoneckas G., Ožeraitis E., Podlipskyte A., 2001. Autonomic Heart Rate Control Evaluation by Means of Heart Rate Poincare Plot Analysis. Biomedicine, 1 (1), 1-44.