Research in Physical Education, Sport and Health
2014, Vol. 3, No. 1, pp. 75-80
ISSN(Print):1857-8152; ISSN(Online):1857-8160

CARDIOVASCULAR ADAPTATION OF JUVENILE COMPETITIVE FEMALE ATHLETES DURING THE INTENSIVE TRAINING

UDC:796.42.015.572:616.12-073.97
(Original scientific paper)

Oľga Kyselovičová[1], Miroslav Holienka[2], Martin Žamba[2], Martina Tibenská[3]
[1]*Comenius University, Faculty of Physical Education and Sports, Department of Gymnastics, Bratislava, Slovakia,*
[2]*Comenius University, Faculty of Physical Education and Sports, Department of Sport Games, Bratislava, Slovakia*
[3]*Comenius University, Faculty of Pharmacy, Department of Physical Education & Sport, Bratislava, Slovakia*

***Abstract**:*
Exercise alone induces only a small increase in cardiac mass, which is followed by a corresponding increase of performance. The aim of this project was to study changes in ECG (QRS amplitude) in junior female athletes during the initial twenty-one months of competitive training program in aerobic gymnastics. A group of 12 girls aged 13.8 ± 1.3 years underwent a newly designed intensive training program in competitive aerobic gymnastics for 21 months. The girls were routinely screened in 3-month intervals. None of the girls had any history or symptoms of underlying cardiovascular disease, or of a family history of premature death from cardiovascular disease. None was taking any form of prescribed cardiovascular drug treatment. During the study period, the number of training sessions was 4 to 5 days per week (2 hours per training session). The overall design of the training program contained the aerobics (up to 50%), dynamic strength (10%), dynamic and static strength (10%), flexibility and coordination activities (30%). The anthropometric data (BW and BH, BMI, BF%, ABM, %ABM and cardiovascular parameters (diastolic BP and systolic BPs, standard 12-lead ECG, Sokolow-Lyon index, approximated maximum spatial QRS vector magnitude – QRS_{max}) were measured and calculated. Results: The BW, BMI and ABM values increased significantly during the second half of the follow-up period compared to the initial values. The values of HR, as well as systolic BP, did not change significantly during the study period with respect to the initial values. However, the mean values of QRS_{max} and of SLI decreased gradually in the study period, and the values at the end differed significantly with respect of the initial values. The results showed that 21 months of competitive aerobic gymnastics training led to a decrease in the QRS_{max} magnitude and voltage parameters of ECG ($p \leq 0.001$). We suppose that the decrease in the QRS amplitude could be an early sign of the rebuilding of myocardium, reflecting the changes in electrical properties of myocardium at the early stage of left ventricular hypertrophy development.

Key Words: *female juvenile athletes, anthropometric and cardiovascular variables, electrocardiogram, QRS voltage*

Introduction

Exercise alone induces only a small increase in cardiac mass, which is followed by a corresponding increase of performance. 12-lead ECG in athletes frequently shows an increased QRS voltage and these QRS changes are attributed to the physiological adaptation of the heart that occurs as a consequence of systematic physical training. There is also poor agreement between the QRS voltage and the size and morphology of the left ventricle (Kansal et al, 1983; Douglas et al, 1988; George et al, 1995; Somauroo et al, 2001).

The aim of this project was to study changes in ECG (QRS amplitude) in junior female athletes during the initial twenty-one months of competitive training program in aerobic gymnastics. In this study, we tested the hypothesis that the early period of intensive physical training is associated with a decrease in

QRS amplitude. The changes in QRS amplitude in junior female athletes were analyzed during the course of 21 months training after their entry into a competitive aerobic gymnastics program.

Material & methods

A group of 12 girls aged 13.8 ± 1.3 years underwent a newly designed intensive training program in competitive aerobic gymnastics for 21 months. The girls were routinely screened in 3-month intervals. None of the girls had any history or symptoms of underlying cardiovascular disease, or of a family history of premature death from cardiovascular disease. None was taking any form of prescribed cardiovascular drug treatment.

During the study period, the number of training sessions was 4 to 5 days per week (2 hours per training session). The overall design of the training program contained the aerobics (up to 50%), dynamic strength (10%), dynamic and static strength (10%), flexibility and coordination activities (30%).

<u>The following anthropometric parameters were measured and calculated:</u>

- Body weight, body height, body mass index (BMI);
- Body fat percent (BF%) calculated as BF% =0.365×(TS+SSS+SIS+MCS)+0.62, where TS is the triceps skinfold width, SSS is the subscapular skinfold width, SIS is suprailiacal skinfold width and MCS is medial calf skinfold width;
- Absolute active body mass (ABM) calculated as ABM = bodyweight – (BF% × BW/100);
- Relative active body mass (%ABM), calculated as %ABM = 100 – BF%.

Blood pressure was recorded in sitting position after 5 minutes of rest, using the automatic barometer OMRON M4-I, Omron Matsusaka, Japan.

Then standard 12-lead ECG was recorded in supine position using the electrocardiograph SEIVA EKG, Czech Republic. Each ECG was recorded for 15 s, the average value of the first three QRS complexes were used for further calculation. This electrocardiograph works in a semi-automated mode, e.g. the onset and the end of the QRS complexes can be corrected manually, and the QRS amplitude and the heart rate (HR) are given automatically. All electrocardiographs were evaluated by one blinded researcher.

The following QRS voltage parameters were calculated and analyzed:

- Sokolow-Lyon index, calculated as the sum of SV2 plus RV5,6 [15];
- Approximated maximum spatial QRS vector magnitude (QRS_{max}), calculated using the following formula:

  $QRS_{max} = \sqrt{RV5^2 + RaVF^2 + SV2^2}$ QR

Data are presented as mean and standard deviation (SD), or standard error of the mean (SEM), respectively. The differences between the values at particular time intervals were tested using the Friedman test. A probability value $p < 0.05$ was accepted as significant. This study was approved by the Ethics Committee of Faculty of Physical Education and Sports, Comenius University, Bratislava. The girls' parents gave their informed consent for the inclusion of the girls in the study.

Results

Table 1 presents the basic statistics of the anthropometric variables in the study group. The mean values of anthropometric parameters increased significantly during the second half of the follow-up period compared to the initial values. At the end of the study period the height of the girls increased by an average of 2 cm, this increase was statistically significant as compared to the initial values. In addition, the values of body weight, BMI and ABM increased significantly during the second half of the follow-up period compared to the initial values.

The values of HR, as well as systolic BP, did not change significantly during the study period with respect to the initial values (Table 2). However, the mean values of QRS_{max} and of SLI decreased gradually in the study period, and the values at the end differed significantly with respect of the initial values. The difference between the mean QRS_{max} values at the beginning and at the end of the study period was 0.6 mV ($p \leq 0.001$), and the difference between the initial and final values of SLI was 0.5 mV ($p \leq 0.01$).

The results showed that 21 months of competitive aerobic gymnastics training led to a decrease in the QRS_{max} magnitude and voltage parameters of ECG ($p \leq 0.001$).

Table 1 *Anthropometric variables: body weight (BW), height, body-mass index (BMI), the body-fat percentage (BF%), the absolute active body-mass (ABM) and the relative active body-mass (%ABM), in the group of female athletes during the study period (mean ± SD are presented).*

Measurement	**Height [cm]**	**BW [kg]**	**BMI [kg/m²]**	**BF%**	**ABM [kg]**	**ABM %**
1	159.7 ± 4.3	46.2 ± 5.5	18.0 ± 1.5	12.4 ± 2.4	40.7 ± 4.1	87.6 ± 2.4
2	159.7 ± 4.3	46.2 ± 5.5	18.0 ± 1.5	11.3 ± 2.1	41.2 ± 4.2	88.7 ± 2.1
3	159.8 ± 4.3	46.2 ± 5.5	18.0 ± 1.5	11.5 ± 2.2	41.1 ± 4.2	88.5 ± 2.2
4	160.2 ± 4.6	47.3 ± 5.0	18.4 ± 1.3	11.5 ± 2.5	41.8 ± 3.9	88.5 ± 2.5
5	160.4 ± 4.6	48.8 ± 4.8*	18.9 ± 1.3*	12.3 ± 2.3	42.7 ± 3.5	87.7 ± 2.3*
6	160.8 ± 4.7	49.6 ± 4.4***	19.2 ± 1.2**	12.3 ± 2.3	43.4 ± 3.1	87.7 ± 2.3***
7	161.0 ± 4.6**	50.6 ± 4.4***	19.5 ± 0.9***	12.7 ± 1.9	44.1 ± 3.4**	87.3 ± 1.9***
8	161.1 ± 4.6***	50.7 ± 4.7***	19.5 ± 1.0***	12.6 ± 2.0	44.3 ± 3.6**	87.5 ± 2.0***

*p < 0.05, **p < 0.01, ***p < 0.001 (*vs.* 1st measurement)

Table 2 *The values of systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) in the group of female athletes during the study period (mean ± SD are presented).*

Measurement	**SBP [mm Hg]**	**DBP [mm Hg]**	**HR [bpm]**
1	116.8 ± 7.0	67.1 ± 7.9	77.3 ± 14.2
2	118.2 ± 8.2	66.5 ± 7.1	73.2± 14.1
3	115.2 ± 6.8	69.9 ± 7.5	76.0 ± 14.2
4	116.2 ± 5.6	67.4 ± 5.9	69.3 ± 12.2
5	115.8 ± 6.9	66.1 ± 6.5	75.8 ± 14.8
6	111.4 ± 11.1	67.3 ± 6.0	68.3 ± 10.8*
7	114.3 ± 5.2	65.0 ± 7.2	72.3 ± 12.6
8	116.3 ± 4.1	68.8 ± 6.1	68.3 ± 10.8*

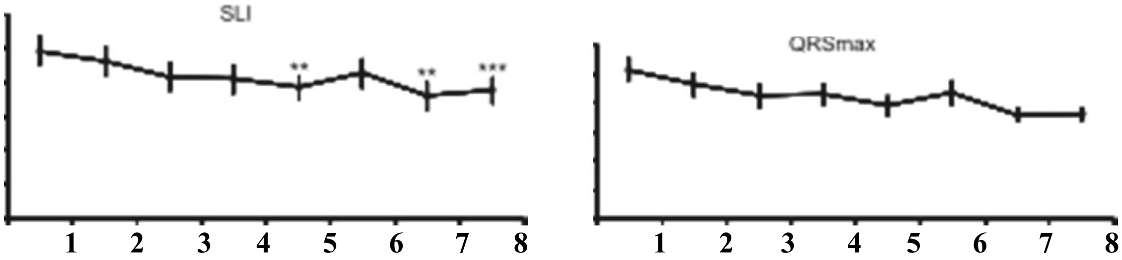

Fig. 1 Values of Sokolow-Lyon index (SLI) and of approximated maximum spatial QRS vector magnitude (QRS_{max}) during the follow-up period. Values are presented as mean, error bar indicates standard error of the mean;
$^{**}p < 0.01$, $^{***}p < 0.001$ (*vs*. 1st measurement).

Discussion

The main results of this study were the significant decrease in the QRS_{max} and SLI values, respectively. These findings were in contrast with the findings of increased QRS amplitude in athletes.

In this study, the girls were taller at the end of the follow-up period and they increased their body weight and BMI due to active body mass. However, the increase in height in the healthy population is associated with the augmentation of QRS; similarly, the body weight shows the same association (Ishikawa et al, 1976; Norman & Levy, 1996). The increased BMI and obesity are reported to decrease significantly the QRS voltage (Levy et al, 1990; Norman & Levy, 1996; Okin, 1996). However, Eisenstein et al. (1982) and Frank et al. (1986) show that low voltage is not a significant feature in the ECG of obese people. Furthermore, the increase in BMI in our study group was not due to increased percentage of fat, but to increased active body mass. Therefore, we do not suppose that the decrease in QRS voltage found in this study can be attributed to the changes in anthropometric parameters.

In this study, two QRS voltage parameters were used. The Sokolow-Lyon index represents a classical clinical ECG voltage parameter for LVH detection. It is calculated as the sum of two defined leads, i.e. it reflects changes in the cardiac electric field only in the plane defined by these two particular leads — in the horizontal plane. The reasoning for the use of the maximum spatial QRS vector is its rationality: firstly, it involves changes in all three spatial components (anterio-posterior, vertical and left-to-right), and secondly, it does not de- pend on the position of the heart.

The lack of the evidence of the influence of the "classical" factors on the QRS amplitude in this study favours the alternative explanation we hypothesize. The alternative hypothesis considers the false negative ECG results in LVH diagnostics as the reflection of the relative voltage deficit caused by changes in active and passive electrical proper- ties of myocardium in LVH (Bacharova et al, 2001). In our previous studies, we have shown the decrease in the absolute QRS amplitude as well as in the QRS to LVM ratio (the specific potential of myocardium) in the early stage of experimental models of pathological LVH, both volume and pressure overload induced (Bacharova et al, 2001; Bacharova et al, 2003). Similar results, e.g. the decrease in QRS amplitude and in the SP, are observed also in the early stage of exercise-induced left ventricular hypertrophy in swimming normotensive rats (Bacharova et al, 2005). In the literature, we have found so far only one pa- per reporting an initial decrease in QRS amplitude due to training — in obese children who participated in a jogging program. Hayashi et al. (1987) report a decrease in SV1 + RV5 voltage after 3 months of exercise training, and a return to pre-training values is observed one year after training.

Increased QRS voltage is more frequently found in highly trained athletes as compared to sedentary controls (Bjornstad et al, 1991; Bjornstad et al, 1993), and it was shown to be enhanced with increased level of training (Sharma, 2003).

Limitations of the study

The number of girls in this study is relatively small. While at the beginning, 17 girls entered the program, during the follow-up period the number decreased to 12. Only those girls who participated continuously in the competitive training during the whole study period were included in this study. In this arrangement, the girls served as their own control and the influence of inter-individual variability was reduced.

Echocardiography was not performed to quantify the changes in LVM and in the morphology of the heart since only a slight increase in LVM might be theoretically expected in this study, which would not explain the decrease in QRS voltage. It was shown that regular intensive physical training in highly trained adults is associated with a modest increase in cardiac dimensions (Oakley, 2001; Fagard, 2003; Sharma, 2003). Sharma (2003) showed that highly trained adolescents have only a slightly greater dimension of LV and LVM — they are physically less mature and have been training intensively for a shorter period.

In the design of this study, we did not use a control group. We wanted to avoid biases possibly arising from the different constitutional characteristics, incomparable life style, physical load and psychological stress between competitive athletes and sedentary controls. Furthermore, the number of girls was relatively small, which could addition- ally lead to a bias by selection in the control group.

Conclusions

This study confirmed that 24 months of competitive aerobic gymnastics training keep anthropometric and hemodynamic characteristics without the significant changes. However the specific electric parameters led to a decrease in the QRSmax magnitude. This finding is in contrast with the classical hypothesis on the ECG diagnostics of left ventricle hypertrophy and is in agreement with an alternative hypothesis on the relative voltage deficit during the early stage of LVH development.

Acknowledgements

This study was supported by projects VEGA 1/0270/13 & VEGA 1/0882/14.

References:

Bacharova, L., Kyselovic, J. (2001). Electrocardiographic diagnosis of left ventricular hypertrophy: is the method obsolete or should the hypothesis be reconsidered? *Med Hypotheses, 2001; 57:* 487-490.

Bacharova, L., Bernadic, M. & Fizelova, A. (1992). Electrocardiographic manifestation of experimental left ventricular hypertrophy. *In: Jagielski, J., Gornicki, M. eds. Electrocardiology 91. World Scientific Publ Co, Singapore 1992:* 29–32.

Bacharova, L., Kyselovic, J. & Klimas, J. (2004). The initial stage of left ventricular hypertrophy in spontaneously hypertensive rats is manifested by a decrease in the QRS amplitude/left ventricular mass ratio. *Clin Exp Hypertens, 2004; 26:* 557–567.

Bacharova, L, Michalak, K., Kyselovic, J. & Klimas, J. (2005). The relation between QRS amplitude and left ventricular mass in the initial stage of exercise-induced left ventricular hypertrophy in rats. *Clin Exp Hypertens, 2005; 27:* 533-541.

Bjornstad, H., Storstein, L., Meen, H.D. & Hals, O. (1991). Electrocardiographic findings in athletic students and sed- entary control. *Cardiology, 1991; 79:* 290-305.

Bjornstad, H., Storstein, L., Dyre, D., Meen, H.D. & Hals, O. (1993). Electrocardiographic findings according to level of fitness and sport activity. Cardiology, 1993; 83: 268-279.

Douglas, P. S., O'Toole, M.L., Hiller, W.D., Hackney, K. & Reichek, N. (1988). Electrocardiographic diagnosis of exercise-induced left ventricular hypertrophy. *Am Heart J, 1988; 116:* 784-790.

Eisenstein, I., Edelstein, J., Sarma, R., Sanmarco, M. & Selvester, R.H. (1982). The electrocardiogram in obesity. *J Electrodiol, 1982; 15:* 115-118.

Fagard, R. (2003). Athlete's heart. *Heart, 2003; 89:* 1455-1461.

Frank, S., Colliver, J.A. & Frank, A. (1986). The electrocardiogram in obesity: statistical analysis of 1,029 patients. *J Am Coll Cardiol, 1986; 7:* 295 –299.

George, K.P., Wolfe, L.A., Burggraf, G.W. & Norman, R. (1995). Electrocardiographic and echocardiographic characteristics of female athletes. *Med Sci Sports Exerc, 1995; 27:* 1362-1370.

Hayashi,T., Fujino, M., Shindo, M., Hitoki, T. & Arakawa, K. (1987). Echocardiographic and electrocardiographic measures in obese children after an exercise program. *Int J Obes, 1987; 11:* 465-472.

Ishikawa, K. (1976). Correlation coefficients for electrocardiographic and constitutional variables. *Am Heart J, 1976; 92:* 152–161.

Kansal, S., Roitman D.I. & Sheffield, L.T. (1983). A quantitative relationship of electrocardiographic criteria of left ventricular hypertrophy with echocardiographic left ventricular mass: a multivariate approach. *Clin Cardiol 1983; 6:* 456-463.

Levy, D., Labib, S.B., Anderson, K.M., Christiansen, J.C., Kannel, W.B. & Castelli, W. P. (1990). Determinants of sensitivity and specificity of electrocardiographic criteria for left ventricular hypertrophy. *Circulation, 1990;* 81: 815–820.

Norman, J.E., & Levy, D. (1996). Adjustment of ECG left ventricular hypertrophy criteria for body mass index and age improves classification accuracy. The effect of hypertension and obesity. *J Electrocardiol, 1996; 29 (suppl):* 241–247.

Okin, P.M., Roman, M.J., Devereux, R.B. & Kligfield, P. (1996). Electrocardiographic identification of left ventricular hypertrophy: test performance in relation to definition of hypertrophy and presence of obesity. *J Am Coll Cardiol, 1996; 27:* 124–131.

Oakley, D. (2001). General cardiology: The athlete's heart. *Heart, 2001; 86:* 722–726.

Sharma, S. (2003). Athlete's heart-effect of age, sex, ethnicity and sporting discipline. *Exp Physiol, 2003; 88:* 665–669.

Somauroo, J.D., Pyatt, J.R., Jackson, M., Perry, R.A. & Ramsdale, D.R. (2001). An echocardiographic assessment of cardiac morphology and common ECG findings in teenage professional soccer players: reference ranges for use in screening. *Heart, 2001; 85:* 649–654.

Corresponding Author
Oľga Kyselovičová
Comenius University, Faculty of Physical Education and Sports
Bratislava,
Slovakia,
E-mail:kyselovicova@fsport.uniba.sk