CLINICAL STUDY

Sensitive markers of the repolarization alterations in systemic hypertension

Andrasyova D, Regecova V, Tonkovic M, Kellerova E, Krc-Turbova Z, Novotna E

The Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia. **andrasy@unpf.savba.sk**

Abstract

Introduction: **The early phase of essential hypertension has been associated with changes in cardiovascular regulation caused by imbalance in some parts of autonomic nervous system. Autonomic effect of various stimuli on haemodynamic variables is usually tested by changes in blood pressure (BP) and/or heart rate (HR). It is known that increased sympathetic drive of ventricles can interfere with repolarization process.**
The aim: **This study was focused on reactive changes of maximal spatial T vector (sTmax) and R-R intervals, in relation to BP changes in 79 boys and men, averaged age 17±2 yrs. 36 from them where adolescents with elevated BP (high normal or hypertension I according to WHO/ISH1999) (EBP), 19 normotensives (NBP), and 24 normotensive sportsmen. R-R intervals and maximal spatial T vector were recorded by a PC (Cardiag METE, Prague) with Frank lead system while sitting in mid-respiratory position, during mental arithmetic (MA) and during passive head-up tilting to 60°. BP was measured simultaneously by a cuff sphygmomanometer, using phases 1 and 5 of Korotkoff sounds.**
Results: **MA resulted in significant BP increase in all subgroups, however the reactive changes of systolic BP as well as magnitude of R-R shortening, and sTmax decline were about two times higher in sportsmen. Head-up tilting evoked in all subgroups a significant increase of diastolic BP that was again higher in sportsmen vs. EBP and NBP. R-R interval became significantly ($p<0.02$) and more often shortened in sportsmen than in EBP and NBP. Relatively more evident decline of sTmax (more than 20 %) in EBP was the highest change from all observed parameters to both tested stimuli.**
Conclusion: **Our results indicate that for analysis of the effect of stimuli, which modulate balance in autonomic nervous system, it is helpful to pay attention also to the parameters of repolarization process that may represent a sensitive indicator of sympathetic tonization in myocardial ventricles.** ***(Tab. 4, Fig. 2, Ref. 27.)***
Key words: BP reactivity, R-R interval, maximal spatial T-vector, mental stress, head-up tilting.

Alterations in the cardiovascular homeostasis resulting from the disbalanced autonomic nervous system regulation play an important role in the pathogenesis of essential hypertension. They are ascribed mainly to the absolute or relative increase of the sympathetic activity, or to the increased sympathetic drive combined with decreased vagal activity.

Particularly the early phase of essential hypertension is characterized by hyperkinetic circulation, by increased stroke volume and cardiac output as well as by increased myocardial contractility due to the adrenergic hyperactivity (Finkelman et al, 1965; Julius et al, 1971). Several authors evidenced in hypertensives an exaggerated cardiovascular response to mental or to physical stress (Folle et al, 1970; Dlin et al, 1983; Fagard 1993; Nazar et al, 1997; Nawarycz et al, 1999). On the other hand no significant differences in hemodynamic response to mental stress

The Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, St. Cyril and Method Hospital, Bratislava, and Institute of Physical Education and Sport, Faculty of Medicine, Comenius University, Bratislava, Slovakia

Address for correspondence: D. Andrasyova, Institute of Normal and Pathological Physiology SAV, Sienkiewiczova 1, SK-813 71 Bratislava 1, Slovakia. Phone: +421.2.52926271, Fax: +421.2.52968516

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Tab. 1. Characterisctics of the sample.

	N	Age x±SD years	Min-Max
Normal BP	19	17.6±6.4	6.1-36
Sportsmen	24	22.3±3.8	18.2-32.9
Elevated BP	36	18.4±2.4	12.8-46.6

(Lindquist et al, 1993), static (Champlain et al, 1991), or dynamic exercise (Julius and Conway, 1968; Amery et al, 1970) between normotensive and hypertensive subjects were described. This inconsistency in literary data may be due to several factors e.g. age, gender and different body build of the subjects (Regecová and Andrásyová, 1998), selection of the normotensive controls as well as to the categorization of the hypertensives, to the suitable base line from which to analyse the reactive changes etc.

By affecting the electrophysiological functions of the heart, the increased sympathetic outflow elicits not only accelerated heart rate but also differences in the pattern of ventricular repolarization, evaluated in the earlier studies by changes of the T wave shape and amplitude (Guazzi et al, 1978; Heslegrave and Furedy, 1979). To enable the quantitative evaluation of the functional changes in repolarization, the maximal spatial T vector was proposed as a convenient parameter (Ruttkay-Nedecký, 1978). Alterations in repolarization were shown to be more frequent in hypertensives in response to stress situations as well as at rest. It is possible, that this may be an indicator of myocardial impairment even in early stages of high blood pressure development (Wu et al, 1984). The significance of the T wave changes for the assessment of the left ventricular strain in hypertensives was pointed out by Sannerstedt et al (1970).

The aim of the study was to investigate the relationship between reactive changes of BP, of R-R intervals and of the ventricular repolarization indicated by the maximal spatial T-wave vector provoked by simple non-invasive tests, increasing the sympathetic effects on the cardiovascular system. The study was performed in three groups of male subjects in whom we hypothesized different autonomic nervous cardiovascular regulation.

Methods

The study population consisted of 79 males aged 6,1—46,6 years (Tab. 1); subdivided into 3 subgroups: (1) 36 subjects (EBP) with increased BP values (high normal or hypertension I according the classification WHO/ISH 1999) without ECG signs of left ventricular hypertrophy and without antihypertensive treatment (2), 19 young normotonics (NBP) and (3) 24 healthy normotensive age matched sportsmen (Sport) active in hockey, athletic disciplines and karate respectively.

The length of R-R intervals and the magnitude of maximal spatial T vector were obtained from orthogonal Frank electrocardiography lead system (Cardiag, Mete, Prague). BP was measured simultaneously on a left arm by sphygmomanometer. The first measurement was performed in sitting probands in mid-respiration; these recordings were used as reference data. Then the test of mental arithmetic's followed (again in sitting persons): repeated substractions a two-digit number from a three-digit one. The subjects were asked to do it as quickly as possible. The next recordings of VCG and BP were performed in supine position of the proband lying on a tilt-table after 5—6 minutes. The table with proband was slowly tilted and the readings were taken immediately after achieving the 60° head-up position. By the evaluation of the size of the reactive orthostatic change, the readings in supine position were considered as initial values.

After completing the measurements in each situation the heart beat was ascertained by radial artery palpation and the next examination followed only after the HR returned to the initial level.

Statistical evaluation

Data were analysed by statistical software package STATGRAPHIC. Analysis of variance ANOVA was used to evaluate the reactive changes in each situation. In addition percentual values of the reactive changes were computed. The general relations between initial and reactive values of BP, sTmax and R-R intervals were evaluated in each subgroup separately by regression analysis. Chi-square was used for qualitative evaluation of reactive changes of electrocardiologic variables and BP significance of intraindividual reactivity was proved by one paired Student's t-test, unpaired Student's and Wilcoxon test evaluated quantitative differences in reactive changes between entire subgroups. The magnitude of the reactive changes exceeding the value of the upper quartile of the respective responses for the whole group of subjects was used as a cut-of value for definition of hyperreactivity. The relationship between investigated parameters was assessed by regression analysis.

Tab. 2. Average initial resting values x±SD of blood pressure (BP), R-R intervals (R-R) and maximal spatial T vector (sTmax) in sitting position.

	BPs (mmHg)	BPd (mmHg)	R-R (ms)	sTmax (mV)
Normal BP	117.05 ± 8.4	74.57 ± 5	762.1 ± 137.7	0.448 ± 0.2
		x	xxx	x
Sportsmen	115.83 ± 8.4	77.5 ± 4.4	985.3 ± 153.8	0.579 ± 0.2
	*** +++	*** +++	***	***+
Elevated BP	133.36 ± 6.2	84.33 ± 8,6	733.9 ± 153.7	0.326 ± 0.1

Legend: *** p<0.001 EBP vs sport, +++ p<0.001 EBP vs NBP, xxx p<0.001, x p<0.05 NBP vs sport,

Tab. 3. Average reactive changes (x±SE) of blood pressure (BP), R-R intervals (R-R) and maximal spatial T vector (sTmax) during mental arithmetics.

	BPs (mmHg)	BPd (mmHg)	R-R (ms)	sTmax (mV)
Normal BP	**14.05 ± 3.01**	**10.1 ± 1.6**	**-117.8 ± 29.9**	-0.043 ± 0.024
Sportsmen	**15.21 ± 2.16** ** +	**9.17 ± 1.43** +	xx **239.7 ± 25.6** ***	**-0.048 ± 0.023**
Elevated BP	**8.39 ± 1.34**	**6.03 ± 1.16**	**-102.8 ± 26.7**	-0.025 ± 0.013

Legend: bold - significant with respect to initial value, ** p<0.01, *** p<0.001 EBP vs sport, + p<0.05 EBP vs NBP, xx p<0.01 NBP vs sport.

Results

As expected, the average resting BP values were significantly higher in the EBP subgroup than in normotensives and sportsmen (p<0.001).

R-R intervals were significantly (p<0.001) longer in sportsmen in comparison with EBP or NBP subgroup. There were not significant differences between EBP and NBP. Magnitude of sTmax was highest in sportsmen and lowest in EBP (p<0.001), also in comparison with NBP (p<0.05). There was a significant difference between EBP and NBP as well (p<0.05) (Tab. 2).

Reactivity during mental arithmetic's

Blood pressure

BP increased significantly in all subgroups; in sportsmen the magnitude of the systolic BP increment was significantly (about two times) higher as compared to EBP group. The lowest increase of the diastolic BP (p<0.05) was observed in the EBP group (Tab. 3 and Fig. 1). The magnitude of systolic BP increments did not correlate with the initial values in none of the subgroups. The reactive increment of the diastolic BP in NBP correlated negatively with its initial value (p<0.05).

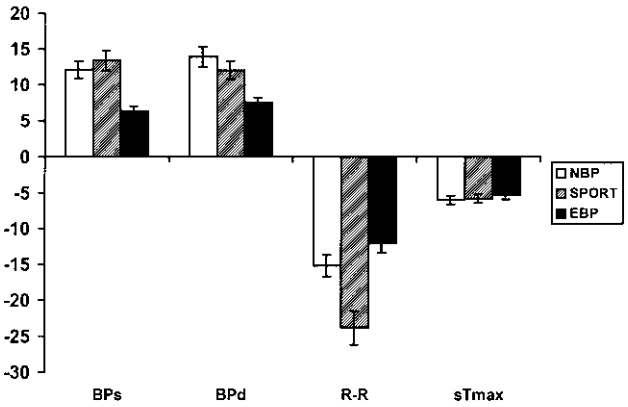

Fig. 1. Average percentual magnitude of reactive changes (x±SE) of blood pressure (BP), R-R intervals (R-R) and maximal spatial T vector (sTmax) during mental arithmetics. ** p<0.01, *** p<0.001 EBP vs sport, + p<0.05 EBP vs NBP, xx p<0.01 NBP vs sport.

During MA the BP increased (with only 1—2 exceptions) in all of the sportsmen and normotonics. Greater variability in reactivity of BP and heart rate was observed in EBP subgroup, where in 20 % not only BP but also heart rate did not increase.

R-R intervals

During mental arithmetic's there was a significant decrease of R-R interval duration in all subgroups, whereby this shortening in sportsmen was approximately two times greater in comparison with EBP and NBP. There were no significant differences in shortening of R-R intervals between EBP and NBP subgroups. Whereas in sportsmen R-R intervals shortened in all cases (in NBP subgroup only with one exception), in EBP subgroup this pattern of reactivity was present only in 77 %. Paradoxically in 8 subjects R-R intervals prolonged and were accompanied with a tendency to lower reactive increments of the systolic BP (4.6±2.5 mmHg versus 10 mmHg, p<0.062).

Amplitude of sTmax

There was an average reactive decrease of the sTmax amplitudes in all subgroups, but significant only in sportsmen (almost two times greater in comparison with EBP p<0.05) (Tab. 3 and Fig. 1).

The relationship between R-R intervals and sTmax amplitude

The relationship between the sTmax magnitude and the length of R-R intervals was confirmed in all subgroups (p<0.001) also during mental arithmetic's. Shortening of the R-R intervals was proportional to the decrease of s Tmax amplitude. Coefficient of determination ranged from 16.5 in EBP to 25 % in NBP. In one half of those subjects who prolonged R-R intervals, the amplitude of sTmax significantly increased (by 0.067±0.03 mV versus -0.066±0.03 mV, p<0.001).

Reactivity during passive orthostasis

Blood pressure

The only significant (p<0.03) change of systolic BP was its decrease in average by -5.1 mmHg in NBP subgroup. This type of reactivity was significantly (p<0.04) different from sportsmen whose systolic BP moderately increased. Diastolic BP in all subgroups significantly (p<0.001) increased without any intergroup differences (Tab. 4 and Fig. 2).

Tab. 4. Average reactive changes (x±SE) of blood pressure (BP), R-R intervals (R-R) and maximal spatial T vector (sTmax) during tilting.

	BPs (mmHg)	BPd (mmHg)	R-R (ms)	sTmax (mV)
Normal BP	**-5.1 ± 2.32**	**10.1 ± 1.22**	**-141 ± 23.3**	**-0.082 ± 0.013**
	x		x	
Sportsmen	1.2 ± 2.02	**12.7 ± 1.41**	**-198 ± 23.2**	**-0.109 ± 0.081**
			*	
Elevated BP	-2.9 ± 1.8	**9.9 ± 1.32**	**-130 ± 23.9**	**-0.092 ± 0.082**

Legend: bold - significant with respect to initial value, * p<0.05 EBP vs sport, x p<0.05 NBP vs sport.

R-R intervals

The shortening of R-R intervals was among all investigated parameters the most pronounced phenomenon in tilting, similarly as it was in MA. The Wilcoxon test confirmed (p<0.02) more frequent and significantly greater degree of shortening of R-R intervals in sportsmen and NBP subgroup in comparison with EBP. Anyhow, this orthostatic R-R shortening in sportsmen did not achieve such a great extend as it was observed in MA. In contrast to it, absolute changes in R-R intervals in EBP and NBP subjects were more pronounced in tilting than in MA (Tab. 4).

sTmax amplitude

The magnitude of maximal sTmax decreased in the average significantly in all subgroups without significant quantitative intergroup differences. Taking into account the initial values in supine position the relatively greatest decrease was shown in the EBP subgroup (over 22 %).

The relationship between R-R intervals and sTmax

The magnitude of sTmax increased in supine position simultaneously with prolongation of R-R intervals and during passive orthostatic test decreased proportionally with shortening of R-R intervals (p<0.002).

Our results have shown, that among all investigated parameters, the most pronounced changes (shortening) occurred in R-R intervals in sportsmen during MA, whereas in EBP and NBP subjects the most pronounced shortening was observed during tilting. In the whole sample the passive orthostatic test was a stronger stimulus for changes (decrease) of sTmax amplitude than MA. Tilting resulted in its greatest percentual change in the EBP.

Discussion

According to our previous preliminary results (Kellerová et al, 1999; Regecová et al, 2000), the group of subjects with elevated BP had — as expected — at rest significantly lower sTmax amplitude than normotensives and sportsmen and shorter R-R intervals but in comparison with sportsmen only. The difference in ventricular recovery may reflect an augmented sympathetic activation of the ventricular myocardium in the EBP subjects even under resting conditions. It is consistent with the increased sympathetic cardiac activity in borderline hypertension, evidenced by beta-adrenergic blockade (Julius et al, 1971; Dilaveris et al, 2001).

The reaction pattern to mental stress and to head-up tilting was in the average comparable in all three subgroups of subjects, although there were significant differences in the amplitude of the reactions. The group of sportsmen reacted to the mental arithmetic test uniformly with heightened, in some parameters almost doubled responses (systolic BP, R-R intervals), namely in comparison with the EBP subgroup. This may indicate presence of a more pronounced component of the reactive decrease of vagal inhibition in sportsmen, concomitant sympathetic activation. Among EBP subjects the reactions of BP and R-R intervals to mental stress were less consistent, 22 % of them displayed even a paradox prolongation of R-R intervals associated in the average also by smaller systolic BP changes. This type of reaction was present only in 1 out of 19 normotensive controls. Observed irregularities in the blood pressure and heart rate responses may be due to interindividually different alterations in the autonomic cardiovascular regulations. During mental arithmetic, the absolute as well as relative rise in both the systolic and diastolic blood pressure, shortening of R-R intervals and decrease of sTmax magnitude, were less in the EBP subgroup. All investigated subgroups including EBP, responded to the 60° tilt to the head-up position in a very similar fashion. Increases of diastolic blood pressure and shortening of R-R intervals in the

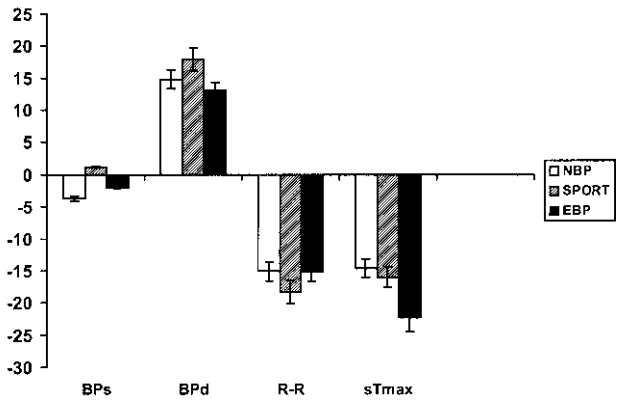

Fig. 2. Average percentual magnitude of reactive changes (x±SE) of blood pressure (BP), R-R intervals (R-R) and maximal spatial T vector (sTmax) during tilting. * p<0.05 EBP vs sport, x p<0.05 NBP vs sport.

average of similar degree were observed in both controls and EBP subjects. Above mentioned results are on the side of previous studies reporting that young patients with borderline or mild hypertension respond practically in the same manner as normotensive controls to different stress procedures like mental arithmetic (Brod et al, 1959), head up tilt (Essler and Nestel, 1972), static (Sannerstedt and Julius, 1972) or dynamic (Amery et al, 1967) exercise. It supports also the conclusion of Sannerstedt et al (1970) based on BP, HR and cardiac output responses to 45° head-up tilt, that there is no hyperactivity in borderline hypertension and that the acute regulation of circulation is not abnormal. In contrast to it, the heightened BP reactions to head-up tilt (Westheim et al, 1990) or dynamic exercise (Amery et al, 1967) were described, but in older subjects with mild or moderate hypertension.

Considering subjects responding by an exaggerated systolic BP increase to mental arithmetic's (greater than 15 % of the resting value), their proportion was surprisingly less in the EBP subgroup — 8 %, in comparison to 29 % in sportsmen ($p<0.05$) and 26 % in controls. It is in contrast with the specific hyperreactivity to mental stress in subjects with a high screening casual blood pressure percentiles described by Rostrup et al (1993). The systolic BP hyperresponsiveness to mental arithmetic did not show correlation to any other investigated parameters, except to shortening of R-R intervals in sportsmen. There were no significant differences among subgroups in the occurrence of the exaggerated diastolic BP or R-R intervals response to head-up tilt.

The effect of the different physiological stimuli, known to engender an increased sympathetic drive to the heart, on the ventricular repolarization vectors has been scarcely investigated. The magnitude of the maximal spatial repolarization vector (sTmax) decreased during the mental arithmetic test in approximately 2/3 of subjects in all groups, whereby its decrement in mV was less in the EBP subgroup and greatest in sportsmen. It may be speculated that it is due to the higher baseline sympathetic drive of the ventricular myocardium in the EBP subjects. Ruttkay-Nedecký (1978) described in a comparable percentage (65 %) of healthy subjects significant diminution of the maximal spatial repolarization vector (sTmax) due to emotional stress of mental arithmetic. Alterations of the repolarization during mental stimuli, concomitant with enhancement in myocardial contractility were suggested to be associated with, and possibly a consequence of adrenergic activation (Guazzi et al, 1978). This explanation is supported by similar repolarization changes observed during dopamine infusion (Kellerová et al, 1984).

The sTmax diminution due to the tilting was more than doubled in magnitude comparing to the mental arithmetic response and observed in 85 % of subjects. The exaggerated response of ventricular repolarization to head-up tilt clearly differentiated the groups of subjects analysed. Those with EBP showed not only the most pronounced relative diminution of the sTmax, but also significantly higher percentage (39 %) of excessive sTmax responses, in comparison with normotensives (10 %, $p<0.025$) and sportsmen (0 %, $p<0.001$). This seems to reflect a difference among the subgroups in the sympathetic stimulation of the ventricular myocardium.

To analyse the effect of physiological stimuli modulating the autonomic nervous regulation of the heart, it is of use to investigate not only the HR reflecting the combined vago-sympathetic effect on the sino-atrial node, but additionally to it the pattern of ventricular repolarization, which is considered to be influenced mainly by the variations of the adrenergic discharge to the heart.

The baseline repolarization parameter was sensitive enough to discriminate groups of subjects with hypothetically different autonomic regulation of the heart (EBP subgroup, controls and sportsmen), whereas the R-R intervals at rest distinguished only the subgroup of sportsmen.

The same discriminative effect was observed in exaggerated changes of repolarization elicited by tilting, compared to R-R intervals.

References

Amery A, Julius S, Whitlock S, Conway J: Influence of hypertension on the hemodynamic response to exercise. Circulation 1967; 36: 231—237.

Brod J, Fencl V, Hejl Z, Jirka J: Circulatory changes underlying blood pressure elevation during acute emotional stress (mental arithmetic) in normotensive and hypertensive subjects. Clin Sci 1959; 18: 269—279.

Dilaveris P, Gialafos E, Pantazis A, Synetos A, Triposkiadis F, Gialafos J: The spatial QRS-T angle as a marker of ventricular repolarization in hypertension. J Hum Hypertens 2001; 15 (1): 63—70.

Dlin RA, Hanne N, Silverberg DS, Bar-Or O: Follow-up of normotensive men with exaggerated blood pressure response to exercise. Amer Heart J 1983; 106: 316—320.

Esler MD, Nestel PJ: Sympathetic responsiveness to head-up tilt in essential hypertension. Clin Sci 1973; 44: 213—226.

Fagard RH: Physical fitness and blood pressure. J Hypertens 1993; 11 (Suppl 5): 47—52.

Finkielman A, Worcel M, Agrest A: Hemodynamic patterns in essential hypertension. Circulation 1965; 31 (3): 356—368.

Folle L, Dighiero J, Sadi I, Pommerenck C, Elena R: Hemodynamic response to exercise after beta-adrenergic blockade in normal and labile hypertensive patients. Cardiology 1970; 55: 105—113.

Guazzi MD, Magrini F, Olivari MT, Polese A, Fiorentini C: al: Influence of the adrenergic nervous system on the repolarization phase of the electrocardiogram. Angiology 1978; 29 (8): 617—630.

Haslegrave FJ, Furedy JJ: Sensitivities of heart rate and T-wave amplitude for detecting cognitive and anticipatory stress. Physiol Behav 1979; 22 (1): 17—23.

Champlain J, Petrovich M, Gonzalez M, Lebeau R, Nadeau R: Abnormal cardiovascular reactivity in borderline and mild essential hypertension. Hypertension 1991; 17 (Suppl III): III-22—III-28.

Julius S, Conway J: Hemodynamic studies in patients with borderline blood pressure elevation. Circulation 1968; 38 (8): 282—288.

Julius S, Pascual AV, London R: Role of parasympathetic inhibition in the hyperkinetic type of borderline hypertension. Circulation 1971; 44 (9): 413—418.

Kellerová E, Vigaš M, Kvetňanský R, Ježová D: The influence of dopamine on the maximal spacial repolarization vector of the human heart. 78—83. In: Ruttkay-Nedecký I, Macfarlane P (Eds): Electrocardiology•83, Excerpta Medica, Amsterdam 1984.

Kellerová E, Regecová V, Andrásyová D: Evidences for increased vasomotor and myocardial symphatetic drive in hypertensives and subjects with high normal blood pressure. Cor Vasa 1999; 41 (5): K150.

Lindqvist M, Kahan T, Melcher A, Hjemdahl P: Cardiovascular and sympatho-adrenal responses to mental stress in primary hypertension. Clin Sci 1993; 85: 401—409.

Nawarycz T, Ostrowska-Nawarycz L, Kaczmarek J: (Abstract) Impact of cardiovascular reactions using the impendance cardiography method in borderline hypertension. Ann NY Acad Sci 1999; Apr 20, 873: 174—181.

Nazar K, Kaciuba U, Ziemba W, Krysztofiak H, Wojcik-Ziolkowska E, Niewiadomski W, Chwalbinska-Moneta J, Bicz B, Stupnicka E, Okinczyc A: Physiological characteristics and hormonal profile of young normotensive men with exaggereted blood pressure response to exercise. Clin Physiol 1997; 17: 1—18.

Regecová V, Andrásyová D, Ruttkay-Nedecký I: Electrocardiologic objectivitation of sympathetic nervous drive of ventricles in subjects with elevated blood pressure and in sportsmen, Homeostasis 2000; 41 (3—4): 118—120.

Regecová V, Andrásyová D: Stavba tela a distribúcia podkožného tuku u juvenilných hypertonikov. Cardiol 1998; 7 (1): 9—14.

Rostrup M, Westheim A, Kjedsen ES, Eide I: Cardiovascular reactivity, coronary risk factors, and sympathetic activity in young men. Hypertension 1993; 22: 891—899.

Ruttkay-Nedecký I: Effect of emotional stress (mental arithmetic) on amplitudes of P and T waves of the orthogonal electrocardiogram. Bratisl Lek Listy 1978; 69: 638—646.

Sannerstedt R, Bjure J, Varnauskas E: Correlation between electrocardiographic changes and systemic hemodynamic in human arterial hypertension. Amer J Cardiol 1970; 26 (8): 117—122.

Sannerstedt R, Julius S, Conway J: Hemodynamic responses to tilt and beta-adrenergic blockade in young pattients with borderline hypertension. Circulation 1970; 47 (12): 1057—1064.

Sannerstedt R, Julius S: Systemic haemodynamics in bordeline arterial hypertension:responses to static excercise before and under the influence of propranolol. Cardiovasc Res 1972; 7 (4): 398—403.

Westheim A, Kjeldsen SE, Fonstelien E, Eide IK: Renal haemodynamic and sympathetic responses to head-up tilt in essential hypertension. Scand J Clin Lab Invest 1990; 50: 815—822.

Wu SC, Secchi S, Mancarella L, Fossa L, Bettazzi L, Oltrona L, Ciro A, Civelli J, Folli G: Usefulness of stres testing for the evaluation of hypertensive heart disease in young hypertensive subjects. Cardiology 1984; 71: 277—283.

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