Short Comunications

Hemodynamics patterns at rest and during isometric sustained weight test in normorreactive, hyperreactive and with hypertensive response young people: gender differences

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ABSTRACT

Introduction: a number of adjustments of the cardiovascular system are required during isometric exercise; variations in the components involved in young people blood pressure response result controversial.

Objective: to determine the difference between gender at baseline hemodynamic parameters and during isometric Sustained Weight Test in normorreactive, hyperreactive and with hypertensive response young people.

Methods: sample was constituted by 97 young people of both genders, 41 males and 56 females, with an average age of 19±1,40 years, whom was applied hemodynamic monitoring in supine decubitus position with non-invasive by impedance cardiography at rest and while the sustained weight test was performed.

Results: significantly superior values of heart rate and cardiac index were obtained in normorreactive women in basal conditions, and at the exercise. Normorreactive male had significantly higher systemic vascular resistance index than females in both conditions and the hypertensive response group had differences only in the exercise. Women achieved higher heart rate increments than men during isometric exercise. Systemic vascular resistance index were increased in all groups of both genders, mainly in normorreactive men.

Conclusions: at baseline, women had higher values of hemodynamic variables related to cardiac activity and men related to vascular tone. Differences between both genders remained during isometric exercise, and the increased blood pressure was mainly due to the increase of systemic vascular resistance.

Keywords: cardiovascular reactivity, sustained weight test, hemodynamics, cardiography impedance.

INTRODUCTION

Arterial Hypertension is a health problem worldwide and in Cuba, so the improvement of strategies to achieve prevention and the search for methods to predict it is a major challenge. At present, there are different methods that allow finding individuals at risk and establish appropriate mechanisms to reduce the prevalence of that entity. Those individuals that show an increase in response or a greater sensitivity of the cardiovascular system to sympathetic activity have a state called cardiovascular hyperreactivity.[(1)]

Benet M. and collagues[(1)] have shown that the tests that detect hyper-reactive cardiovascular individuals can be good predictors of hypertension, based on the fact that those with greater hyperreactivity have an increased risk of developing established hypertension and that this risk is independent of the presence of other markers of cardiovascular risk.

There are several tests to induce cardiovascular hyperreactivity, one of them is the use of isometric exercise. Within the isometric tests is the Sustained Weight Test (SWT). It was developed at the University of Medical Sciences of Villa Clara in the 80s of the last century by Paz Basanta and colleagues[(2)], which has been applied in multiple investigations in the country. These studies have confirmed that the SWT guarantees adequate sensitivity, specificity and feasibility, as well as reproducibility for diagnosis of hypertension in primary health care.

Several studies carried out in healthy adults show that the pressor response to isometric exercise is established through an increase in cardiac output, vascular resistance or both. The variability of the findings is attributed to the fact that there are individual differences in the components of this response. The hemodynamic modifications that occur during the classical handgrip test are well established; nevertheless, the sustained weight test is a new variant of isometric test that includes other muscle groups and has not been sufficiently studied, as well as its behavior in relation to sex in young individuals with different degrees of cardiovascular reactivity.

Therefore, the aim of this study was to determine the gender differences in baseline hemodynamic variables and during isometric exercise in normorreactive, hyperreactive and with hypertensive response young people.

METHODS

A transversal analytical study was carried out in the Biomedical Research Unit of the University of Medical Sciences of Villa Clara. The sample consisted of 97 young people, 41 males and 56 females, with an average of 19 ± 1,40 years old.

The individuals underwent a medical interview and a physical examination, which included a basal systolic blood pressure (SBP) and diastolic blood pressure (DBP) in the right upper limb in a sitting position by the classical auscultatory method and, subsequently, the WST was carried out in compliance with the established requirements[(2)]. Individuals were classified as normorreactive, hyperreactive and with hypertensive response, according to the values of mean arterial pressure (MAP) reached during the WST. One individual was considered a normorreactive when MAP was less than 110 mmHg in men and 105 mmHg in women. Hyperreactive if it was equal to or greater than 110 mmHg and less than 120 mmHg in men and equal to or greater than 105 mmHg and less than 115 mmHg in women and with a hypertensive response if it was equal to or greater than 120 mmHg in the male sex and the same or greater than 115 mmHg in the female sex[(2)]. The group of normorreactives was formed by 59 individuals, the hyperreactive group by 32 young people and only six individuals had hypertensive response to the SWT.

A non-invasive hemodynamic study was performed using transthoracic impedance cardiography. Each individual was monitored for 10 minutes in supine position at baseline and, later, during the WST. In this study we obtained variables that indicate both cardiac and vascular functional status: Heart Rate (HR) in beats per minute, Systolic Volume (SV) in ml, Cardiac Index (CI) in Lxmin^{-1}xm^{-2}, Left Cardiac Work (LCW) in Kgxm, Left Ventricular Ejection Time (LVET) in ms, Systemic Vascular Resistance Index (SVRI) in dinasxsegxcm^{-5}xm^{2}, Total Compliance Arterial Index (TCAI) in ml/m^{2}/mmHg.

For the statistical analysis, the student's T test was used in the comparison of independent groups, after checking the assumptions. An α significance level of 0.05 was established.

RESULTS

Table 1 shows the hemodynamic variables at rest according to the study groups, grouped by sex. The variables are expressed in values of the mean and the standard deviation.

Table 1. Baseline hemodynamic variables distributed by group and gender

	Normorreactives		Hyperreactives		Hypertensive response		p		
	Fem	**Males**	**Fem**	**Males**	**Fem**	**Males**	**NR-HR**	**NR-HT**	**HR-HT**
n	**31**	**28**	**21**	**11**	**4**	**2**			
SBP	109,9 ± 9,8	114,5 ± 11,3	120,6 ± 7,1	127,5 ± 12,4	130,5 ± 14,6	139,0 ± 18,4	0,000	0,000	0,032
DBP	70,6 ± 10,4	73,5 ± 7,4	78,5 ± 7,9	78,7 ± 6,0	88,5 ± 9,8	91,0 ± 9,9	0,001	0,000	0,003
MAP	83,65 ± 9,3	87,2 ± 7,7	92,5 ± 6,2	95,0 ± 7,0	102,2 ± 11,1	107,0 ± 12,7	0,000	0,000	0,002
TCAI	1,15 ± 0,39	0,98 ± 0,30	1,11 ± 0,31	0,88 ± 0,24*	1,09 ± 0,28	0,83 ± 0,23	0,446	0,646	0,841
SVRI	1177,3 ± 383,5	2396,7 ± 419,0*	2015,9 ± 329,5	2330,6 ± 426,1*	2025 ± 467,2	2317,0 ± 359,2	0,998	0,994	0,992
HR	76,1 ± 9,3	68,4 ± 8,0*	78,1 ± 9,6	74,5 ± 12,0	89,8 ± 15,6	78,0 ± 1,4	0,044	0,002	0,072
SV	67,00 ± 13,7	66,8 ± 10,6	73,0 ± 15,1	76,27 ± 19,0	75,2 ± 26,3	81,0 ± 1,4	0,019	0,072	0,690
CI	3,3 ± 0,6	2,7 ± 0,4*	3,5 ± 0,43	3,1 ± 0,59	3,9 ± 1,0	3,5 ± 0,12	0,020	0,008	0,113
LCW	5,66 ± 1,64	4,89 ± 0,98*	6,56 ± 1,19	7,30 ± 1,76	12,18 ± 8,89	8,32 ± 2,15	0,000	0,000	0,006
LVET	297,39 ± 16,40	293,21 ± 26,57	296,28 ± 18,54	293,52 ± 24,20	284,06 ± 24,38	259,88 ± 36,87	0,948	0,096	0,104

Legend: Fem: females, NR: Normorreactives, HR: Hyperreactives, HT: Hypertensive response. SBP: Systolic blood pressure (mmHg), DBP: Diastolic blood pressure (mmHg), MAP: Mean arterial pressure (mmHg), TCAI: Total Compliance Arterial Index ($ml/m^2/mmHg$), SVRI: Systemic Vascular Resistance Index ($dinasxsegxcm^{-5}xm^2$), HR: Heart Rate (lat / min), SV: Systolic volume (ml), CI: Cardiac Index($Lxmin^{-1}xm^{-2}$), LCW: Left Cardiac Work (Kgxm), LVET: Left Ventricular Ejection Time (ms). The asterisk represents significant differences in the comparison between sexes of the same group.

The hypertensive response group was formed of a very small sample, which is to be expected, since the sample was randomly selected in young individuals, in whom this disease has a low prevalence.

Regarding the variables that determine the vascular functional status, it was found that the values of the mean of the SBP, DBP and MAP were higher in males in all groups, but without significant differences with females. The mean of the TCAI showed lower values in men in all groups, but only in the group of hyperreactive the differences between the sexes was significant ($p < 0.05$); In addition, no significant differences were found between the groups. In men, SVRI was higher in the three groups, with significant differences in the normorreactive and hyperreactive groups ($p < 0.05$).

On the other hand, the mean HR and CI was higher in women than in men in all groups, although differences between the sexes were only highly significant in the normorreactive group ($p < 0.01$). The SV did not differ between the sexes, although it was higher in the men of the hyperreactive and with hypertensive response groups. LVET presented similar values in both sexes in all groups. However, LCW presented significant differences ($p<0.01$) in the comparison between groups, with higher numbers in hyperreactive and with hypertensive response subjects. In the comparison of the TCI between genders, there were significant differences only in the normorreactive group, in which women showed higher values than men.

Table 2 shows the hemodynamic variables of the study according to the values reached at the second minute of the WST grouped by sex in the different groups.

Table 2. Hemodynamic variables during the isometric weight test distributed by group and gender

	Normorreactives		Hyperreactives		Hypertensive response		p		
	Fem	Males	Fem	Fem	Males	Fem	NR-HR	NR-HT	HR-HT
n	31	28	21	11	4	2			
SBP	118,4 ± 7,7	122,6 ± 11,2	129,0 ± 8,3	134,4 ± 10,7	141,5 ± 14,0	151,0 ± 12,7	0,000	0,000	0,004
DBP	82,6 ± 8,8	82,9 ± 7,1	91,1 ± 5,6	90,5 ± 5,6	98,5 ± 8,0	100,0 ± 8,5	0,000	0,000	0,004
MAP	94,6 ± 7,3	96,1 ± 7,5	103,7 ± 5,6	105,4 ± 4,7	112,8 ± 9,6	117,0 ± 9,9	0,000	0,000	0,001
TCAI	1,26 ± 0,39	1,03 ± 0,24*	1,21 ± 0,29	0,96 ± 0,26*	1,04 ± 0,22	0,88 ± 0,06	0,553	0,049	0,143
SVRI	2129,3 ± 372,2	2611,6 ± 352,1*	2235,7 ± 356,8	2494,7 ± 371,2	2193,3 ± 56,6	2567,5 ± 350,0	0,715	0,825	0,967
HR	82,8 ± 9,0	72,6 ± 11,2*	85,2 ± 9,8	81,1 ± 14,6	101,8 ± 1,9	88,0 ± 5,7*	0,022	0,000	0,011
SV	65,0 ± 14,1	67,3 ± 11,1	72,6 ± 13,8	77,8 ± 15,0	72,5 ± 15,1	80,5 ± 15,1	0,005	0,106	0,906
CI	3,4 ± 0,5	3,0 ± 1,3	3,5 ± 0,5	3,2 ± 0,5	3,9 ± 0,3	3,4 ± 0,2	0,218	0,174	0,151
LCW	6,59 ± 1,91	5,65 ± 1,08*	7,48 ± 1,47	8,23 ± 1,86	9,63 ± 2,23	9,08 ± 2,79	0,000	0,004	0,084
LVET	293,98 ± 21,89	297,42 ± 24,46	297,08 ± 15,51	298,33 ± 25,24	273,13 ± 12,18	290,78 ± 18,91	0,577	0,040	0,021

Legend: Fem: females, NR: Normorreactives, HR: Hyperreactives, HT: Hypertensive response. SBP: Systolic blood pressure (mmHg), DBP: Diastolic blood pressure (mmHg), MAP: Mean arterial pressure (mmHg), TCAI: Total Compliance Arterial Index ($ml/m^2/mmHg$), SVRI: Systemic Vascular Resistance Index ($dinasxsegxcm^{-5}xm^2$), HR: Heart Rate (lat / min), SV: Systolic volume (ml), CI: Cardiac Index($Lxmin^{-1}xm^{-2}$), LCW: Left Cardiac Work (Kgxm), LVET: Left Ventricular Ejection Time (ms). The asterisk represents significant differences in the comparison between sexes of the same group.

Similar to the baseline status, it could be observed that the mean SBP, DBP and MAP were higher in men in all groups, but without significant differences with females. The mean of the TCAI showed lower values in the men in all groups, although during the exercise the differences between the sexes were statistically significant between normorreactive and hyperreactive groups. In addition, significant differences were found between normorreactive and with hypertensive response groups. The SVRI was also higher in the male sex but the differences were only significant in the normorreactive group ($p<0.01$).

On the other hand, the mean HR and CI was higher in women than in men in all categories, similar behavior was presented in the baseline state, although only significant differences were obtained in the normorreactive and with hypertensive response groups for the FC. The SV was higher in men, but without differences between the groups. The LVET presented similar figures in both sexes in each group; however, significant differences were found between hyperreactive and normorreactive with hypertensive response groups. On the other hand, the mean of the LCW presented statistically significant higher values in hyperreactives with respect to the normorreactives and the differences between the men and the women in the group of normorreactives were maintained.

DISCUSSION

Cardiovascular hyperreactivity (CVHR) is the increase of blood pressure (BP), heart rate and other hemodynamic parameters beyond the values considered normal, in the presence of a physical or mental stimulus. Several investigations have determined that CVHR is an independent risk marker for hypertension in normotensive or prehypertensive individuals.[(1)]

This has been tried to explain by the hypothesis that in the heart and the blood vessels structural adaptations take place in response to a greater pressure overload and these changes could contribute to the structurally induced hyperreactivity. Therefore, it could be postulated that repeated episodes of pressure response induced by stress could be enough to trigger hypertrophy of the vascular smooth muscle and this, in turn, increase the total peripheral resistance, which would contribute to the subsequent elevation of the BP.[(1)]

It is noteworthy that several authors consider the category of hyperreactive as a state of prehypertension and constitutes, in a significant group of individuals, a state of transition towards hypertension. The exaggerated cardiovascular response is largely due to the increase in the activity of the sympathetic nervous system (SNS), to the imbalance in the functioning of this system or to a greater sensitivity of the cardiovascular system to the activity of the SNS.[(1)]

It is a known fact that in the initial stages of hypertension, individuals present a state characterized by increased cardiac output, considered hyperdynamic. This state is related to the increase in stroke volume and/or heart rate as a consequence of hyperactivity of the SNS and/or a decrease in vagal tone. As the disease progresses, through the development of compensatory mechanisms of local flow in the tissues, arteriolar tone increases and consequently increases the systemic vascular resistance (SVR), so that the individual goes from a hyperdynamic state to a vasocontrictor[(3,4)]

In this study, the values of HR, SV and CI were higher in hyperreactives, which can be explained by what was stated above, that the initial stages of BP elevation are characterized by a hyperdynamic phase. In addition, it is found that as the values of the arterial compliance index are lower and those of vascular resistance are higher, the cardiac index is lower, which is related to the fundamental law of hemodynamics.

In basal conditions, LCW was also higher in the hyperreactive than in the normorreactive young people. It is known that work is equal to the product of pressure by volume; therefore, in the left ventricle, external work is equal to the systolic output multiplied by the difference in the mean expulsion pressure of the left ventricle minus the mean input pressure in the left ventricle during diastolic filling. For practical purposes, it is assumed that mean expulsion pressure is similar to MAP; in this way, the hearts of the subjects of the hyperreactive group have to perform a greater work per heartbeat of the left ventricle, which is related to the increase of MAP.[(5)]

It has been shown that in the young individual there is an increased activity of the autonomic nervous system (ANS), which is associated with a high SVR and a lower cardiac output.[4] However, it is suggested that ANS activity at the peripheral vascular level in young adults can also change from seven to ten times between men and women. It has been reported that there is a greater β-adrenergic vasodilator response in women than in young men.

This type of response confers a lower arteriolar resistance to women and may explain that the SVRI in females is lower than in males, especially in normorreactives. In young women there is a loss of the relationship between ANS activity and SVR, as estrogen receptors in women exert protective vascular action, both by genomic and non-genomic mechanisms, which include: vasodilation mediated by the nitric oxide and prostacyclines, as well as the inhibition of the sympathetic vasoconstrictor system and the release of angiotensin. It is known that the described extranuclear prototype action of estrogens in the cardiovascular system is the induction of rapid vasodilatation.[(6)]

This adrenergic vasodilation has an important hemodynamic function in the average sympathetic control of blood pressure in this age group and is a decoupling factor of the vasoconstrictor activity of ANS. In addition, it is an important component of the balance of the factors that maintain normotension in young women. On the other hand, this decoupling effect of ANS and SVR, in a certain way, is lower as blood pressure increases, which in this investigation justifies the fact that in hyperreactive the lower difference between the sexes than in the normorreactives.

In all categories, women presented higher values of CI than men, which contrasts with that postured by Guyton,[(4)] who establishes a value of 10-20% lower in women than men, although it does not take into account the differences between men and women in different age groups. Other investigations have reported lower SVRI values in women younger than 20 years, similar to what was found in this study, which is reversed in the group of 21 to 30 years,[(7)] so it can be suggested that this age group has its particularities.

On the other hand, hemodynamic changes during the performance of dynamic exercise have been well researched; however, the modifications that occur during the isometric exercise are still little studied. Some authors suggest that BP in young adults increases as a consequence of the increase in cardiac output and there are no changes in SVR after isometric exercise.

Numerous studies have shown that the increase in cardiac output is due to the increase in heart rate and not to stroke volume.[(8,9)] Alegret and colleagues[(9)] monitored the cardiac response with magnetic resonance during isometric exercise and found a significant increase in HR and MAP, as well as left ventricular contractility during exercise. In the present study, an increase in CI was observed, which is related to the increase in HR, since the values of SV hardly changed with the WST.

The exaggerated increase in sympathetic activity during physical stress leads to a decrease in vascular adaptability, whose consequence on the ventricular pumping activity would be an elevation of the potential energy during the systolic ejection phase. Added to this pressure, are the increase in heart rate, contractility and the force of contraction by adrenergic stimulation, which, finally, determines the increase in afterload, an elevated cardiac work that is released as kinetic energy in the form of pressure that accelerates the blood.[(10)]

In this study, a significant increase in HR and CI was found in both sexes; however, unlike what was reported in other studies, the SVRI increased significantly in men. So in them, in the elevation of the BP influenced the increase in SVR and not so much the increase in the cardiac output, this difference could be related to the age range of the population studied. As mentioned above, the patterns hemodynamic changes with age, therefore, the response to isometric exercise may also be different.

It has been commented that women have less activity of the sympathetic muscular system than men; however, apparently, the inotropic activity of the heart in response to isometric exercise was greater in women than in men, which is reflected in a higher CI. Likewise, the chronotropic activity in females was superior, although the vasoconstrictor response was lower. This fact seems to indicate that young women respond to the isometric test with an increase in cardiac activity; in contrast, men respond more with an increase in arterial tone, which may be related to differences in the individual pressor response to which the variation of the muscular metaboreflex contributes, which may be cardioaccelerating and/or vasoconstrictive.

CONCLUSIONS

At baseline, normorreactive and hyperreactive women had higher values of heart rate, cardiac index, left cardiac work and total compliance arterial index in men and lower in mean arterial blood pressure and systemic vascular resistance index with respect to men. In the isometric exercise, the gender differences found in these hemodynamic variables were maintained. This evidenced the existence of gender differences at baseline hemodynamic patterns and during exercise between in young individuals.

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