Specific features of hemodynamics in individuals with different body mass: correlation with composition of the body and insulin resistance

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Abstract. Objective of the work — to determine changes of hemodynamic parameters by integral rheography of the body technique in Kharkiv adult population with different body mass in correlation to its composition, specifics of adipose tissue accumulation topography, liquid areas, presence and degree of insulin resistance.

Material and methods. 250 individuals (mean age 65.48±11.86 year) were examined. Patients with arterial hypertension, coronary artery disease and cardiac failure were excluded from the examination. The body mass index was calculated, waist and hip circumferences were measured in the examined patients; adipose, fat-free active body cell mass, total liquid contents and blood volume were determined by bioimpedance technique; systolic volume, cardiac ejection, systolic and heart indices, integral tonicity coefficient were revealed by integral rheography of the body; systolic and diastolic arterial pressure were measured; HOMA insulin resistance index was determined.

Results. It was proved that increasing body mass from normal to overweight and obesity class 1, 2, 3 reveals growing volume of total liquid at statistically valid values $p<0.001$; $p<0.05$; $p<0.001$ and $p<0.001$, respectively. It was determined that while body mass increases from normal to overweight mass; from obesity class 1 to obesity class 2; from obesity class 2 to obesity class 3, blood level also grows statistically valid ($p<0.001$; $p<0.014$ and $p<0.001$, respectively).

Patients with overweight body mass, obesity class 1 and class 2 are characterized with absolute increase of systolic heart function according to the determined beat volume and cardiac output. In obesity class 3 relative systolic failure developed relatively to the body square.

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Statistically valid correlation between parameters of systolic function and body mass index, accumulation either adipose or fat-free mass in the body was found. It was determined that changes of systemic arterial tone in overweight subjects are mostly connected with contents in the body fat-free tissues.

Evidence of correlation between insulin resistance and levels of systolic volume, cardiac ejection, coefficient of integral tonicity, systolic and diastolic arterial pressure has been confirmed by statistical difference at p<0.001 level of these parameters in the groups of patients with insulin resistance and normal tissue insulin sensitivity.

Conclusions. Representatives of Ukrainian population with overweight body mass of different classes are proved to have correlation between parameters of cardiac systolic function and changes of body composition, liquid areas, degree of accumulated visceral adipose tissue. At insulin resistance evidence, these shifts are intensified.

Keywords: overweight body mass, obesity, bioimpedance analysis, liquid areas of the body, integral rheography of the body, hemodynamic parameters.

Disordered hemodynamics in overweight patients is a topical issue both medical and social: obese patients develop blood circulation disorders thrice more frequently compared to those with normal body weight, that increases in them significantly the risk of vascular events onset [1, 2].

It was proved that hemodynamic changes in obesity (OB) are manifested, primarily, in growing (proportionally to body mass growth) of the circulating blood volume (CBV) (total volume of liquid blood in functioning blood vessels); stroke volume (SV) (the volume of blood ejected at each heartbeat) and cardiac output (CO) (the volume of blood ejected by the heart ventricles per minute) [1-6].

It is considered that such SV and CO alterations in overweight individuals are caused by CBV gradual increase under growing blood stream; and risen cardiac output in obesity is a physiological process determined by necessity to meet metabolic needs of the body at growing body mass and heart function, compared to the calculated value for ideal body weight [13]. It causes more quick exhaustion of physiological reserve, enlargement of left ventricular sizes, rigidity of its myocardium, stroke volume [14].

Hemodynamic alterations in overweight body mass are determined, except the above mentioned, by hormonal metabolic changes in the body of those individuals with extra accumulation of adipose tissue. Among them, insulin resistance and compensatory hyperinsulinemia play the key role. Hyperinsulinemia, enhancing renal sodium retention, favors the further CBV increase. Under impact of hyperinsulinemia, the central sympathetic nervous system activity is raising, renin-angiotensin-aldosteron system is being activated [15]. Bio inhibition occurs [6]. The fact of the extra fluid accumulation in the body was also confirmed by the own target research which determined fluid areas in the body in Kharkiv city residents with various degrees of overweight. As it was determined, overweight patients develop absolute increase of total water, and total extracellular, including interstitial, and intracellular fluid. The revealed changes grow deeper along with the progression of the obesity degree [7].

In response to the increased CBV and CO in those subjects with no evidence of arterial hypertension (AH), peripheral systemic vascular resistance reduces. Intensity of this process shows negative correlation with the body mass increase, as well [6, 8].

The blood stream growth intensity, and, consequently, CBV increase, depends on the proportion of shares of tissues with different vascularization in the body. Fatless tissues (metabolic active), compared with adipose tissue, are characterized with a greater degree of vascularization. The research which applied bio-impedance technique proved that CBV mostly correlates namely with fatless tissues mass in the body [9, 10].

However, it should be considered that potential capacities of fatless tissues to grow are physiologically limited, and in case of the developed marked OB, potential of their growth may be exhausted long before the growth of adipose tissue stopped, which (adipose tissue) is capable to demonstrate scores fold overgrowth compared to the physiological norm. At the stage of accumulation of mostly adipose tissue, the dynamics of changing CBV, SV and CO is somewhat modified: adipose tissue is supplied with blood worse than internal organs and muscles, but adipose tissue vascularization is intensive enough and in case of its accumulation in the body its proper blood circulation volume may increase additionally the total volume of circulating blood [6, 11, 12].

In obesity, increased CBV, CO and SV determines the growth of natriuretic peptide total logic activity [16]. Besides, hyperinsulinemia stimulates cell proliferation of vascular wall smooth muscles, that causes arteriolar stenosis and vascular resistance increase [17].

Thus, exhaustion of myocardial compensatory mechanisms due to left ventricular hemodynamic pre- and post-load is one of the principal mechanisms which cause incapacitating cardio-vascular complications development in OB [14]. Pre-load is determined by alterations occuring in fluid areas of the body, primarily CBV, and post-load is associated with the factors increasing arterial flow resistance, with the development of metabolic disorders caused by insulin resistance.

However, as the current state of the art regards, insulin resistance in overweight patients is not so much dependent on absolute growth of the body mass, as on extra accumulation of just adipose tissue, firstly in the visceral fatty depot. But, unfortunately, most investigations related to AH development in OB patients are carried out considering such parameter as body mass index (BMI) which doesn't give comprehensive information regarding proportion of adipose and metabolically active tissues in the body. Presence and character of the changes held in fluid areas of the body are also practically not taken into consideration for preventive medical practice to the overweight body mass (BM) and OB patients.

Currently, bio-impedance analysis (BIA) is the most wide-spread method which is applied to determine these parameters, that presents an up-to-date high precision tool technique based on the measurement of electric resistance of the body tissues considering the different contents of fluid and electrolytes. BIA provides determination of the following body composition parameters: adipose mass (AM); fatless mass (FLM) of the body (FLM = body mass — AM); active cell mass (ACM) (mass of all cells in which metabolic processes take place); index (ACM / AM). BIA allows to evaluate fluid areas of the body as well, which significantly influence on hemodynamics state: blood volume (BV) and total fluid (TF) (water in unbound state) [18].

Rheographic recording of arterial system alterations, integral rheography of the body (IRB) is considered to be one of reliable, not expensive, technically simple methods for assessment of integral hemodynamic features of the body. Its efficiency was proved in massive examinations of large-scale cohorts of people. Recently, during the last decades it has been used in surgery, resuscitation, oncology, dentistry, other fields of medicine [19, 20, 21, 22, 23].

Information value of cardiac output level determined by this method is equal to the figures obtained by ultrasound examination. Herewith, IRB technique is more cheap and simple to be performed [24]. Withal, no reports of its application for assessment of hemodynamic characteristics in the patients with different body mass among the population of Ukraine are available.

Thus, determination of hemodynamic specificity of subjects with various body mass depending on principal anthropometric features, specific features of fluid areas and body composition, insulin resistance presence and degree, targeted to refine approaches to preventive measures for OB comorbidities, is considered to be topical.

Therefore, the **objective of our research** was to determine changes of some hemodynamic parameters values by integral rheography of the body in adult population of Kharkiv city with different body mass depending on its distinct composition features as for the topography of adipose tissue accumulation, fluid areas, presence and degree of insulin resistance.

Object and methods of research. 250 subjects, mean age (65.48±11.86) year were examined. Only those patients with exogenous constitutional OB, free of severe comorbidity, taking no medication therapy at the moment of study were enrolled in the investigation. Diabetes mellitus patients and those with diagnosed hypertension disease were excluded from the examination.

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All the enrolled patients were measured body mass, waist circumference (WC) (cm) and hip circumference (HC) (cm); BMI was calculated, and by its values 4 examination groups were set:

- group 1 — overweight body mass patients (owBM) (mean group BMI — (26.66±1.44) kg/m^2), (n = 62 patients; m/f = 46/16);
- group 2 — class 1 OB patients (mean group BMI was equal to (32.11±1.49) kg/m^2) — (n = 59 patients; m/f = 39/20);
- group 3 — class 2 OB patients (mean group BMI was equal to (37.27±1.33) kg/m^2) — (n = 45 patients; m/f = 23/22);
- group 4 — class 3 OB patients (mean group BMI was equal to (42.90±2.97) kg/m^2) — (n = 40 patients; m/f = 17/23).
- Control group — 44 practically healthy subjects with normal body mass (nBM), mean group BMI was equal to (23.06±1.30) kg/m^2, (m / f = 18/26).

The evidence of abdominal OB (abOB) was identified in women in case of the waist circumference (WC) value was > 0.80 m, in men it was done in case of WC value was > 0.94 m. Apart, along with the study, two subsets both of males and females with moderate abOB and marked OB were distinguished. WC size was chosen as a criterion: in men from 0.94 to 1.02 m, and more than 1.02 m, respectively; in women, from 0.80 to 0.88 m and more than 0.88 m, respectively [25].

Analysis of clinical biochemical parameters included determination of fasting blood glycemia (FBG) parameters by glucose oxydase method with «Biosen C line» express analyzer. All patients were determined HOMA insulin resistance index (HOMA-IR), which was calculated by the formula: HOMA-IR = (fasting glycemia (mmol/L) * fasting insulin (mcU/L)) / 22.5. The normal value of this parameter was considered to be at the level up to 2.7. At HOMA-IP values from 2.7 to 4.0 we diagnosed moderate, and over 4.00 — significant decrease of tissue insulin resistance.

Systolic and diastolic arterial pressure (SAP, DAP) levels were measured with «Microlife» (Switserland) semi-automatic tonometer № 623416.

Specific features of central hemodynamics were assessed by IRB technique with «Diamant-R» computered rheoanalyzer (manufactured by «DIAMANT» Closed Joint-stock Company) according to M.I. Tishchenko technique [26, 27], considering the recommendations made by I.S. Kolesnikova, et al. [19, 20]. Such integral parameters as: SV, CO, stroke volume index (SVI), cardiac index (CI) and integral tonicity coefficient (ITC) which allows quantitative assessment of systemic arterial tone state, were assessed.

SVI (mL/m^2) was calculated as a proportion of SV to the body surface area.

CI (L/min m^2) — as a ratio of CO to the body surface area.

Integral tonicity coefficient (ITC) (equivalent units) — as an entire cardiocycle and catacrotism duration ratio.

Changes of fluid areas of the body — TF (L) and BV (L); parameters of the body composition — (AM) (kg) and ABCM (kg) were assessed by bio-impedance technique with software-hardware complex «Diamant — AIST-IRB» Ltd «DIAMANT» [28]. Such parameters of the body composition as FLM (kg) and index ABCM / AM were determined as well.

Main anthropometric characteristics of the studied groups are presented in the **Table 1**.

Descriptive statistical analytic methods were used for the clinical functional results processing.

Results of the research and their discussion

The performed research revealed that the examined subjects along with the body mass increase occurring from nBM to owBM and class 1, 2, 3 OB, demonstrated statistically significant 1.1-, 1.2-, 1.2-, and 1.4-fold growth, respectively, of total fluid volume (**Table 2**).

Blood volume values along with the body mass growth from nBM to owBM; from class 1 OB to class 2 OB; from class 2 OB to class 3 OB were also statistically significantly 1.2-, 1.2-, and 1.4-fold increased, respectively. No differences in these parameter values were found in the patients with owBM and class 1 OB.

The above mentioned changes in fluid areas determined increase of the amount of blood which is ejected by the heart ventricles in one systole: in the overweight BM, class 1 and class 2 OB examined patients, the SV increased at significant level of $p<0.01$; $p<0.005$ and $p<0.05$ (**Table 3**).

No additional increase of this parameter was registered in class 3 OB that is an evidence of

Table 1. Anthropometric characteristics of the enrolled participants

Parameter	Statistical parameter	Study groups				
		nBM	owBM	Class 1 OB	Class 2 OB	Class 3 OB
Waist circumference, cm	Mean (SD)	79.9 (13.27)	88.65 (10.66)	102.25 (11.71)	108.71 (12.16)	119.33 (11.78)
	Median	78	90	100	106	120
	[Q1-Q3]	[78.00-90.00]	[79.0-98.00]	[94.00-110.00]	[99.00-118.00]	[110.00-129.50]
Hip circumference, cm	Mean (SD)	96.99 (6.32)	100.06 (7.10)	108.98 (11.02)	111.42 (10.82)	124.15 (15.80)
	Median	97	100	108	113	123.5
	[Q1-Q3]	[92.00-100.00]	[96.00-105.00]	[102.00-112.00]	[102.00-118.00]	[113.00-130.00]
Adipose mass, kg	Mean (SD)	14.35 (3.57)	22.76 (4.68)	31.69 (4.0)	40.67 (5.65)	54.95 (12.34)
	Median	14.05	22.60	31.99	40.98	51.98
	[Q1-Q3]	[12.6-16.8]	[20.2-26.38]	[28.86-33.99]	[36.63-43.93]	[41.17-57.82]
Fatless mass, kg	Mean(SD)	48.78 (10.27)	57.02 (9.07)	58.96 (8.74)	63.59 (7.82)	71.04 (10.37)
	Median	46.95	53.38	56.01	60.81	68.26
	[Q1-Q3]	[42.26-52.58]	[50.09-66.02]	[52.99-62.78]	[57.81-69.37]	[63.36-76.88]
Active body cell mass, kg	Mean (SD)	31.93 (5.95)	36.84 (5.46)	38.14 (5.68)	41.38 (5.00)	46.12 (6.37)
	Median	30.29	34.82	36.54	39.26	44.49
	[Q1-Q3]	[27.49-34.69]	[32.44-41.8]	[34.44-40.56]	[37.67-45.38]	[41.31-50.49]

Table 2. Specificity of fluid areas of the body of the examined subjects

Parameter	Statistical parameter	Observation group					P
		nBM	owBM	Class 1 OB	Class 2 OB	Class 3 OB	
Total fluid, L	Mean (SD)	31.19 (4.96)	35.07 (4.33)	36.22 (4.35)	38.88 (3.78)	43.1 (5.42)	P* <0.001
	Median	30.54	34.69	35.57	38.06	41.65	P** <0.05
	[Q1-Q3]	[27.5-34.01]	[31.84-38.36]	[32.87-38.11]	[36.15-41.45]	[39.23-46.36]	P***<0.001 P****<0.001
Blood volume, L	Mean (SD)	4.2 (0.82)	4.85 (1.14)	4.89 (0.82)	5.2 (0.7)	5.76 (1.01)	P* <0.001
	Median	4.06	4.55	4.66	5.02	5.37	P**<0.72
	[Q1-Q3]	[3.60-4.56]	[4.18-5.48]	[4.32-5.29]	[4.72-5.64]	[5.06-6.12]	P***<0.014
	Median	72.45	76.9	79.18	80.46	84.05	P****<0.001
	[Q1-Q3]	[67.26-76.81]	[72.17-77.9]	[72.16-83.66]	[75.9-87.36]	[78.23-88.39]	

*Note: * — P — mean differences in overweight patients compared to the patients with normal body mass.*
*** — P — mean differences in the overweight patients compared to the patients with class 1 OB.*
**** — P — all mean differences in the patients with class 1 OB compared to those with class 2 OB.*
***** — P — all mean differences in the patients with class 2 OB compared to those with class 3 OB.*

existing factors which can decrease SV in the subjects with OB morbid forms.

CO demonstrated increase associated with the body mass growing from owBM to class 1 OB and class 2 OB ($p<0.001$ and $p<0.001$), respectively. No significant changes of this parameter were registered along with the development of overweight BM and class 3 OB.

The above mentioned SV and CO dynamics indicates increased load on the heart in the overweight patients associated with the weight increased up to class 2 OB.

But, nevertheless, this research registered statistically significant fall of SVI and CI ($p<0.001$; $p<0.001$) in the examined patients with class 3 OB compared to those subjects with nBM (1.3- and 1.2- fold increase, respectively), that proves relative decline in contractile function of the heart related to body surface area.

No changes of systemic arterial tone in relation to ITC mean levels in the groups of subjects with different body mass were registered.

SAP and DAP levels in the patients with overweight BM were higher than compared to those individuals with nBM ($p<0.001$; $p<0.001$). No significant statistically changes of DAP in further increase of the body mass were registered. SAP level increased only when class 3 OB developed ($p<0.001$).

Presence and degree of correlation between the parameters of contractile function of the heart, systemic arterial tone, SAP, DAP and main anthropometric parameters were analyzed in the research (**Table 4**).

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Table 3. Hemodynamic specificity of the observed subjects

Parameter	Statistical paerameter	Observation group					P
		nBM	owBM	class 1 OB	class 2 OB	class 3 OB	
SV, mL	Mean (SD) Median [Q1-Q3]	73.6 (13.73) 71.65 [64.34-85.01]	80.3 (16.91) 77.52 [68.74-92.16]	86.09 (18.15) 85.6 [75.65-96.09]	93.35 (17.97) 88.87 [80.18-108.13]	87.01 (23.74) 84.41 [74.81-90.97]	P* <0.01 P**<0.05 P***<0.05 P****<0.15
CO, L/min	Mean (SD) Median [Q1-Q3]	5.33 (0.93) 5.33 [4.69-6.02]	5.67 (1.1) 5.64 [4.92-6.37]	6.18 (1.29) 6.29 [5.21-6.92]	6.97 (1.39) 6.65 [6.12-7.41]	6.49 (1.17) 6.49 [5.82-7.25]	P*<0.06 P**<0.001 P***<0.001 P****<0.07
SVI, mL/m²	Mean (SD) Median [Q1-Q3]	46.6 (80.49) 46.2 [39.4-52.84]	44.48 (8.64) 43.82 [38.5-50.69]	43.62 (8.9) 43.98 [39.48-48.79]	43.54 (8.9) 42.97 [36.86-50.25]	35.69 (10.56) 36.1 [29.27-40.68]	P*<0.12 P**<0.5 P***<0.9 P****<0.001
CI, L/min m²	Mean (SD) Median [Q1-Q3]	3.39 (0.68) 3.27 [3.01-3.66]	3.15 (0.63) 3.06 [2.73-3.7]	3.13 (0.6) 3.11 [2.81-3.52]	3.24 (0.64) 3.16 [2.91-3.44]	2.76 (0.79) 2.54 [2.27-3.02]	P*<0.058 P**<0.8 P***<0.35 P****<0.001
ITC, equivalent unit	Mean (SD) Median [Q1-Q3]	77.84 (2.8) 78 [75.5-80.5]	78.87 (3.88) 79.4 [76.7-81.8]	78.59 (3.01) 78.9 [76.3-80.7]	78.09 (3.57) 78.1 [76.7-79.9]	77.91 (3.43) 77.75 [75.9-80.3]	P*<0.084 P**<0.5 P***<0.41 P****<0.61
SAP, mm Hg	Mean (SD) Median [Q1-Q3]	114.89 (11.72) 116.27 [111.05-120.04]	126.73 (8.29) 125.09 [122.07-132.33]	126.92 (8.11) 127.39 [120.85-132.7]	130.46 (8.66) 129.22 [124.08-137.56]	136.93 (7.58) 137.11 [130.12-143.43]	P* <0.001 P**<0.8 P***<0.03 P****<0.001
DAP, mm Hg	Mean (SD) Median [Q1-Q3]	71.76 (6.67) 72.45 [67.26-76.81]	77.42 (6.97) 76.9 [72.17-77.9]	77.49 (8.27) 79.18 [72.16-83.66]	81.07 (7.18) 80.46 [75.9-87.36]	83.3 (8.37) 84.05 [78.23-88.39]	P*<0.001 P**<0.9 P***<0.02 P****<0.19

*Note: * — P — mean differences in overweight body mass patients compared to the subjects with normal body mass.*
*** — P — mean differences in those patients with overweight body mass compared to the class 1 OB patients.*
**** — P — all mean differences in subjects with class 1 OB patients compared to those with class 2 OB.*
***** — P — all mean differences in the subjects with class 2 OB compared to class 3 OB patients.*

Table 4. Correlation matrix of hemodynamic and anthropometric parameters

Parameters	Waist circumference, cm		Hip circumference, cm		Body mass index, kg/m²	
	Spearman's R coeffic.	p	Spearman's R coeffic.	p	Spearman's R coeffic.	p
SV, mL	0.220974	0.001	0.297349	0.001	0.268912	0.001
HE, L/min	0.336042	0.001	0.380395	0.001	0.380067	0.001
SVI, mL/m²	-0.382175	0.001	-0.255852	0.001	-0.345594	0.001
CI, L/(min.m²)	-0.325982	0.001	-0.225998	0.001	-0.286770	0.001
ITC, equivalent unit	0.103469	0.205	-0.121865	0.052	-0.029470	0.34
SAP, mm Hg	0.525	0.001	0.461	0.001	0.672	0.001
DAP, mm Hg	0.312	0.001	0.293	0.001	0.452	0.001

It was revealed that the majority of hemodynamic parameters (SV, CO, SVI, CI, SAP, DAP) are statistically significantly at $p<0.001$ level associated not only with BMI, but with parameters which characterize topography of adipose tissue accumulation, which are WC and HC. It indicates their information value as for presence of possible hemodynamic changes in overweight and obese patients.

But the character of these correlations differs. So, SV, CO, ITC, SAP and DAP show positive correlation with BMI, WC and HC; parameters which characterize contractile function of the heart in relation to the body surface area (SVI and CI), demonstrate negative correlation.

As for ITC, the present research proved correlations of this parameter and HC ($p<0.001$)

and WC (p=0.015). No correlation between ITC and BMI was registered.

In the research we analyzed which of these anthropometric parameters influence mostly on SVI and CI level. In multidimensional regression analysis we selected the following as independent parameters: BMI, WC/HC (**Table 5**). Standardized coefficients of regression β, which were received, indicate that BMI shows the major statistically significant influence on the levels of hemodynamic features.

To confirm intercorrelation between contractile function of the heart and type of adipose tissue accumulation, dynamics of SV, CO, SVI and CI in relation to the presence and degree of abdominal obesity was characterized (**Fig.**).

It was established that the subjects with marked abOB demonstrate more statistically significant higher SV value compared either to the patients with moderate abOB (p<0.001), or with those patients, whose WC doesn't exceed the normal values (p<0.001), respectively (86.038±19.736) mL vs (82.128±18.854) mL and (77.415±15.346) mL.

Analogue dynamics we registered for CO: in the patients with marked abOB it was registered on the level of (6.306±1.328) mL/min, with moderate abOB it was of (5.815±1.231) mL/min, in normal WC it was of (5.550±0.999) mL/min (p<0.001. p<0.001 and p<0.001, respectively).

Changes in SVI and CI values in growing WC size demonstrated the opposite features: in those patients with marked abOB levels of these parameters were statistically significantly less than in those with moderate abOB or free of it: SVI — (41.175±9.650) mL/m^2 vs (45.088±8.336) mL/m^2 and (46.569±8.462) mL/m^2 (p<0.001. p<0.001), respectively; CI — (3.035±0.687) L/min m^3 vs (3.208±0.625) L/min m^3 and (3.359±0.677) L/min m^3 (p<0.001, p<0.001), respectively.

Table 5. Association of anthropometric parameters with stroke volume and cardiac indices

Independent variables	Regression b coefficients	Standardized regression β coefficients	P significance level of the regression coefficients	Determination R2 coefficient and P significance level of the model
		Stroke volume index		
WC/HC	-15.479	-0.179	0.001	R2 = 0.617 P = 0.001
BMI, kg/m^2	-0.4105	-0.335	0.001	
Free term	69.879		0.001	
		Cardiac index		
WC/ HC	-0.785	-0.126	0.001	R2 = 0.656 P = 0.001
BMI, kg/m^2	-0.0233	-0.2634	0.001	
Free term	4.576		0.001	

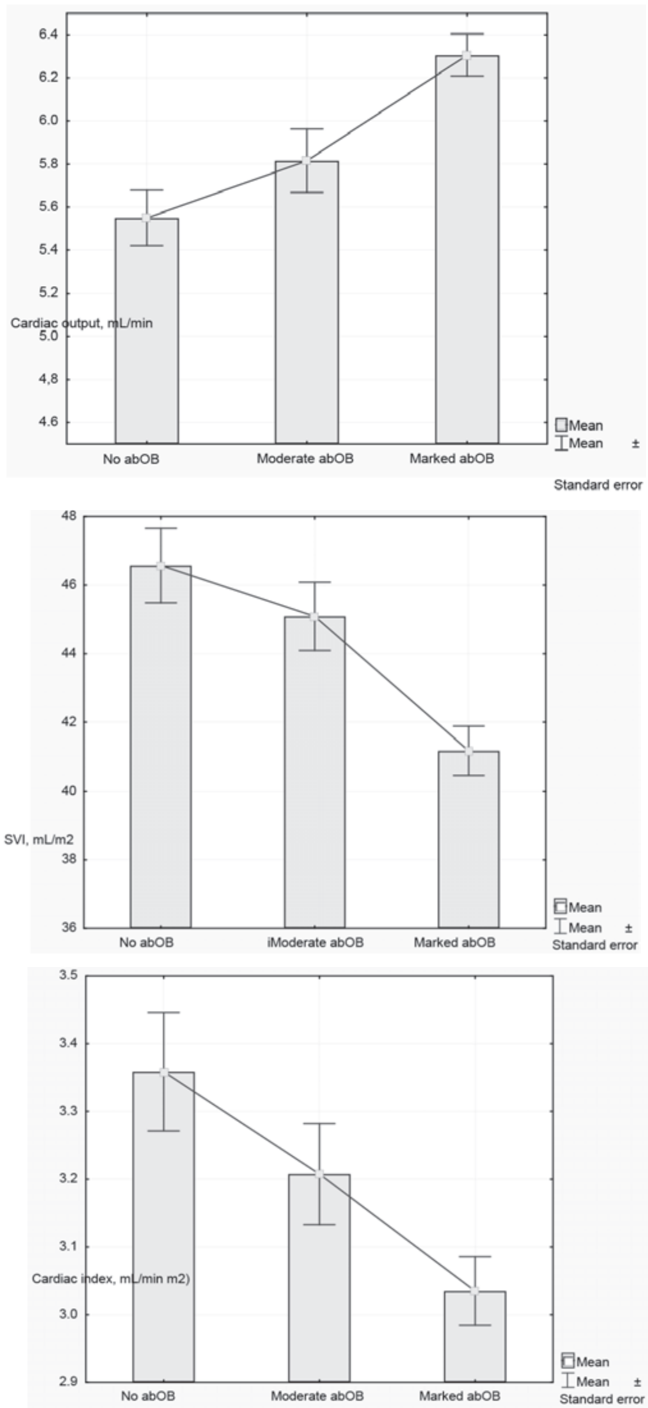

Fig. Dynamics of changes of heart contractile function parameters depending on abdominal obesity presence and degree.

Note: Kruskal — Wallis test p<0.001.

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The research analyzed the character of correlations between SV, CO, SVI, CI, SAP and DAP and parameters of the body composition (**Table 6**). It was determined that AM, FLM and ABCM levels correlate positively with SV, CO, SAP and DAP; negatively – with SVI and CI. ABCM/AM shows positive correlation with SVI and CI, negative correlation with SV, CO, SAP and DAP. Thus, the alterations in contractile function of the heart and systemic arterial pressure in the patients with overweight body mass of various degree depend on accumulation in the body either of adipose, or fatless tissues, and as well on proportion of adipose and metabolic active tissues. Accumulation of mostly adipose tissue in the body may determine the growing load on myocardium on account of increasing SV, CO, SAP, DAP while contractile cardiac function decreases in relation to the body area (reducing SV and CO).

As for ITC, its positive correlations only with FLM, ABCM and proportion ABCM / AT were registered. No correlations between ITC and AM were registered that proves the key role of fatless tissues in changes of systemic arterial tone in overweight patients.

As it was above mentioned, special features of hemodynamics in overweight BM and OB patients are determined significantly also by hormonal metabolic shifts in the body which

Table 6. Matrix of correlation of hemodynamic parameters and parameters of the body composition

Parameter	AM, kg		FLM, kg		ABCM, kg		ABCM / AM	
	Spearman's R coeffic.	p	Spearman's R coeffic.	p	Spearman's R coeffic.	p	Spearman's R coeffic.	p
Spearman's R	p-level	0.001	0.328	0.001	0.339	0.001	-0.200	0.003
CO, L/min	0.415	0.001	0.381	0.001	0.387	0.001	-0.311	0.001
SVI, mL/m^2	-0.303	0.001	-0.334	0.001	-0.327	0.001	0.239	0.033
CI, mL/m^2	-0.247	0.001	-0.331	0.001	-0.334	0.001	0.182	0.001
ITC	-0.107	0.041	0.178	0.007	0.155	0.019	0.185	0.002
SAP, mm Hg	0.532	0.001	0.324	0.001	0.432	0.001	-0.371	0.001
DAP, mm Hg	0.43	0.001	0.307	0.001	0.3	0.001	-0.352	0.001

Table 7. Levels of hemodynamic parameters in the examined subjects with different tissue insulin sensitivity

Hemodynamic parameter	Statistical parameter	Patients with no evidence of insulin resistance (HOMA-IR<2.77)	Insulin resistant patients (HOMA-IR>2.77)	Spearman's/ HOMA-IP correlation coefficient	U test	P
SV, mL	Mean (SD)	76.04 (20.9)	84.57 (18.53)	0.298	3943.5	0.001
	Median	72.96	82.37			
	[Q1-Q3]	[45.04-51.86]	[35.89-50.48]			
CO, mL/min	Mean (SD)	5.41 (1.2)	6.14 (1.27)	0.389	3580	0.001
	Median	5.4	6.11			
	[Q1-Q3]	[4.51-6.14]	[5.22-6.79]			
SVI, mL/m^2	Mean (SD)	44.86 (9.68)	42.17 (9.39)	-0.276	5283.7	0.082
	Median	44.43	42.91			
	[Q1-Q3]	[34.17-49.72]	[36.95-49.63]			
CI, (L/(min* m^2))	Mean (SD)	3.23 (0.55)	3.14 (0.69)	-0.198	5222.4	0.079
	Median	3.17	3.08			
	[Q1-Q3]	[2.64-3.45]	[2.71-3.49]			
ITC	Mean (SD)	80.42 (1.02)	78.06 (0.85)	-0.204	3109	0.001
	Median	80.74	78.05			
	[Q1-Q3]	[78.34-82.6]	[78.9-80.45]			
SAP, mm Hg	Mean (SD)	120.57 (13.45)	126.64 (10.8)	0.317	9432.1	0.001
	Median	121.17	126.21			
	[Q1-Q3]	[114.91-127.88]	[120.23-134.41]			
DAP, mm Hg	Mean (SD)	75.2 (8.06)	77.61 (8.49)	0.254	10817.5	0.001
	Median	74.56	77.92			
	[Q1-Q3]	[69.69-80.93]	[72.06-83.69]			

result from extra adipose tissue, that is insulin resistance, in the first place. To specify correlation between the values of the studied hemodynamic parameters and insulin resistance, all patients were divided additionally into two groups:

a) subjects with HOMA index within normal values — (n = 110 individuals; m/f = 73 / 37);

b) subjects with HOMA index over 2.77 — (n = 140 patients; m/f = 70 / 70) (**Table 7**).

The obtained data analyzed gave evidence of the present correlation between insulin resistance and SV, CO, ITC, SAP and DAP levels proved by statistical difference at $p<0.001$ level of these parameters in the groups of insulin resistant patients and those within normal tissue insulin resistance.

It was determined that SV in insulin resistant subjects is registered, in average, at the level of (84.57±18.53) mL; CO — (6.14±1.27) mL/min; ITC — (78.6±0.85) eq. units; SAP — (126.64±10.80) mm Hg; DAP — (77.61±8.49) mm Hg.

Thus, the carried research worked out in details specific hemodynamic features in the subjects with various body mass, rising to BMI higher levels and associated with the disordered composition and fluid areas of the body, development of insulin resistance.

Cardiac preload growth was proved with simultaneous decline in cardiac contractile function in relation to the body area in the patients with marked OB.

The revealed features allow to work out personified preventive and therapeutic measures for comorbidities in various degree overweight adult population.

The factors which cause no registered SV and CO alterations in the patients with morbid OB at the level of significant blood volume increase require additional investigation.

Conclusions

1. Significant accumulation of total fluid and increasing blood volume are considered to be an essential distinction of the fluid area state in the patients with class 2 and 3 obesity compared to those patients with normal body mass.
2. It was proved that the patients with overweight body mass, class 1 and 2 obesity are characterized with absolute increase of systolic function of the heart determined by the stroke volume and cardiac output levels. In class 3 OB, relative systolic failure in relation to the body area develops.
3. It was established that in insulin resistance, extra accumulation of visceral adipose tissue in the overweight patients, the changes of systolic function of the heart determined by stroke volume and cardiac output are intensified.
4. The patients with various degree overweight demonstrated a relation between the parameters of systolic function with body mass index, accumulation in the body either adipose or fatless tissue. Alterations in systemic arterial tone in overweight patients depend mostly on fatless tissues contents in the body.

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Стан гемодинаміки в осіб із різною масою тіла: взаємозв'язок зі складом тіла та інсулінорезистентністю

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Резюме.

Мета роботи — визначення змін параметрів гемодинаміки методом інтегральної реографії тіла в дорослого населення м. Харкова із різною масою тіла залежно від його складу, особливостей топографії відкладання жирової тканини, рідинних секторів, наявності та ступеня інсулінорезистентності.

Матеріали та методи. Обстежено 250 осіб (середній вік 65,48±11,86 року). Особи з наявністю артеріальної гіпертензії, ішемічної хвороби серця та серцевої недостатності до дослідження не залучались. У обстежених визначався індекс маси тіла, вимірювалися обвід талії та стегон; біоімпедансним методом — жирова, безжирова, активна клітинна маса тіла, вміст загальної рідини та об'єм крові; методом інтегральної реографії тіла — ударний об'єм, серцевий викид, ударний та серцевий індекси, коефіцієнт інтегральної тонічності; вимірювалися систолічний та діастолічний артеріальний тиск; визначався індекс інсулінорезистентності HOMA.

Результати. Доведено, що в разі збільшення маси тіла від нормальної до надлишкової та ожиріння 1, 2 та 3-го ступеня має місце зростання об'єму загальної рідини на рівні статистичної значущості $p<0,001$, $p<0,05$, $p<0,001$ та $p<0,001$ відповідно. Об'єм крові в разі збільшення маси тіла від нормальної до надлишкової, від ожиріння 1-го ст. до ожиріння 2-го ст., від ожиріння 2-го ст. до ожиріння 3-го ст. також статистично значуще збільшується ($p<0,001$, $p<0,014$ та $p<0,001$ відповідно).

Пацієнти з надлишковою масою тіла, ожирінням 1-го та 2-го ступенів характеризуються абсолютним збільшенням систолічної функції серця за визначенням ударного об'єму та серцевого викиду. За ожиріння 3-го ступеня розвивається відносна систолічна недостатність щодо площі тіла.

Виявлено статистично значущий зв'язок між параметрами систолічної функції та індексом маси тіла, накопиченням в організмі як жирової, так і безжирової маси. Визначено, що зміни системного артеріального тонусу осіб із надлишком ваги більшою мірою залежать від вмісту в організмі безжирових тканин.

Наявність зв'язку між інсулінорезистентністю і рівнями ударного об'єму, серцевого викиду, коефіцієнта інтегральної тонічності, систолічним та діастолічним артеріальним тиском підтверджено статистичною відмінністю на рівні p<0,001 цих параметрів у групах осіб із наявністю інсулінорезистентності та з нормальною чутливістю тканин до інсуліну.

Висновки. У представників української популяції з надлишком ваги різного ступеня доведено взаємозв'язок між параметрами систолічної функції серця та змінами складу тіла, рідинних секторів, ступенем відкладання вісцеральної жирової тканини. За наявності інсулінорезистентності ці зміни поглиблюються.

Ключові слова: надлишкова маса тіла, ожиріння, біоімпедансний аналіз, рідинні сектори тіла, інтегральна реографія тіла, параметри гемодинаміки.

Состояние гемодинамики у лиц с различной массой тела: взаимосвязь с составом тела и инсулинорезистентностью

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Резюме.

Цель работы — изучение изменений параметров гемодинамики методом интегральной реографии тела у взрослого населения г. Харькова с различной массой тела в зависимости от его состава, особенностей топографии отложения жировой ткани, жидкостных секторов, наличия и степени инсулинорезистентности.

Материалы и методы. Обследовано 250 человек (средний возраст 65,48±11,86 года). Лица с наличием артериальной гипертензии, ишемической болезни сердца и сердечной недостаточности к исследованию не привлекались. У обследованных определялся индекс массы тела, измерялись окружность талии и бедер; биоимпедансным методом — жировая, безжировая, активная клеточная масса тела, содержание общей жидкости и объем крови; методом интегральной реографии тела — ударный объем, сердечный выброс, ударный и сердечный индексы, коэффициент интегральной тоничности; измерялись систолическое и диастолическое артериальное давление; определялся индекс инсулинорезистентности HOMA.

Результаты. Доказано, что при увеличении массы тела от нормальной до избыточной и ожирения 1, 2 и 3-й степеней наблюдается увеличение объема общей жидкости на уровне статистической значимости p<0,001, p<0,05, p<0,001 и p<0,001 соответственно. Объем крови при увеличении массы тела от нормальной к избыточной, от ожирения 1-й ст. к ожирению 2-й ст., от ожирения 2-й ст. к ожирению 3-й ст. также статистически значимо увеличивается (p<0,001, p<0,014 и p<0,001 соответственно).

Пациенты с избыточной массой тела, ожирением 1-й и 2-й степени характеризуются абсолютным увеличением систолической функции сердца в соответствии с определением ударного объема и сердечного выброса. При ожирении 3-й степени развивается систолическая недостаточность относительно площади тела.

Выявлена статистически значимая связь между параметрами систолической функции и индексом массы тела, накоплением в организме как жировой, так и безжировой массы. Определено, что изменения системного артериального тонуса лиц с избытком веса в большей степени зависят от содержания в организме безжировых тканей.

Наличие связи между инсулинорезистентностью и ударным объемом, сердечным выбросом, коэффициентом интегральной тоничности, систолическим и диастолическим артериальным давлением подтверждено статистически значимым на уровне p<0,001 различием этих параметров в группах лиц с инсулинорезистентностью и с нормальной чувствительностью тканей к инсулину.

Выводы. У представителей украинской популяции с избытком массы тела разной степени доказана взаимосвязь между параметрами систолической функции сердца и изменениями состава тела, жидкостных секторов, степенью отложения висцеральной жировой ткани. При наличии инсулинорезистентности эти изменения усугубляются.

Ключевые слова: избыточная масса тела, ожирение, биоимпедансный анализ, жидкостные сектора тела, интегральная реография тела, параметры гемодинамики.