HEMODYNAMIC CHANGES AFTER AN INTENSIVE SHORT-TERM EXERCISE AND NUTRITION PROGRAM IN HYPERTENSIVE AND OBESE PATIENTS WITH AND WITHOUT CORONARY ARTERY DISEASE

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Purpose: *To assess the effectiveness of the Pritikin diet and exercise program on cardiovascular hemodynamics using the noninvasive technique of Thoracic Electrical Bioimpedance (TEB).*

Material and Methods: *Twenty subjects divided in two groups, according to their body habitus and hemodynamic disturbances. These data were compared to a group of 10 healthy individuals not involved in the program.*

Hemodynamic parameters were collected at admission and at the end of the intensive 26-day program of exercise and nutrition.

Results: *In obese and hypertensive subjects not on medication we observed that cardiac index increased from 3.27 ± 0.4 to 3.58 ± 0.5 L/min/m2; mean arterial pressure decreased from 100 ± 8.5 to 94.8 ± 7.9 mmHg while systemic vascular resistance index decreased from 2362 ± 391 to 1934 ± 357 dynes. sec. cm-5/m2; p < 0.05 (Data obtained in supine position).*

Also documented was a improvement in ventricular performance after postural changes from upright to supine based on indices of left ventricular performance, uniquely obtained by the TEB technique.

From admission to discharge, changes were: Ejection fraction 48% to 53%; Peak flow index 295 to 316 ml/s/m2 and Index of contractility 40 to 47 s^{-1}*, explained by a shift on the ascending limb of the Starling curve.*

Conclusion: *In a selected population, this rehabilitation program is effective for hemodynamic improvement that can be partially explained by metabolic and biochemical changes already reported from this Center.*

Key words: *Cardiac Output Thoracic Electrical, Bioimpedance, Noninvasive hemodynamics.*

VARIAÇÕES HEMODINÂMICAS APÓS PROGRAMA INTENSIVO DE DIETA E EXERCÍCIO HIPERTENSOSO OBESOS COM OU SEM DOENÇA CORONÁRIA

Objetivo: *Avaliar a eficácia da dicta de Pritikin e programa de condicionamento físico pela análise de parâmetros hemodinâmicos obtidos com a técnica não invasiva de Bioimpedância Torácica (BIT).*

Pacientes e Métodos: *Vinte hipertensos obesos foram divididos em dois grupos de acordo com o uso ou não de drogas para coronariopatia e hipertensão arterial. Os dados hemodinâmicos foram obtidos no início e no fim de um programa intensivo de condicionamento (exercício e dieta) com duração de 26 dias. Estes dados foram comparados com os de outro grupo e dez indivíduos normais.*

Resultados: *No grupo de obesos hipertensos não medicados, foi documentuao aumento do índice cardíaco de 3,27 ± 0,4 para 3,58 ± 0,5 L/min/m2, diminuição da pressão arterial média de 100 ± 8,5 para 94,8 ± 7,9 mmHg e queda do índice de resistência vascular periférica de 2362 ± 391 para 1934 ± 357 dyne. seg. cm-5/m2.*

Os índices de contratilidade ventricular esquerda fornecidos pela BIT, variando-se o decúbito do erecto para supino, melhoraram significativamente no fim do programa: Fração de ejeção 48% para 53% pico de fluxo 295 para 316 ml/s/m2 e índice de contratilidade 40 para 47 s^{-1}*, o que seria explicado por mudança na porção ascendente da curva de Starling.*

Conclusão: *Melhora hemodinâmica ocorreu principalmente em indivíduos que não usavam drogas para coronariopatias e hipertensão arterial.*

Palavras-chave: *Débito cardíaco, Bioimpedância Torácica. Hemodinâmica não invasiva.*

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It is well known that obesity, hypertension, physical inactivity, smoking and poor habits are associated with elevated risk of atherosclerotic cardiovascular disease and its sequelas, accounting for the majority of adult mortality in the United States[1,2].

The effectiveness of the Pritikin program of exercise and diet in changing these risk factors in the obese and in some patient with coronary artery disease has been well documented[3-5].

Also reported is a significant reduction in the arterial blood pressure after a 26 days of this rehabilitation program in 85% of this patients with or without medications[5].

A simple equation shows that systemic mean arterial pressure (MAP) equals cardiac index (CI) times total systemic vascular resistance index (SVRI). Therefore, the lowering of blood pressure can occur with an unchanged, increased or even a decrease in CI, the latter certainly being an undesirable outcome.

Despite cardiac output (CO) determination being mandatory in order to derive SVRI, these parameters have never been studied on a routine basis in this ambulatory population; this is due to the risk and complexity of the invasive thermodilution technique the most commonly used method for CO assessment[67].

Electrical Bioimpedance (TEB), an affordable, nonivasive and atraumatic method of measuring CO, has been shown to possess same level of accuracy of other accepted CO methods[8-11]. It is thus suitable for use in this particular population.

The purpose of this paper is to report our experience with use of TEB incorporated into que routine assessment of the medically supervised program a the Pritikin Center.

MATERIAL AND METHODS

Among those that attended the Pritikin Center, as resident or outpatient, there were 20 study subjects together with 10 individuals who were considered healthy. These 30 individuals therefore constituted the clinical material of a mixed adult population. They were divided into three groups as follow: group I: 10 normal individuals, 7 males + 3 females, aging from 25 to 64 yr, mean (M) = 38.9 + 11.5 (s.d), in whom no major changes would occur through the study. Anthropometric data on admission were: Height 160-190 cm, M = 172.5 + 8.5; Weight 53 to 82 kg., M = 69.2 + 9.2; Body surface area (BSA) 1.56 to 2.05 M2, M = 1.82 + 0.16; group II: 10 participants, in general overweight and slightly hypertensive who were on medication. 6 males + 4 females, aging 30 to 67 yr. M = 47.6 + 11.9. Height 163-191 cm, M = 173.0 + 9.3; Weight 63 — 142 kg, M = 94.4 + 27.1; BSA = 1.66-2.73 m2, M = 2.07 ± 0.35; group III: 10 participants patients that had sustained some degree of cardiovascular impairment and were under medication to control their hemodynamic status (table I).

TABLE I - Cardiovascular conditions and medications group III

Pt. [1]	Age (yr)	Sex	Condition	Medication
1	69	M	C.A.D.	Diltiazem, Isorbide, Atenolol
2	70	M	C.A.D.	Diltiazem
3	41	F	CA.D.+S.S.S.	Enalapril
4	63	M	C.A.D.	Diltiazem, Atenolol
5	80	M	CA.D.+C.H F.	Digoxin, Diltiazem, Atenolol
6	60	F	C.A.D.	Propanolol, Gemfibrozil
7	51	F	Hypothi roidism	Synthroid, Furosemide
8	71	M	C.A.D.	Nifedipine
9	70	F	C A.D.	Diltiazem
10	76	F	C.A.D.	Captopril, Amiodarone, Digoxin,

S.S.S. = Sick sinus syndrome; C.A.D. = Coronary Artery Disease: C.H.F. = Congestive Heart Failure.

There were 5 males + 5 females, aging 41-80 yrs., M = 64.5 + 11.3. Height 152-182 cm. M = 167.3 + 8.6; Weight 53-128 kg., M = 84.1 + 23.2; BSA = 1.49-2.25 m2, M = 1.92 = 0.28.

Thoracic Electrical Bioimpedance (TEB)—We used the technique of TEB improved by Kubicek and col[12] to meet the requirement of the Apollo space mission and based on mathematical conversions of blood volume and velocity changes occuring in the thoracic aorta coincident with the cardiac cycle.

The updated equation of Sramek-Bernstein[13,14] was applied in order to correct most of the problems inherent in the original equation of Kubicek. This equation was incorporated into a special monitor (NCCOM-3, BoMed Medical Manufacturing Ltd., Irvine-CA). The application of the new equation, implemented in this monitor has been validated against measurement of CO determined by thermodilution, dopplerecho, Fick, electroflowmetry and other techniques in animals and humans[15-20].

In short, a tetrapolar system of disposable surface low contact electrodes is applied to the thorax: One current sensing pair is located bilaterally at the root of the neck and the other at the mid-axillary line at the level of the xyphoid process. Another two pairs of current injecting electrodes are placed 5 cm above and below these sensing electrodes. A constant sinusoidal (alternating) current of high frequency and low magnitude (70 kHz and 2.5 mA) is applied to the outer electrodes; the current sensors (internal electrodes) process the changes in impedance during the systolic upstroke.

The NCCOM-3 Revision 7, measures and displays a total of 13 hemodynamic parameters. A special software program (CDDP) also displays bar-graphs plus a chart that automatically calculates the deviation from normal ranges (Fig. 1 and 2).

A detailed explanation of the theory of TEB and the CDDP system can be found in a recent article[21].

Following an individual explanation about the

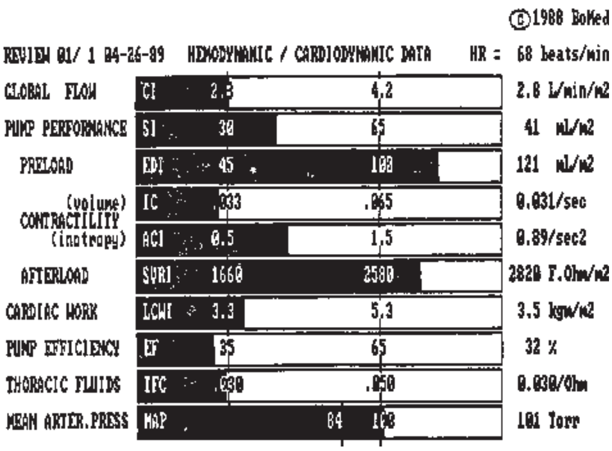

Fig. 1—Diagnostic page of the Cardiodynamic data processing system (CDDP) with bar graphs display of 10 parameters obtained by Thoracic Electrical Bioimpedance (NCCOM3-R7) in a supine resting slightly hypertensive patient. Note a increase in mean arterial pressure (MAP) mmHg, with a marginaly low cardiac index (CI) L/min/m2 and a high systemic vascular resistance index (SVRI), dyne. sec. cm-5/m2.

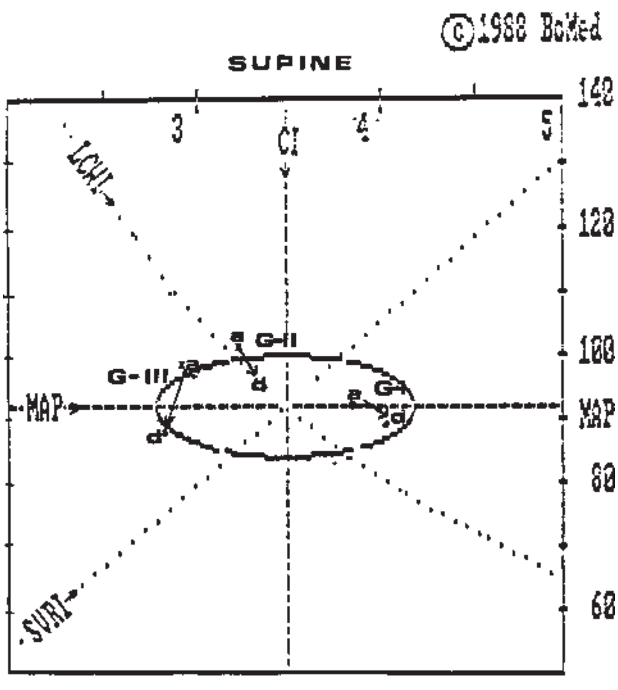

Fig. 2—Composed therapeutic management page of the cardiodynamic data processing system showing average data in all three groups on admission (A) and discharge (D). Note a significant improvement in patients of G-II with a decrease in mean arterial pressure (MAP), mmHg and increase in cardiac index (CI), L/min/m2. SVRI = Systemic Vascular Resistance Index, dyne. sec. cm-5/m2; LCWI = Left Cardiac Work Index, Kgm/m2. (See discussion on text).

noninvasive method, protocol study was carried out in upright (Up) and supine (Sp) positions upon admission (A) and at discharge (D). The entire rehabilitation program averaged four weeks in duration.

The direct parameters were recorded by a printer in all subjects. In some representative individuals of each group, hemodynamics were also graphically recorded by the CDDP software program. At least 30 consecutive beats were averaged and this value was taken as representative. Derived parameters were calculated according to the tandard formulas[22].

Direct and derived parameters were collected both in Up and Sp position after adaptation time following the change in decubitus.

The data were also analyzed by significant differences using the Student t test for matched pairs, with $p < 0.05$ considered significant. The teaching support, the diet, exercise and overall program at the Pritikin Center has been described elsewhere[3-5].

RESULTS

Data on body weight, height, body surface area (BSA) on admission (A) and at discharge (D) from the rehabilitation program did not show any changes in group I. Both group II and III showed a similar percentage decrease in body weight (5% and 4.4%) whereas the decreases in BSA were 2.4% and 2.1%, respectively. Consequently, when flow derived parameters are indexed, it is necessary to compare values related to body weight with those stated by BSA such as SI, EDVI and CI.

For the reasons listed above, the absolute value of CO alone does not express the adequact of the global perfusion. In fact, tissue perfusion of some subjects bearing unchanged CO through the study, coupled with a decrease in body weight and BSA, would be better defined as CO per kg (CO/kg) as well as CO per m2 (CO/BSA = Cardiac Index). This may explain some incorrect data in articles that state unchanged CO and a misinterpreted, unindexed, systemic vascular resistance[23,24]. As a basic rule, all parameters in our study were indexed on a per kg and per m2 basis and our subsequent discussion will be based on this premise.

Table II summarizes the mean values of 13 hemodynamic parameters that were obtained in all 3 groups at A and D in Up and Sp position.

Data obtained on normal subjects were used as a reference to define normal values. Hemodynamic variables such as HR < CI, MAP and SVRI were within normal physiological limits and were consistent with previous studies with TEB[25].

However, on three healthy young females, not included in this normal series, we documented a persistent abnormally high value (in the supine position) of SI plus CI and, accordingly, a very low SRVI. The average values were as follow- SI = 104 ml/beat/m2; CI = 7.2 1/min/m2 and SVRI = 916 dyne.sec. cm-5/m2. Despite these results being in agreement with the findings of Sramek and DeBow[25], the pertinent clinical interpretation remains to be explained either as a real hyperdinamic situation or as an extreme individual deviation from the upper normal limits[27]. This situation was never observed in any of the remaining individuals of any of the other groups.

The preload (EDVI), ejection fraction (EF) and their effects on the SI and HR were routinely assessed through postural changes such as moving from Up to Sp position. EDVI was always higher in the Sp than Up position and the resulting SI was dependent on left ventricular contractility expressed as their indexes: EF, IC and PFI.

Therefore, by comparing SI, HR and indexes of contractility, we were able to decide wheter the patient's ventricular function was operating on the ascending the plateau or the descending limb of the Starling curve.

Table III gives the approximated comparative percentage of changes from Up to-Sp in all three groups. Data drawn from this table regarding normal group were consistent with results reported by Buell[28] and Wong and col[29] and were essentially the same at A and D.

TABLE II—Mean values of hemodynamic parameters in upright and supine positions at admission and at discharge for all groups (G)

	Upright admission			Upright discharge			Supine admission			Supine discharge		
	GI	GII	GIII	GI	GII	GIII	GI	GII	GIII	GI	GII	GIII
Heart rate beats/min	78	79	71	80	79	66	64	70	64	65	63	60
Stroke index ml/beat/m2 39	39	40	44	43	41	41	63	48	47	67	58	48
Stroke index ml/beat/kg	1.04	0.86	0.97	1.14	0.98	1.00	1.70	1.19	1.11	1.80	1.28	1.14
Cardiac index L/min/m2	2.93	2.98	2.80	3.27	3.07	2.74	3.94	3.27	2.95	4.24	3.58	2.88
Cardiac index ml/min/kg	78	67	65	87	78	68	103	74	69	112	84	70
Systolic pressure mmHg	122	128	123	117	117	125	118	120	114	118	124	124
Diastolic pressure mmHg.	81	86	79	78	80	74	75	91	90	77	80	74
Mean arterial pressure mmHg	94	100	94	91	93	91	89	100	94	90	95	89
Systemic vascular resistance dyne.s.cm-5/m2	2504	2599	2671	2165	2330	2757	1870	2363	2543	1634	1934	2534
End diastolic volume ml/beaVm2	76	94	80	76	89	81	103	98	85	107	100	87
Ejection Faction %	50	48	51	50	48	51	61	53	56	61	57	57
Index contractility sec^{-1}	42	40	39	41	40	40	56	43	42	61	47	42
Peak flow index mlsec/m2	263	294	268	262	295	284	357	316	278	402	346	266

TABLE III—Percentage of change from upright to supine

	Group I		Group II		Group III	
	A	D	A	D	A	D
Heart rate beats/min	-18%	-19%	-12%	-20%	- 9%	- 9%
Stroke index ml/beat/m2	+61%	+57%	+27%	+43%	+21%	+18%
Cardiac index L/min/m2	+34%	+30%	+ 10%	+ 17%	+ 5%	+ 5
Mean arterial pressure mmHg	- 3%	- 1%	0%	+ 2%	0%	-2%
Sistemic vascular resistance index dyne.sec.cm-5/m2	- 25%	- 24%	- 9%	- 17%	- 5%	- 8%
End diastolic volume index ml/bet/m2	+36%	+35%	+ 4%	+ 13%	+7%	+ 7%

A = Admission D = Discharge

In group II, the low initial values at A improved at D, approaching the normal range; in group III as a whole, there was no significant change in the abnormally low initial values. Nevertheless, in 2 patients of this group we documented a similar improvement as in the majority of G II.

DISCUSSION

The results of our study show that this short-term exercise and nutrition program can significantly improve the hemodynamic condition of a well defined class of patients.

The simple idea that the lowering of mean arterial pressure in this particular population, by means of salt restriction and an increase in diuresis, (herein documented as the decrease in MAP from 10 mmHg to 95 mmHg in Group II and from 94 to 89 mmHg in Group III) would be related to a decrease in circulating blood volume, implies a decrease in cardiac output.

Our results (in Group II, Sp) showed opposite findings, since the preload (EVDI) increased slightly (98 to 100 ml/beat/m2) and the CI also increased (3.27 to 3.58 L/min/m2).

In the obese hypertensive subjects not receiving medications (Group II), the physiological effects of exercise in lowering HR was surpassed by the increase in the SI and the net result was a significant increase in CI. Heart rate decreased from 70 to 63 in G II and from 64 to 60 in G III, considering that many of these latter patients were receiving beta-blocker agents.

The increase in CI was documented only in G II (3.27 to 3.58 L/min/m2; $p < 0.05$). Despite similar body weight loss, patients who were older and had sustained cardiovascular impairment (G III), failed to improve cardiovasculr dynamics and kept operating on he flat or descending lima of the Starling curve (CI decreased from 2.96 to 2.88 L/min/m2).

The technique of TED, as used in this study, owes much of its value to its ability to reflect changes in SI during such dynamic maneuvers as changes in posture as well as in the Valsalva maneuver[29-31].

By defining the hemodynamic problem, the therapeutic intervention might better be directed to the underlying mechanism. It is our impression that the failure in hemodynamic improvement seen in many of the older patients in G III, compared to the universal improvement seen in subjects of G II, can be, at least partially, related to inappropiate drug selection. Two patients in G III however, showed significant improvement that was probably due to the correct therapeutic intervention.

We may anticipate that the routine utilization of the TEB technique in these particular subset of old high risk population would give new insight and a better understanding on the action of therapeutic agents, including those still in the experimental phase[32].

The evaluation and rational approach to hypertension, including the approapiate time for drug selection, can be based on this affordable noninvasive means of reflecting CI and SVRI[28,33].

Although not primarily emphasized in this first protocol, the systolic and diastolic time intervals, respectively, relating to left ventricular contractility and compliance[34,35], can also be obtained by the analysis of the first derivative of impedance changes (dZ/dt tracing) which are easily derived from the NCCOM-3 and a strip chart recorder.

Monitoring of thoracic fluid dynamics and the new indexes of left ventricular contactility were also discriminating for patients who did not show hemodynamic improvement. In G II, EF increased from 53% to 57% IC increased from 43 to 47 sec-1 and PFI increased from 316 to 346 ml/sec/m2; in patients of G III, the EF changed from 56% to 57%, IC did not change (42 to 42 sec-1—and PFI decreased from 278 to 266 ml/sec/ m2.

Finally, for the design of a more extensive and complete protocol, the combined approach of TEB with the total body impedance technique will be of value in attempting to better understand the interaction of body composition, dynamics of fluid compartments and hemodynamics imposed by weight loss and exercise[36-38].

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