Diet optimization for overweight cardiovascular patients by Simplex algorithm

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Abstract

Improving diet is a critical component for cardiovascular disease risk reduction in all around world strategies. Specific goals in this paper was to design diet rich in vegetables and fruits, whole grains, high fiber food, fish with minimum salt, fat (especially reduced amounts of saturated fatty acids) and cholesterol. Model was based on generally available food and beverages in Croatia. Diet optimization was done for overweight cardiovascular patients with body mass index (BMI) over 25 kg/m^2 by using Simplex algorithm. Model was developed for determination of minimum objective function value (minimum price) and meals content in accordance with Dietary Reference Intake for set of nutrients. Constraints in the model were ensured nutrients adequacy and diet palatability during seven days and can be used for designing diet for any other group of patients with restricted diet. Optimized diet provided from 1500 to 1800 kcal/day. Total fats contributed less than 30% of total energy intake per day while cholesterol intake was less than 300 mg/day. Mean daily intake of some vitamins and minerals was less than recommended because of reduced energy intake for targeted patients and can be compensated with fresh fruit and vegetables. Weekly intake that was proposed in this paper was not influenced by seasonal variations.

Key words: optimized diet, cardiovascular patients, Simplex algorithm

Introduction

Normal blood pressure which does not damage cardiovascular system has values 120/80 (± 5%) mmHg. One can have even lower blood pressure not because of disease but because of body construction. Hypertension diagnosis is based on more pressure measurements. If the blood pressure was measured more than three times and was found to be over 140/90 mmHg, which is the upper limit of normal pressure, it can be said that a patient has increased blood pressure. It is reflection of intensive heart work and increased resistance to blood flow in vessels. In Table 1 is shown how hypertension can be graded at different levels dependent on blood pressure values.

Table 1. Categories of blood pressure (1)

CATEGORY	SISTOLIC PRESSURE (mmHg)	DIASTOLIC PRESSURE (mmHg)
optimum	<120	<80
normal	<130	<85
higher normal	130-139	85-89
hypertension - low	140-159	90-99
hypertension - middle	160-179	100-109
hypertension – high	>180	>110

Primary or essential hypertension is found in about 95% of high blood pressure cases and no disease of some organic systems for pressure regulation can be diagnosed. Firstly, causes are inherited factors, unhealthy diet and overweight. Also the causes are reactions on psychosocial factors and stress.
Rarely, in about 5% cases, when the cause of high blood pressure is disease of some of vital organs, secondary hypertension is diagnosed. The most often, kidney diseases, kind of tumor, narrowed blood vessels and even using of oral contraception (1, 2).

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Food is a source of 40 essential compounds that is, with oxygen and water, human life and health are dependent on that. Deficit or increased intake of any mentioned element (for instance fat or cholesterol) leads to ruined balance in organism and diseases appear. Inappropriate diet can ruin vital capabilities of hearth and blood vessels. Qualitatively and quantitatively daily intake under normal level can cause disease of hearth muscle and slower blood circulation. Besides obesity, caused by fat and sugar intake, can cause the same damage. All of that lead to fat and cholesterol saturation in blood vessels and atherosclerosis appears with its consequences: higher blood pressure, thrombosis, brain or hearth stroke (3).

Although obesity is an individual clinical condition, it is increasingly viewed as a serious and growing public health problem. A large number of various diseases have been associated with excessive body mass, particularly cardiovascular diseases, diabetes mellitus type 2, sleep apnea and osteoarthritis. Growing body of scientific research is beginning to provide important clues about how diet choices affect health. In some areas, the relationship between specific foods or dietary supplements and particular health outcomes is fairly clear. For cardiovascular patients, including those with hypertension the recommendations are to balance caloric intake and physical activity, to achieve and maintain a healthy body mass, which can be done by consuming a diet rich in vegetables and fruits, whole-grains, fish, especially oily fish, at least twice a week; reducing intake of saturated fatty acids to <7% of energy, trans fatty acids to <1% of energy, and cholesterol to < 300 mg/day by choosing lean meats and vegetable alternatives, fat-free (skim) or low-fat (1% fat) dairy products and minimize intake of partially hydrogenated fats; minimizing intake of beverages and foods with added sugars; preparing foods with little or no salt; avoiding excessive alcohol intake (4). It is also necessary to take care of everyday diet which should consist of recommended foodstuff. It means that daily intake must at least have one foodstuff from each food group (milk and products, meat, fish, eggs, cereals and products, vegetables, fruits). Such a diet ensures varied and well balanced diet.

Recent researches showed that blood pressure can be decreased when Dietary Approaches to Stop Hypertension (DASH) is applied. DASH puts accent on decreased sodium intake. There are two version of DASH plan; standard plan (about 2300 mg of sodium per day) and plan with decreased sodium intake for blood pressure regulation (about 1500 mg of sodium per day) (5).

In spite of fact that medications are used in cardiovascular disease therapy they will not obtain respective results if diet is not optimized.

Linear programming was involved for menu and diet modelling and planning with the aim of providing a desired nutrient content, habitual diet patterns of target population and to identify the most stringent constraints in nutritional recommendations regarding the minimum costs of optimized diet (6 – 10).

Therefore, this study was aimed to optimize diet for overweight cardiovascular patients by using linear programming with respect to all demanded constraints.

Materials and methods

Foodstuff found in neighborhood was used in preparing weekly menu for overweight cardiovascular patients (BMI>25 kg/m^2). All food groups were included in model. By using linear programming method and Simplex algorithm menus were created and breakfast, lunch, additional meal and supper were defined.

The model of program LINDO (11) included sets of constraints (Table 2), intake set of nutrients which are in accordance with the Dietary Reference Intakes (12), limiting energy and fat intakes, and not selecting food quantities exceeding the amount usually eaten in the population. Constraints also ensured minimum objective function value (minimum price) as well as diet palatability for proposed meal. Sodium intake is decreased and was used in about 40% of usual daily intake for healthy adult person.

Table 2. Constraints applied in proposed model

NUTRIENT	MAX. BOUNDARIES (% of total daily energy)	NUTRIENT	MAX. BOUNDARIES (g/day)
proteins	20	cholesterol	0.3
fats (total)	30	dietary fiber	35
saturated fatty acids	10	potassium	3.5
unsaturated fatty acids	20	calcium	1
carbohydrates	50	magnesium	0.35
		vitamin C	0.09
		salt	2

Results

Table 3 presents daily menu for a seven day period for overweight cardiovascular patients. The mean daily cost was 26.04 HRK (range = 22.32 – 36.76 HRK).

Table 3. Contents and costs for all daily menus

DAY	MEAL	COMPONENTS (content)	COSTS (HRK)	TOTAL COSTS (HRK/day)
Mon	breakfast	fruit tea (200 mL), frankfurters (100 g), dark bread (100 g), peach (150 g)	5.08	24.49
	lunch	soup with beef (300 g), stewed beef (120 g), stewed rice (150 g), tomato sauce (125 g)	14.42	
		apple juice (200 mL)	1.60	
	dinner	corn grits (100 g), yoghurt (200 g), orange (150 g)	3.39	
Tue	breakfast	biscuit Petit Beure (50 g), milk with 0,9% m.f. (250 g), banana (100 g)	3.30	24.94
	lunch	French cooked beans (350), hashed steak (150), dark bread (100), ice cream (80)	11.03	
		coffee (100 g), stewed ananas (100 g)	2.25	
	dinner	risotto with beef (300 g), fresh paprika (100 g), apple (100 g)	8.36	
Wed	breakfast	milk with 0,9% m.f. (200 mL), honey (25 g), dark bread (100 g), pear (150 g)	3.44	25.24
	lunch	soup with vegetables (300 g), pasta bolognese (250 g), red beet canned (100 g)	10.80	
		orange juice (200 mL)	1.40	
	dinner	stewed chicken (150 g), stewed kohlrabi (200 g), lettuce (120 g)	9.60	
Thu	breakfast	milk with 0,9% m.f. (200 mL), cornflakes (50 g), apple (150 g)	4.30	24.86
	lunch	soup with wheat grits (250 g), baked turkey (150 g), rice with green pea (300 g), salad with tomato (200 g)	15.16	
		coffee (100 mL), chocolate pudding (100 g)	2.00	
	dinner	pasta with cheese (300 g), orange (150 g)	3.40	
Fri	breakfast	yoghurt (180 g), ham (60 g), dark bread (100 g), tangerine (150 g)	4.59	36.76
	lunch	soup with tomato (300 g), stewed hake (100 g), stewed kale (255 g), dark bread (100 g)	10.84	
		stewed pears (200 g)	2.50	
	dinner	mixed vegetable stew (300 g), stewed beef (100 g), dark bread 850 g)	18.83	
Sat	breakfast	tea (200 mL), fresh cheese (100 g), fresh paprika (100 g), orange (100 g)	5.91	23.66
	lunch	soup with potatoes (300 g), hashed steak (150 g), spinach with milk (250 g), boiled potatoes (200 g)	12.71	
		coffee (100 mL), wafers (25 g)	1.70	
	dinner	wheat grits with milk (250 g), stewed peaches (150 g)	3.34	
Sun	breakfast	milk with 0,9% m.f. (200 mL), jam (30 g), dark bread (100 g), banana (150 g)	2.67	22.32
	lunch	soup with chicken (300 g), baked chicken (200 g), stewed carrot (120 g), potatoes with milk (120 g), salad with cabbage (150 g)	15.35	
		apple (150 g), biscuit (25 g)	2.20	
	dinner	pasta with cabbage (250 g), dark bread (50 g), paprika canned (80 g), lemon juice (200 mL)	2.10	

Daily consumption of selected food groups for seven days is shown in Table 4. The consumption of fruits and vegetables was completely satisfactory ($\overline{X}$ = 590 g/day), regarding the recommended 400 g/day fruits and vegetables (13).

Table 4. Daily intakes of selected food groups (g) in optimized diet for overweight cardiovascular patients

FOOD GROUP	MON	TUE	WED	THU	FRI	SAT	SUN	$\overline{X}$ ± SD	CV (%)
milk (products)	200.0	205.0	107.2	155.3	180.0	102.1	100.0	149.9 ± 46.7	31.1
meat, fish, eggs	229.9	185.1	192.9	128.0	248.6	87.7	200.5	181.8 ± 56.3	30.9
cereals	165.2	61.5	60.5	191.8	17.4	44.1	54.6	85.0 ± 66.0	77.7
bread	100.0	133.3	100.0	0.0	250.0	133.3	150.0	123.8 ± 74.4	60.1
vegetables	79.3	256.3	423.4	284.8	510.0	313.2	429.8	328.1 ±142.4	43.4
potatoes	0.0	61.6	20.4	0.0	45.0	215.9	86.8	61.4 ± 75.3	122.7
fruits	302.9	300.1	150.0	300.0	228.7	252.9	300.0	262.1 ± 57.4	21.9
sugar and sweets	16.5	54.5	25.6	21.2	19.8	56.6	55.0	35.6 ± 18.7	52.6
fats and oils	11.3	28.3	36.7	49.9	22.8	23.2	38.5	30.1 ± 12.7	42.1

Table 5 presents daily dietary intake of energy and nutrients. This optimized diet provided 1516 – 1751 kcal/day ($\overline{X}$ = 1618 kcal/day) because of the fact that we optimized diet for overweight patients. Total fats and saturated fatty acids contributed 27% and 7% respectively of total energy intake, while cholesterol intake was less than 300 mg/day (range = 95.8 – 205.6 mg/day). Carbohydrates and proteins provide approximately 52% and 18% respectively of the total energy supply. The mean daily intake of sodium was somewhat lower ($\overline{X}$ = 2069.8 mg/day) than in the DASH eating plan, whose recommendation is up to 2300 mg/day. The mean daily intake of some vitamins and minerals was less than recommended because of reduced energy intake for targeted patients and can be compensated with fresh fruit and vegetables. Weekly intake that was proposed in this paper was not influenced by seasonal variations.

Table 5. Daily intakes of energy and nutrients in optimized diet for overweight cardiovascular patients

NUTRIENT	MON	TUE	WED	THU	FRI	SAT	SUN	$\overline{X}$ ± SD	CV (%)
energy (kcal)	1751.0	1717.3	1660.6	1534.2	1616.5	1516.5	1526.8	1617.6 ± 95.7	5.9
proteins (g)	65.4	59.1	84.2	75.2	83.2	64.2	76.9	72.6 ± 9.8	13.5
fats (g)	56.1	53.7	47.4	44.4	53.7	45.4	37.1	48.4 ± 6.9	14.2
saturated fatty acids (g)	19.0	17.4	13.2	9.8	15.2	12.1	6.2	13.3 ± 4.4	33.3
unsaturated fatty acids (g)	26.2	30.1	33.4	33.0	37.4	28.2	28.3	30.9 ± 3.9	12.5
cholesterol (mg)	205.6	121.0	167.5	205.3	181.6	95.8	153.0	161.4 ± 41.5	25.7
carbohydrate (g)	228.2	225.6	217.2	206.2	200.8	198.5	196.5	210.4 ± 13.2	6.3
dietary fibre (g)	10.3	18.1	22.2	19.1	26.2	19.5	31.0	20.9 ± 6.5	31.3
sodium (mg)	2236.3	1457.3	2839.0	1565.1	2911.0	1442.8	2037.3	2069.8 ± 792.4	38.3
potassium (mg)	1901.3	2656.6	3234.2	2714.6	2946.2	3461.5	3546.6	2923.0 ± 567.8	19.4
calcium (mg)	347.0	585.7	498.0	428.5	459.1	716.2	536.9	510.2 ± 119.0	23.3
magnesium (mg)	152.5	101.2	108.5	127.8	79.2	181.2	186.5	133.8 ± 41.0	30.6
phosphorus (mg)	788.5	897.9	1259.1	1071.3	1345.0	1113.5	1120.5	1083.8 ± 191.5	17.7
iron (mg)	11.0	6.7	11.4	5.8	6.9	13.8	8.6	9.2 ± 3.0	32.5
C vitamin (mg)	65.5	207.0	256.3	110.3	273.2	188.0	219.0	188.5 ± 75.6	40.1
A vitamin (µg)	403.2	293.6	594.9	313.7	377.1	1522.5	189.3	527.8 ± 456.0	86.4
B1 vitamin (mg)	0.76	0.80	1.20	1.03	1.13	1.03	0.93	1.0 ± 0.2	16.6
B2 vitamin (mg)	0.89	0.66	1.20	1.09	1.06	1.75	1.03	1.1 ± 0.3	30.6
B6 vitamin (mg)	0.31	0.70	1.43	1.51	0.81	1.36	2.50	1.2 ± 0.7	57.9

Discussion

Final prices of proposed menu are almost equal for each day in week. The exception is the menu for Friday (36.76 HRK) because of fish. Lunches are slightly more expensive because of more used foodstuff and higher quantity. The mean daily energy intake during seven days (about 1600 kcal) was adapted for overweight cardiovascular patients. It is most important for those patients to reduce fat, cholesterol and salt intake. Total fats in defined meals were under 30%, saturated fatty acids were under 10% while cholesterol intake was under 300 mg/day. All values were under DRI recommendations for healthy consumers. Reduced sodium intake (under 2300 mg/day) was obtained by reduced addition of salt in all prepared meals. Tasteless meals were avoided by keeping salt intake at 40% level according to normal diet.

Daily intake of dietary fibre satisfied lower boundary of recommended values (min. 20 g/day) (14). Higher intake would be desirable and can be reached by increasing the intake of cereals (especially whole grain cereals). The fruits and vegetables consumption is more than satisfactory according to county of this study. Small deviations of vitamin and mineral intakes from recommended levels are not significant and can not cause serious consequences. Increased consumption of whole grain cereals

could ensure more B vitamins as well as more minerals in diet. Recommendations in literature are mostly for healthy people while in this paper menus are prepared for overweight cardiovascular patients and daily intakes of some nutrients are reduced.
Linear programming is a quick and easy way for optimizing diet, but its disadvantage is disability to recognize organoleptic properties of food. The model sometimes offers unusual combinations of foodstuffs in one meal. In these cases, one needs to add new constrains and redirect model to acceptable combinations with the lowest costs. This model was slightly changed and was used in preparing the menu for 20 diabetic patients. The results are very satisfactory and the menu is in daily use for the last few months.

Conclusions

These results suggest that the model presented here can be used to design any other specific diets and nutritional requirement depending on gender, age and other factors. Costs during week are almost fixed, daily intakes of particular nutrients are quite similar while the amount of sodium as the main component was about 40% of the usual daily intakes for healthy people and it was in accordance with the standard DASH recommendation. If it is needed, salt share can be reduced or can be totally excluded from meals.
Simplex algorithm is not sensitive to organoleptic properties and additional constraints should be added in the model for redirecting algorithm to acceptable solution. From a lot of proposed solutions nutritionist will choose the cheapest and more tastefull meals. After preparing the menu for one week, menus for the next week or four seasons could be the next step. Also, this model could be useful for preparing the menus for other patient groups.

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