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THE IMPACT OF FRUIT-VEGETABLE DIET ON HIGH SIGNAL RESOLUTION PULSE WAVE (HSR-PW) PARAMETERS

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Abstract: *Objectives:* The diet and lifestyle affect our life. Inadequate nutrition can cause various diseases including cardiovascular diseases. The aim of this study was to show the correlations between the fruit and vegetable diet and high signal resolution pulse wave parameters. *Design:* This was an observational study. *Settings:* The study was done during two-weeks rehabilitation treatment. *Participants:* In this study 154 people using the fruit and vegetable diet have been examined. *Measurements:* The participants were monitored using a new diagnostic method high signal resolution pulseoximetry (HSR-PW). They were examined two times: before starting the diet and after two weeks of using it. The high signal resolution pulse wave and its characteristic parameters have been compared. *Results:* Analyzing the research results at the beginning and after two weeks of using this diet, the improvement of selected parameters has been noticed. With the improvement in the pulse wave was observed weight loss, improved blood counts (e.g. cholesterol, triglycerides) as well as decreased blood pressure particularly in people with treated hypertension. *Conclusions:* The study shows that applied fruit and vegetable diet influenced favorably the people using it and contributed to the improvement of the HSR-PW parameters which are the source of information about the state of the cardiovascular system.

Key words: Pulseoximetry, high signal resolution pulse wave (HSR-PW), fruit-vegetable diet, cardiovascular diseases, biosignal processing.

Introduction

The science of nutrition is interdisciplinary, combines various fields of knowledge: biology, biochemistry, physiology and also sociological and economic sciences. The range of food science also includes the study of health effects of different ways of feeding, prediction of near and distant consequences of defective trends in consumption and the development of guidelines rational nutrition. With the development of the science of human nutrition discovered proteins having essential to life as the building blocks of all living organisms. They recognized the nature and biological role of amino acids, many minerals and vitamins. It was also found that the fats in foods are not only different calorific value, but also the construction and action in the body. It also explained the importance of individual carbohydrates. Declare that there is a close relationship between nutrition and development, human health and physical fitness caused a rapid increase in the importance of learning about nutrition. The contemporary development of civilization is associated with changes in almost all areas of life, including the field of human nutrition. Unfortunately, natural foods lost its biological value as a result of replacing by processed food. Refining deprived of food priceless fiber, a number of microelements and vitamins, and subjecting foods to high temperatures led to the destruction of enzymes and changes in spatial structures of proteins. The consequence of food processing was the emergence of an unprecedented scale of chronic diseases of civilization of a degenerative-inflammatory character with atherosclerosis and cancer at the head. Man as a biological creature has remained unchanged over the centuries, the cells still have the same functions and needs in terms of nutrients as thousands of years ago. If the departure from nature would be the cause of diseases of civilization, then natural foods based on vegetables and fruit would be a method of casual treatment of these diseases (1-5). On the other hand, the development of medicine and technology provides opportunities and gives appropriate tools for diagnosis of cardiovascular diseases and early intervention in the event of their diagnosis.

The simplest and at the same time non-invasive method used to monitor circulatory system is pulse oximetry. This small device is widely used in various clinical applications, including anesthesia, surgery or critical care (6-10). It is also used in the evaluation of patients with sickle cell disease who are suspected of having acute chest syndrome (11, 12). This method has also found the application in the pediatric ward, and in pediatric intensive and perioperative care (9, 11). The basic physical property that allows to measure oxygen saturation of hemoglobin using pulse oximeter is the fact that oxyhemoglobin absorbs more infrared than red light compared to reduced hemoglobin. Each device contains LEDs, which emit these two wavelengths of light and a photodetector which measures light transmitted through a tissue usually using the finger (8). Unfortunately a standard pulse oximetry monitors only the heart rate and oxygen saturation, which, if more than 95% is assumed to be correct. All the valuable information that allows to diagnose circulatory system and detect even slight irregularities are contained in the pulse wave, a signal, whose analysis can greatly facilitate the diagnosis and treatment process. For this reason a new diagnostic tool High Signal Resolution Pulse Wave (HSR-PW) has been developed to improve the monitoring of cardiovascular system (13).

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The aim of this study was to check if the fruit and vegetable diet has the influence on the cardiovascular system on the basis of high signal resolution pulse wave parameters analysis.

Materials and methods

The study involved 154 patients in the age of 55 – 80 years staying on the two-weeks rehabilitation holiday on a fruit and vegetable diet. Patients were divided into 2 groups: in the first were people with cardiovascular diseases, especially hypertension. In the second group included those without diagnosed before such diseases. All people were monitored using high signal resolution pulseoximetry (HSR-PW). Each person was undertaken two examinations: at the beginning and at the end of staying. At the same time the level of cholesterol divided into fractions, triglycerides, urea, potassium and sodium were controlled. Patients were also monitored blood pressure and body weight. During the diet all people were under the care of a doctor. The study was approved by the ethical committee, and each patient was informed of the aim of this study and filed the signed informed consent form.

Fruit and vegetable diet consists entirely of low-starch plants and low sugar. Compared with conventional feeding delivers a five-fold fewer calories (800 kcal / day), also proteins and carbohydrates and the amount of fat is 20 times smaller. Therefore, for the organism the diet is the type of the medicinal post, in which the metabolism switches to burning, purification and regeneration.

Standard pulse wave was recorded using a commercially available CMS-50E digital pulse oximeter which during the examination was localized on the left hand index finger. Using HSR-PW method not only pulse rate and oxygen saturation but also such parameters like: parameter describing ventricle/aorta volume ratio, aorta valve, pulsatility index, k1/k2 index ventricle/aorta and arteries dynamics, can be determined. They are sensitive indicators of cardiovascular abnormalities such as increased vascular resistance, atherosclerosis, arrhythmia, heart valve defects, etc. (14-16). Additional parameters obtained with the HSR-PW are determined as: ventricle to aorta volume ratio is calculated as the ratio of area under HSR pulse wave generated by the left ventricle until the aortic valve closure to the area of the pulse wave responsible for expanding and shrinking the aorta. This parameter indicates the aortic compliance on changes in blood pressure caused by contraction of the left ventricle. Aorta valve parameter is calculated as the ratio of HSR pulse wave in the moment of the aortic valve closure to the maximum pulse wave amplitude of left ventricle. Pulsatility index is calculated as in the Doppler examination as the ratio of the difference maximum-minimum amplitude of the HSR pulse wave of left ventricle to the average pulse wave evolution of a single heart rate. K1/k2 index ventricle/aorta is the ratio of amplitude of two first maximal peaks of HSR pulse wave. It gives the information about the abnormalities of the left ventricle and the aorta and large vascular resistance. In healthy people this parameter is bigger than 1. The last parameter, artery dynamic, is the sum of the amplitudes of the HSR pulse wave values below and above the average value and gives the information about the flexibility and cardiovascular vulnerability on the distance ventricle-finger.

The procedure of resolution enhancement of standard pulse wave signals was described in previous paper (16) and is as follow. To increase the resolution of biosignal the linear transformation of the digital record is used. The signal, obtained during the examination, can be described by the equation (1),

$$F(x) = \int_{-\infty}^{+\infty} \psi(x')\, K(x - x')dx' \quad (1)$$

where the shape and width of spectral lines is described by a function K, while ψ is a function which describes the positions and intensities of individual components of the signal. To determine the ψ function the F function is transformed using the Fourier Transform (17, 18). The following equation can be obtained (2)

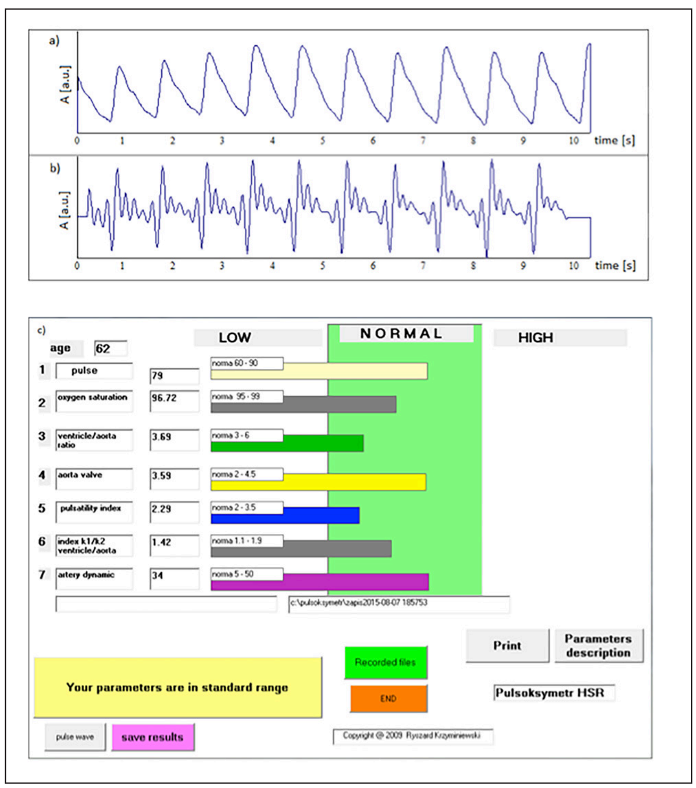
$$\tilde{F}(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} F(x) exp(-iyx)\, dx \quad (2)$$

On the basis of the equation above one can determine ψ(x') function (3):

$$\psi(x') = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+\infty} \frac{F(y)}{K(y)} exp(iyx')dy \quad (3)$$

Figure 1

The exemplary result of normal pulse wave: a) a standard record, b) HSR-PW record, c) HSR-PW parameters



The effect of increasing the signal resolution procedure on pulse wave recorded by the use of pulse oximeter, is shown in Fig. 1. The calculations were made for the core's width for which the increase in the pulse wave enhancement was the greatest and assuming its Gaussian character. The procedure of optimization was described earlier by Krzyminiewski et al. (19).

All results received from the HSR-PW examinations were illustrated as the averages with standard deviation (SD) and standard error (SE) as well as compared with the application of t-Student test. Statistical significance was accepted at the level of $P<0.05$.

Results and discussion

The total number of studied people using fruit and vegetable diet was 154. The results were analyzed and compared in two groups: people with cardiovascular diseases (117 people – 76%), mainly hypertension (91 people – 78%) and without any diagnosed before such diseases (37 people – 24%). In both groups there were people with two results of normal high signal resolution pulse wave (HSR-PW) shape and its parameters. The exemplary result of normal HSR-PW with determined parameters is shown in Fig. 1. For some people the improvement, both in HSR-PW shape and its parameters, was observed after using the diet (Fig. 2).

The shape of HSR-PW normalized after the diet. Before diet the shape of HSR-PW was abnormal (Fig. 2b) what was particularly noticeable in k1/k2 ratio (k1/k2<1). After using the diet the shape of HSR-PW normalized (Fig. 2e) and k1/k2 value was correct (k1/k2>1). Key changes have been observed for three from determined parameters: ventricle/aorta volume ratio (parameter p3), aorta valve (parameter p4) and mentioned earlier k1/k2 index ventricle/aorta (parameter p6). Before starting the diet, these three parameters were out of the norm (Fig. 2c), wherein parameters p3 and p4 clearly exceeded it, while the value of parameter p6 was below the norm. Deviation from a norm for parameter p3 may indicate aortic dysfunction or left ventricular conduction abnormalities. Incorrect value of parameter p4 may indicate aortic valve dysfunction associated with, for example, atherosclerosis. Lowering k1/k2 (parameter p6) below a norm may indicate an increase in peripheral vascular resistance. Observed normalization of the aforementioned parameters after application of diet (Fig. 2f) confirms its positive effect on the cardiovascular system in case of its diseases. Similar abnormalities in these three parameters of HSR-PW were observed in earlier works on the study of patients with various cardiovascular diseases (13-16).

Figure 2

HSR-PW of 72 years old women before (a, b, c) and after diet (d, e, f), where: a) and d) are standard pulse waves, b) and e) are HSR pulse waves, and c) and f) show HSR-PW parameters before and after diet, respectively. The most of parameters normalized after diet

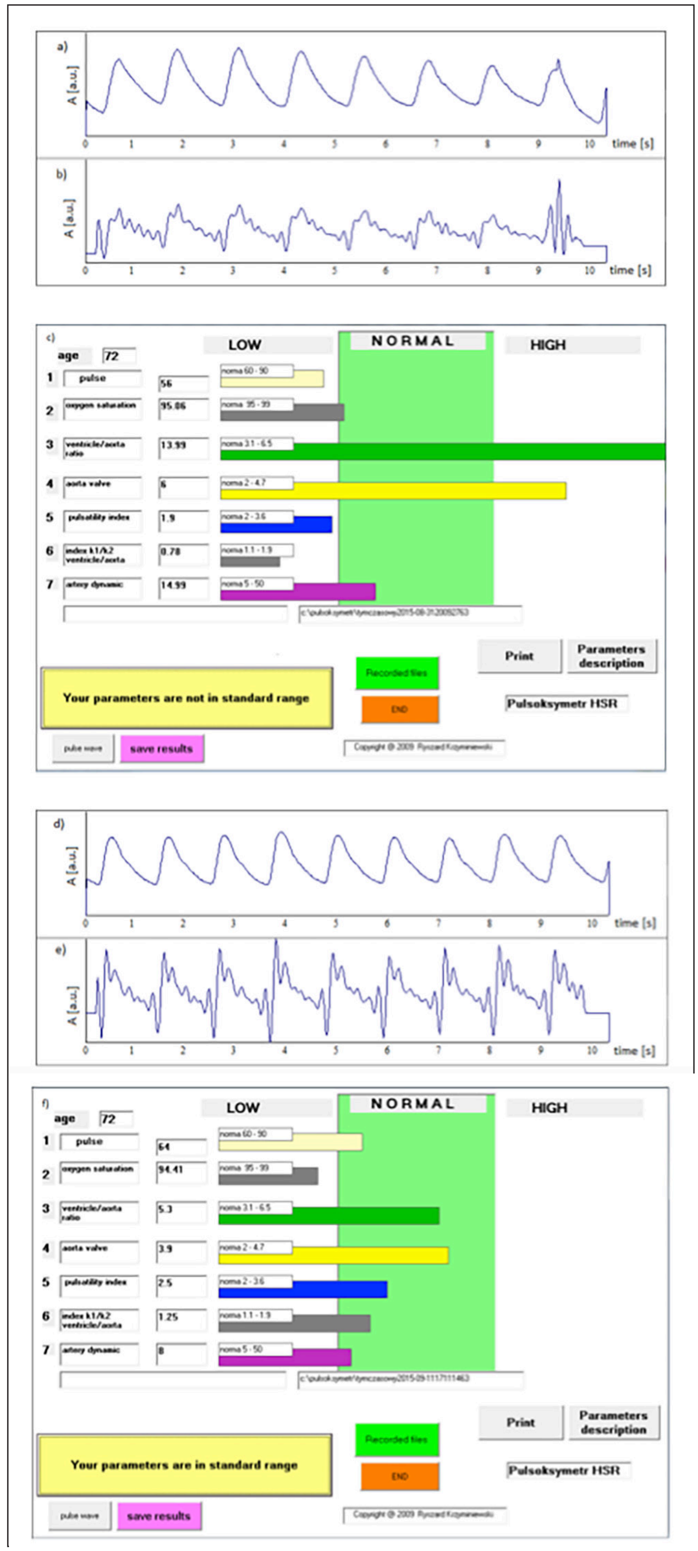


Table 1
Percentage changes in HSR-PW and its parameters (p3, p4, p6) after the fruit and vegetable diet

	All people examined (100%)	People with two normal HSR-PW results	People with first normal HSR-PW result	People with second HSR-PW impro-ved	p3	p4	p6	One of them p3, p4 or p6
Group 1								
People with cardiovascular diseases, mainly hypertension	76%	49%	63%	33%	34%	17%	26%	45%
Group 2								
People without diagnosed any car-diovascular diseases	24%	59%	68%	32%	27%	19%	22%	38%

Table 2
Means, standard deviations (SD) and standard errors (SE) of HSR-PW parameters (p3, p4 and p6) in patients from group I (People with cardiovascular diseases, mainly hypertension) and group II (People without diagnosed any cardiovascular diseases)

HSR-PW			**Group I**				
	Before diet			**After diet**			
	Mean	**SD**	**SE**	**Mean**	**SD**	**SE**	**p-value**
p3	11.80075	6.62624	1.0477	6.0625	1.97802	0.31275	<0.05
p4	5.535	0.74249	0.16603	4.112	0.63841	0.14275	<0.05
p6	0.92179	0.07394	0.01397	1.20536	0.21474	0.04058	<0.05
HSR-PW			**Group II**				
	Before diet			**After diet**			
	Mean	**SD**	**SE**	**Mean**	**SD**	**SE**	**p-value**
p3	8.90333	2.34432	0.78144	5.79889	1.84527	0.61509	<0.05
p4	5.036	0.29905	0.13374	4.052	0.38042	0.17013	<0.05
p6	0.95889	0.05255	0.01752	1.13667	0.1382	0.04607	<0.05

At the beginning it was checked how many people in both groups had two normal results and in how many cases something improved after the diet (Table 1). It was noted that in Group 2 there were more people with two normal HSR-PW (59%) compared to Group 1 (49%), although these differences were not significant. In both groups the shape of HSR-PW improved after diet almost identically, 32% and 33%. Besides the shape of pulse wave also the parameters (p3, p4 and p6) have been compared. In both groups we experienced an improvement in at least one of the parameters after the diet (45% in Group 1 and 38% in Group 2). The greatest improvement was obtained for the parameter p3 (ventricle/aorta volume ratio). The results of these three most important parameters (p3, p4 and p6) were illustrated as the averages with standard deviation (SD) and standard error (SE) to check whether the observed changes were statistically significant (Table 2). It was found that at the level of accepted significance ($P<0.05$) the impact of applied diet was key to HSR-PW parameters. As these parameters give us the information about the status of circulatory system it can be found a beneficial effect of this diet on the health.

Then it was checked how many people in each group had the result of the first examination normal. In Group 1 there were 74 such people (63%) and Group 2 – 25 people (68%). Comparing these two approaches it can be seen that in Group 2 there were more people with first normal examination or two normal examination. However, the differences between the two groups are not large. This may be due to the fact that people with cardiovascular diseases have well-chosen drugs, the cardiovascular system is working properly and there are no irregularities in the pulse wave and its parameters. On the other hand, it is possible that in Group 2 were people with not yet diagnosed cardiovascular diseases.

The results obtained from HSR-PW were related to the standard blood tests, pressure and body weight. After two weeks of use fruit and vegetable diet found to decrease body weight by an average of 4.5 kg where the greatest weight loss was 11 kg, and the smallest 1 kg. In the group of examined people, no significant changes have been observed in the concentration of potassium and sodium in the blood, only small fluctuations not exceeding the standards. In 50% of people in the first test, the cholesterol value was above norm. After a diet in 89% this value decreased, while in 56% it reached a norm. The level of triglycerides was above a norm in 17% of people. In the second study a decrease in triglycerides level has been observed in all of these, while in half of them to a norm. The level of urea has been also controlled. In 79% of people the level of urea in the first study was in a norm and the decrease in the second study was reported in 91%. Such changes in the level of urea can be correlated with increased diuresis caused by fruit and vegetable diet what leads to a reduction of fluids volume. This effect may also contribute to improving the circulatory system by a decrease of blood pressure. Among all people taking part in the study, 91 (62%) were with diagnosed hypertension, stabilized with respective drugs prescribed by a doctor. Changing the diet to fruit and vegetable influenced the decrease in pressure, the effect of which was to reduce the doses of taken drugs.

Because urea is falling what is probably associated with increased diuresis, this has an impact on the volume of body fluids in the circulatory system. This in turn results in lower blood pressure and the tension of the arterial wall. This results in a reduction in vascular resistance, and is reflected by improving parameters such as ventricle/aorta or k1/k2. These parameters, as it has been previously studied, characterized well the changes in the vascular resistance in the circulatory system caused by various factors, for example drugs (16). Because as it can be seen from the above data, the majority of these parameters have been improving, it can be concluded that this diet has a positive effect on the cardiovascular system.

Conclusions

Fruit and vegetable diet with low in animal protein positively affects the cardiovascular system what is manifested by normalization of high signal resolution pulse wave (HSR-PW) parameters.

Conflict of Interest: None

Ethical standard: Approval received from the Bioethical Commission at Karol Marcinkowski Medical University in Poznan, Poland. Agreement No. 937/16.

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