Journal of Human Kinetics volume 16, 2006, 15-24

Effects of Omega-3 Fatty Acids Supplementation on Oxygen uptake in Vegetarian Females

by

Stanislaw Poprzecki[1], Jaroslaw Cholewa[2], Aleksandra Zebrowska[3], Kazimierz Mikolajec[4]

The aim of this work was the evaluation of Omega-3 fatty acid supplementation on haemodynamics and oxygen uptake (VO_2), as well as the concentration of glucose in the blood in vegetarian females. The research material included 18 vegetarian females with an average age of 21,2 ± 1,7 yr, body mass of 58,2±3, 96 kg and body height 167,3±3,42 cm. The subjects were randomly divided into 2 groups: Group S (n=10) was supplemented with omega-3 fatty acids (EPA and DHA) with a daily dose of 2,6 g and a total 4 mg/g of α*-tocopherol over a period of 14 days, while group C (n=8) was treated as a control and received a placebo. VO_2max was evaluated by two methods - indirect Astrand and direct gasometric method. Besides resting heart rate (Polar Electro, Fin), systolic blood pressure (BP) was registered. Blood samples were drawn immediately after exercise and after 1 hour of recovery. Plasma glucose concentration was evaluated at rest and post exercise.*

The research indicated a lower caloric value of the diet in vegetarian females in comparison to average values registered in Polish females. The supplementation with omega-3 fatty acids significantly ($p<0,001$) increased VO_2max evaluated indirectly, although it did not show such changes when measured gasometrical. The supplementation did not change significantly the values of systolic blood pressure and heart rate, however a tendency towards a decrease in these valuables occurred. The obtained research justifies further inquiry of omega-3 supplementation in vegetarians.

Key words: VO_2max, supplementation, omega-3 fatty acid, glucose

[1] - *Department of Biochemistry, Academy of Physical Education in Katowice, Poland*
[2] - *Department of Sports Training Academy of Physical Education, Katowice, Poland*
[3] - *Department of Physiology, Academy of Physical Education, Katowice, Poland*
[4] - *Department of, Sports Games, Academy of Physical Education, Katowice Poland*

Introduction

In the last few years attention has been directed to omega-3 fatty acids as nutritional compounds having a significant role in prevention of cardiovascular diseases. Most likely this is a consequence of stabilization of cardiomyocyte membranes which allow for maintaining a proper structure of ion canals, especially Na^{+} and Ca^{++} (Ismail 2005). Additionally omega-3 fatty acids may change the activity of epinephrine and norepinephrine which influences heart rate. (Mori 2000). It has also been proven that these fatty acids improve micro circulation of blood through vasodilation, decreased viscosity of blood and decreased constriction of blood vesseles (Bruckner 1997). Such factors decrease arterial blood pressure and heart rate, while also diminishing the tendency for blood platelets to aggregate (Lortet et al., 1995).

Omega-3 fatty acid supplementation, along with vitamin E, diminishes the negative effects of free radicals in the blood, which facilitates blood flow in the capillaries. These phenomena may increase oxygen transport to working muscles (Bruckner 1997). It has also been indicated that omega-3 fatty acids supplementation increases insulin sensitivity (Simopoulus 1991). This increases the storage and improves the utilization of glucose in muscle cells. It also stimulates the activity of metabolic cell regulators and glucose transporters through GLUT-4 (Borkman 1993).

Brilla et al., (1990) reported, that fish oil increased maximal oxygen uptake (VO_2max) in men. However, Reastad et al., (1997) found that 10,5 wk of fish oil supplementation did not affect endurance, heart rate or VO_2max of professional male soccer players. The controversies in this area inspired the authors to undertake research concerning female vegetarians in which the concentration of plasma metabolites is significantly lower in comparison to omnivorous subjects (Rossell et al., 2005, Nieman 1999, Conquer et al., 1997a, 1997b).

The main objective of this study was the evaluation of the effects of supplementation with polyunsaturated fatty acids (Omega-3) on hemodynamics and oxygen uptake, as well as blood glucose concentration in vegetarian females.

Material and methods of the investigation

Subjects

The research material included 18 females with an average age of 21,2±1,7 yr, body mass of 58,2±3,96 kg and body height 167,3±3,42 cm. The females claimed to be on a vegetarian diet for a period of at least 2 years. The females had regular menstrual cycles and did not take contraceptives. The menstrual period lasted for 4-5 days and the evaluations were performed 5 days later in the follicular phase. All subjects were informed of the purpose and the nature of the study before giving their written consent to participate in the experiment, which had been approved by the Ethics Committee of the Academy of Physical Education in Katowice.

Supplementation

The subjects were randomly divided into 2 groups. Group S (n=10) was supplemented with omega-3 fatty acids [EPA (C20:5, 30%) and DHA C22:6, 20%)] with a daily dose of 2,6 g with a total of 4 mg/g of α-tocopherol (Rybasol Pronova Biocare A/S Norway) over period of 14 days, while group C (n=8) was treated as a control, receiving a placebo. One week prior to the study, the subjects recorded all food and drink intake for 3 days (including 1 weekend) on a 3-day diet record. From this record a registered dietitian determined daily energy intake for each subject based on total grams of carbohydrate, protein and fat reportedly consumed. Feeding habits were determined by an interview, and than an average dietary energy consumption was calculated with the use of the computer program Dietus (B.U.L. InFit, Pl, 1997).

Exercise protocol

Maximal aerobic uptake (VO_2max, ml/kg/min) was evaluated by two methods. The first utilized the indirect Astrand method, performed on a Monark 829 E ergocycle with a submaximal effort. The second incorporated a direct gasometric method, performed on a Jaeger ER 900 ergocycle, with the use of Jaeger apparatus (Ger), with progressive exercise intensity. Resting heart rate (Polar Electro, Fin), and systolic blood pressure measurements (BP) were registered. Blood samples from the antecubital vein were drawn, before and after exercise as well as after 1 hour of recovery. Haematocrit and plasma glucose concentration values were evaluated with commercial kits (Analco Poland).

Statistics

For statistical purposes the Statistica Software (1997) was used, as mean values (X) and standard deviations (SD) were calculated. To determine the influence of omega-3 supplementation on chosen variables a 2x2 ANOVA and the post hoc Tukey’s tests were used. The level of significance for all variables was accepted at $p<0,05$. The post exercise results were corrected for changes in haematocrit value.

Results of the study

The caloric value of the diet in the tested vegetarian females was significantly lower than the recommended values in Poland. The vitamin and mineral content of the diet was also lower than the recommended values by most health organizations (Tab. 1).

Table 1

Daily energy intake and composition of the diet in vegetarian females in supplemented and placebo groups

Variables		Supplemented group		Placebo group	
		X	SD	X	SD
Caloric value/d	kcal	1717.79	433.76	1792.30	513.65
Protein	g	53.47	17.68	43.14	19.57
FAT	g	59.83	18.14	61.58	33.21
Carbohydrate	g	238.58	63.98	266.38	63.30
Energy from protein	cal%	12.69	2.16	9.56	2.74
Energy from FAT	cal%	31.38	4.84	30.41	9.79
Energy from CHO	cal%	55.93	5.83	60.27	10.33
Calcium	mg	924.14	319.60	600.78	355.90
Phosphorus	mg	1002.78	334.75	815.79	283.47
Iron	mg	7.89	2.18	7.90	2.80
Magnesium	mg	169.13	44.65	154.13	47.89
Sodium	mg	667.47	427.04	767.67	364.34
Potassium	mg	1136.95	460.68	1086.20	330.02
Copper	mg	0.40	0.16	0.41	0.13
Zinc	mg	4.44	1.46	3.62	1.47
Vitamin A	j.m.	1753.82	531.33	2111.39	1729.43
Vitamin B1	mg	0.65	0.22	0.71	0.35
Vitamin B2	mg	1.26	0.42	1.03	0.55
Vitamin PP	mg	5.99	2.81	6.47	2.96
Vitamin C	mg	26.10	11.77	30.21	17.86
Vitamin E	mg	2.96	2.46	1.17	0.46

The research showed significant differences in VO_2max measured directly and indirectly (Tab. 2, Fig. 1). Omega-3 supplementation caused a statistically significant increase ($p<0{,}001$) only in VO_2max measured indirectly (Astrand test). Similarly, the results of ANOVA showed statistically significant affects of omega-3 supplementation on VO_2max only in the indirect Astrand method ($F=2{,}92$), $p<0{,}001$). The results of ANOVA did not show a significant affect of omega-3 treatment on heart rate (p=0,084) or systolic blood pressure (p=0,24). (Tab. 2). Further analysis showed no effect of the omega-3 supplementation protocol on blood glucose concentrations. A significant effect on blood glucose concentration was shown in case of exercise (p<0,01) (Tab. 3).

Table 2

VO_2max (Astrand's method), VO_2max (gasometric method), heart rate (HR) and systolic blood pressure (BP), before and after supplementation in treated (S) and placebo (P) groups

Variables	Group	Before supplementation		After supplementation	
		X	SD	X	SD
VO_2max –Astrand (ml/kg/min)	S	48.2	5.4	54.6**	4.7
	P	41.4	5.9	41.2	5.5
VO_2max (ml/kg/min)	S	30.4	1.8	30.9	1.6
	P	31.1	2.1	31.4	2.6
HR (bts/min)	S	72.6	3.3	70.2	2.2
	P	73.5	3.3	72.6	2.6
BP (mmHg)	S	119.3	4.9	115.0	4.1
	P	118.6	6.6	119.7	4.8

**significantly different in relation to before supplementation value p<0,001, (post hoc Tukey test).

Table 3

Plasma glucose concentration (mg/dl) before and after supplementation, in supplemented and placebo groups at rest, post exercise and after 1 hour of recovery

Period	Exercise	Supplemented group#		Placebo group	
		X	SD	X	SD
Before supplementation	Rest	88.9	11.7	95.9	11.9
	Post exercise	88.6	13.5	102.71*	15.9
	1 h of recovery	84.8	8.6	94.2	13.2
After supplementation	Rest	96.7	11.2	84.4	7.2
	Post exercise	101.1	11.5	95.7	10.4
	1 h of recovery	99.4	11.6	95.4	12.1

#corrected with Ht value, *significantly different in relation to rest value p<0,05,

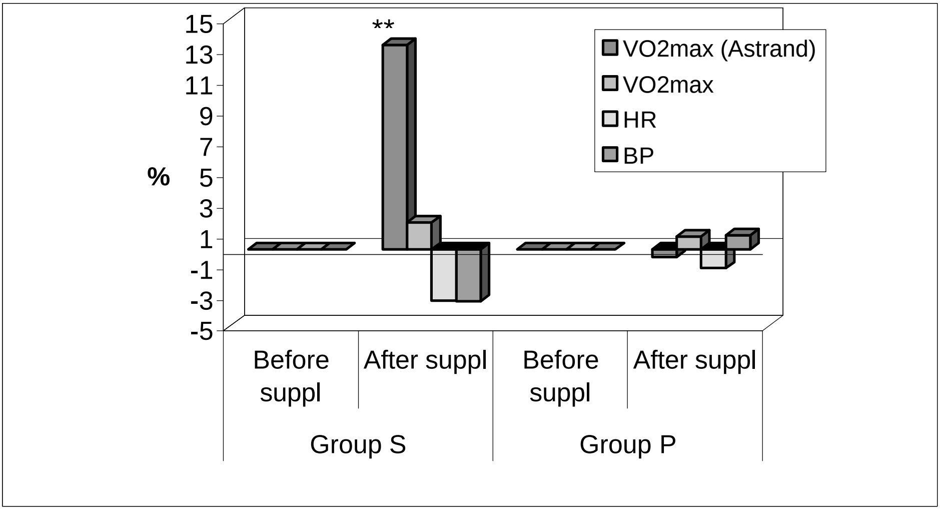

Fig. 1.

Changes (per cent) of the VO_2max (Astrand), VO_2max, heart rate (HR) and systolic blood pressure (BP) before and after supplementation in treated (S) and placebo (P) groups

***significantly different in relation to before supplementation value p<0,001, (post hocTukey test).*

Discussion

A positive effect of polyunsaturated fatty acids on the cardiovascular system is well documented (Dallongeville et al., 2003, Fischler et al., 2003, Pond et al., 2001). Increased concentration of omega-3 in the organism improves blood haemodynamics. This improvement is caused by increased elasticity of erythrocytes and capillary membranes, diminished platelate aggregation, especially in capillaries. The presence of omega-3 fatty acids improves the functioning of cardiomyocytes, and thus improves heart work (Dallongeville et al., 2003, Lornet et al., 1995). Theoretically, such changes should increase oxygen supply to working muscles. The scientific data in this regard are not equivocal. Most scientists do not indicate a positive effect of omega-3 supplementation on cardio vascular fitness evaluated through maximal oxygen uptake (Raastad et al., 1997). However Brilla (1990) showed such positive correlations between omega-3 intake and cardiovascular benefits. Similar results were obtained in this study. The indirect evaluation of oxygen uptake with the Astrand method showed significant increase in cardio vascular fitness after omega-3 intake. This method is based on changes in dynamics of heart rate during submaximal exercises. It can be speculated that under exercise of lower intensity blood flow and heart rate are stabilized and the positive effect of omega-3 is observed. Under such exercise conditions the rate of anaerobic glycolisis is minimal, while the rate of oxygen supply to working muscles is maintained. During the gasometric evaluation procedures, the progressive exercise load causes a significant increase of lactate concentration. Under such conditions the affinity of haemoglobin to oxygen decreases (Bohr's effect) and the transport of oxygen by haemoglobin from lungs to tissues are diminished.

The obtained, positive results of omega-3 supplementation on cardiovascular fitness justify further research in this area especially in endurance athletes and vegetarians (Barr et al., 2004, Janelle et al., 1995, Leaf et al., 1989). Recent data (Rossel et al., 2005) indicate a low blood concentration of omega-3 fatty acids in vegetarians. The increase of VO_2max was most likely caused by a greater sensitivity to omega-3 supplementation in vegetarians in comparison to subjects on normal, mixed diets (Saldeen et al., 2004).

Some researchers indicate that omega-3 fatty acids also affect lipid metabolism (Brylla et al., 1997, Di Marino et al., 2000) indirectly, influencing the effectiveness of cell regulators initiated by insulin (Liu et al., 1994), McCarty et al., 1998). Under such conditions, these supplements may increase the energetic potential of a muscle cell. During this research no effect of omega-3 supplementation on glucose metabolism was observed. Also this supplementation did not significantly affect the hemodynamic variables of systolic blood pressure or heart rate. It is probable that the applied dose of omega-3 may have been too low.

Conclusions

It can be concluded that omega-3 supplementation in vegetarian females significantly affected cardiovascular fitness evaluated indirectly, while this treatment did not influence VO_2max measured gasometrically. The intake of omega-3 also did not significantly influence glucose metabolism, resting heart rate or systolic blood pressure. However a tendency towards a decrease in heart rate and systolic blood pressure was observed following the supplementation. The obtained results indicate a necessity of further research in the area of omega-3 supplementation in vegetarian athletes.

References

Barr S.I., Rideout C.A. (2004) Nutritional considerations for vegetarian athletes. *Nutrition* 20(7-8), 696-703.

Borkman M., Storlein L.H., Pan D.A., Jenkins A.B., Chisholm D.J., Campbell L.V. (1993) The relation between insulin sensitivity and the fatty acid composition of skeletal muscle phospholipids. *N. Engl. J. Med.*. 328, 238-244.

Brilla L.R., Landerholm T.E. (1990) Effect of fish oil supplementation and exercise on serum lipids and aerobic fitness. *J. Sports Med. Phys. Fitness* 30(2), 173-180.

Bruckner G. (1997) Microcirculation, vitamin E and omega-3 fatty acids: an overview. *Adv. Exp. Med. Biol.* 415, 195-208.

Conquer J., Holub B. (1997) Docosahexaenoic acid (n-3) and vegetarian nutrition. *Veg. Nutr. Int. J.* 1, 42-49.

Conquer J.A., Holub B.J. (1997) Dietary docosahexaenoic acid as sources of eicosapentaenoic acid in vegetarians and omnivores. *Lipids* 32(3), 341-345.

Dallongeville J., Yarnell J., Ducimetiere P., Arveiler D. et al., (2003) Fish consumption is associated with lowers heart rates. *Circulation*, 108(9), 820-825.

Di Marino L., Maffettone A., Cipriano P., Sacco M., Di Palma R. et al., (2000) Is the erythrocyte membrane fatty acid composition a valid index of skeletal muscle membrane fatty acid composition? *Metabolism* 49(9), 1164-1166.

Field C.J., Ryan E.A, Thompson A.B., Clandinin M.T. (1990) Diet fat composition alters membrane phospholipids composition insulin binding and glucose metabolism in adiposities from control and diabetic animals. *J. Biol. Chem*. 265, 11145-11150.

Fischler L., Meredith D.O., Reinhart W.H. (2003) Influence of a parenteral fish-oil preparation (Omegaven) on erythrocyte morphology and blood viscosity in vitro. *Clin Hemorheol. Microcirc.* 28(2), 79-88.

Ismail H.M. (2005) The role of omega-3 fatty acids in cardiac protection: an overview. *Front Biosci*. 10, 1079-1088.

Janelle K.C., Barr S.I. (1995) Nutrient intake and eating behavior scores of vegetarian and non vegetarian women. *J. Am. Diet Asso*c. 95, 180-188.

Leaf D.A., Rauch C.R. (1989) Omega-3 supplementation and estimated VO_2max: a double blind randomized controlled trial in athletes. Ann. Sports Med. 4(1), 37-40.

Liu S., Baracos V.E., Quinney H.A., Clandinin M.T. (1994) Dietary omega-3 and polyunsaturated fatty acid modify fatty acyl composition and insulin binding in skeletal muscle sarcolemma. *Bichem. J.* 299, 831-837.

Lortet S., Verger V. (1995) Alteration of cardiovascular function in trained rats fed with fish oil. *Int. J. Sports Med.* 16, 519-521.

McCarty M.I. (1998) Complementary measures for promoting insulin sensitivity in skeletal muscle. *Med. Hypoth.* 51, 451-464.

Mori T.A., Watts G.F., Burke V., Hilme E., Puddey I.B., Beilin L.J. (2000) Differential effects of eicosapentaenoic acid and docosahexaenoic acid on vascular reactivity of the forearm micro-circulation in hyperlipidemic overweight men. *Circulation* 102, 1264-1296.

Nieman D.C. (1999) Physical fitness and vegetarian diets: is there a relation? Am. J. Clin. Nutr. 70(3Suppl), 570S-575S.

Pound E.M., Kang J.X., Leaf A. (2001) Partitioning of polyunsaturated fatty acids, which prevent cardiac arrhythmias, into phospholipids cell membranes. *J. Lipid Res.* 42(3), 346-351.

Raastad T., Hostmark A.T., Stromme S.B. (1997) Omega-3 fatty acid supplementation does not improve maximal aerobic power, anaerobic threshold and running performance in well-trained soccer players. *Scand. J. Med. Sci. Sports* 7(1), 25-31.

Rossel M.S., Lloyd_Wright Z., Appleby P.N., Sanders T.A., Allen N.E., Key T.J. (2005) Long –chain n-3 polyunsaturated fatty acids in plasma in British meat-eating, vegetarian and vegan men. Am. J. Clin. Nutr. 82(2):327-334.

Saldeen P, Saldeen T. (2004) Women and omega-3 fatty acids. *Obstetrical and Gynecological Survey* 50(10), 722-730.

Simopoulos A.P. (1991) Omega -3 fatty acids in health and disease and in growth and development. *Am. J. Clin. Nutr.* 54, 438-463.

Corresponding Author:

Prof. nadzw. dr hab. Stanislaw Poprzecki

Department of Physiological and Medical Science

Academy of Physical Education

40-065-Katowice, Poland

e-mail: s.poprzecki@awf.katowice.pl

Phone: +48 32 207 51 47

Authors submited their contribution of the article to the editorial board.

Accepted for pinting in Journal of Human Kinetics vol. 16/2006 on November 2006.