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Correlation of Various Foods Intakes and Plasma Levels of Omega Fatty Acids in Healthy Japanese Old Men

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Abstract

Background: Trans fatty acids are considered to impair health and some ω fatty acids are protective against atherosclerosis and diabetes mellitus. Trans fatty acids are said to be formed by the partial hydrogenation of vegetable oils. Some amounts are produced in digestive organs of ruminants and present in dairy products or meat. It is important how much these intaken fatty acids influence their plasma levels. **Methods:** Plasma levels of fatty acids including transforms of healthy old men are measured by gas chromatography and correlations between various foods intakes and plasma levels of trans fatty acids, and ω fatty acids are examined. **Results:** Intake of fish resulted in increase in plasma levels of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) but intake of meat such as beef, cow and chicken meat did not increase plasma levels of arachidonic acid (AA). Intakes of oils increased plasma levels of dihomo-g-linolenic acid significantly and AA to some extent. **Conclusion:** Plasma levels of EPA and DHA increased upon intakes of fish in Japanese old men. Oil intake but not meat intake increased DGLA significantly. These results may explain low incidence of cardiovascular diseases in Japanese people compared with American people whose plasma levels of DHA and EPA are lower.

Keywords

Fatty Acid, Trans Fatty Acid, Palmitoelaidic Acid, Elaidic Acid, Linoelaidic Acid, Saturated Fatty Acid, Unsaturated Fatty Acid, Ω Fatty Acid, DGLA (Dihomo-G-Linolenic Acid), DHA (Docosahexanoic Acid), EPA (Eicosapentaenoic Acid), AA (Arachidonic Acid)

1. Introduction

The Global Burden of Disease about overweight and obesity and morbidity and mortality showed that the prevalence of obesity is now 12% world-widely [1]. Similar trends have been shown in type 2 diabetes.

Not only the amounts of foods taken but the kinds of foods are also very important for health. As to fatty acids, saturated fats [2] and trans fatty acids [3] are problematic for health. Saturated fatty acids affect blood lipids and other lipoproteins [2] and glucose-insulin responses [3].

Trans fatty acids, unsaturated fatty acids with at least one double bond in the transform, are formed during the partial hydrogenation of vegetable oils. This process changes vegetable oils to semisolid fats, which can be used in margarines and commercial cooking. The average consumption of industrially produced trans fatty acids in US is 2% to 3% of total calories consumed [4].

Higher intakes of industrially-produced trans fatty acids (IP-TFA) [5] and of saturated fatty acids are associated with increased risk for CHD (coronary heart disease) [6] [7], and higher intakes of both the $\omega 6$ (n − 6) polyunsaturated fatty acids (PUFAs) and the n-3 PUFAs are associated with lower risk of CHD [8].

We recently examined relationships between various foods intake and plasma levels of 3 important TRAs such as palmitoleic, elaidic, and linolelaidic acids and found that there was no correlation between plasma levels of these trans fatty acids and various foods intakes except for preference drink [9].

Since ω fatty acids are very important for health and plasma levels of docosahexanoic acid (DHA) and eicosapentaenoic acid (EPA) are higher in healthy Japanese old men than American old men; we wanted to know what kinds of foods influence plasma levels of these fatty acids.

Currently, CHD death rates in Japan are 3× lower for women and 4× lower for men (ages 35 - 74) compared with the US. The American Heart Association provided CHD death rates among 30 countries in its 2017 Statistical Update [10]; Japan had the 2nd and 3rd lowest rate (men and women, respectively).

Japanese immigrants to the US have increased CHD mortality [11], although it is still lower than US Whites; it may be possible that the Japanese (lifestyle, including diet) must be responsible for this difference. Differences in dietary fatty acid patterns may contribute to this phenomenon.

We wanted to know how foods intake contributes plasma levels of trans and ω fatty acids.

2. Materials and Methods

2.1. Participants

We recruited 44 male volunteers older than 50 who were friends and family members of the research team for this study. Exclusion criteria included the use of medications to treat diabetes, hyperlipidemia, hypertension and/or cardiovascular disease (CVD). Smokers were also excluded. We collected blood samples after an overnight fast, and plasma was isolated for fatty acid analysis. We obtained an informed consent prior to conducting the protocol which had been approved by the Ethical Committee of Showa Women's University and Saiseikai Shibuya Satellite Clinic.

2.2. Analyses of Plasma Samples

Fatty acids levels were measured in plasma obtained from ethylenediamine tetraacetic acid anticoagulated blood samples. Samples were frozen at −80 degrees until analyzed at Omegaquant, LLC (Sioux Falls, SD, USA). After thawing, an aliquot of plasma was combined (1:40 parts) with the methylating mixture (boron trifluoride in methanol [14%], toluene, and methanol [35/30/35 v/v]), shaken at 100˚C for 45 minutes. After cooling, 40 parts of both hexane and distilled water were added. After briefly vortexing, the samples were spun to separate layers, and an aliquot of the hexane layer that contained the fatty acid methyl esters was analyzed by gas chromatography as previously described [12].

Plasma factors such as glucose, lipids, and amino acids were measured at SRI, Inc. Japan.

2.3. Studies of Foods Intakes

Participants were given self-administered diet history questionnaires and described answers on each item by recollection of diets they took (7 days dietary recall). We used a brief-type self-administered diet history questionnaire (BDHQ) by using which the Japanese Ministry of Health, Labour and Welfare reports National Nutrition Surveys. From these questionnaires, we calculated the intakes of energy, and varieties of foods such as proteins, carbohydrates, lipids vitamins etc.

3. Results

Table 1 indicates that plasma lipids levels and fasting glucose levels of participants are in the normal ranges of healthy old men in Japan.

Table 1. Backgrounds of various parameters of Japanese old men.

	Japanese (n = 44)
Age	62.4 ± 9.6
Height (m)	1.68 ± 0.07
Weight (kg)	68.8 ± 10.9
BMI	24.3 ± 3.2
Total cholesterol (mg/dL)	209.9 ± 32.3
Triglyceride (mg/dL)	126.4 ± 81.3
HDL-C (cholesterol) (mg/dL)	60.9 ± 16.6
LDL-C (cholesterol) (mg/dL)	123.8 ± 30.2
Fasting blood glucose (mg/dL)	91.7 ± 16.3

Table 2 shows that fish intake has a positive correlation with DHA and EPA level but meat intake did not have any correlation with plasma levels of arachidonic acid (AA).

On the other hand, Intakes of oils increased plasma levels of dihomo-g-linolenic acid (DGLA) which is converted to AA. Although there was a tendency for increase in plasma levels of AA upon oil intake, the correlation with AA was not statistically significant.

Figure 1 shows that intakes of oils such as lard increase plasma levels of dihomo-g-linolenic acid (DHGL) significantly and some extent of plasma levels of arachidonic acid.

Figure 2 shows that fish intakes significantly increased plasma levels of both EPA and DHA.

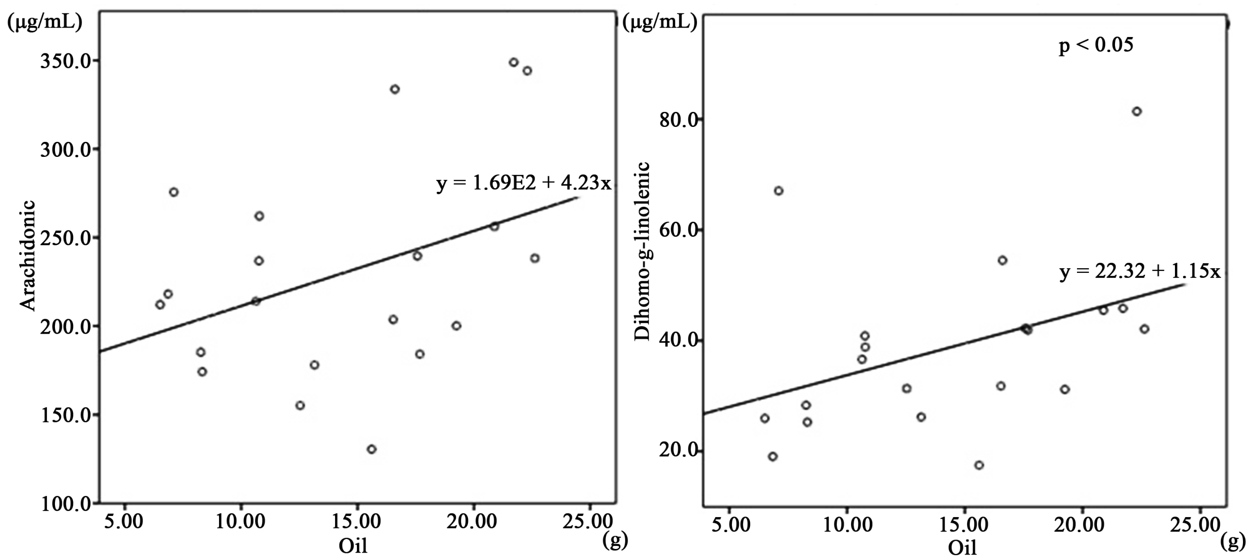

Figure 1. Scatter plot of the correlation of fish intake and EPA, DHA levels.

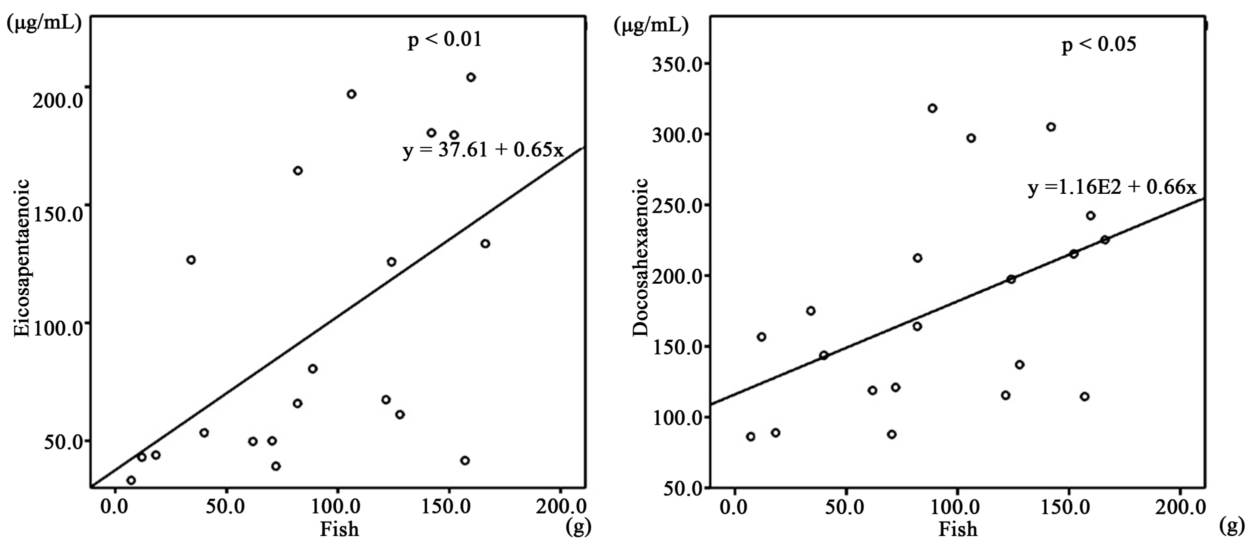

Figure 2. Scatter plot of the correlation of oil intake and plasma levels of DGLA and AA.

Table 2. Correlations between various foods intakes and fatty acids levels.

Fatty acids		mean ± SD	grains	potatos	sugar	beans	green vegetables	other vegetables	fruits	fish
Palmitic		810 ± 238	0.011	−0.129	−0.140	0.011	0.107	−0.035	0.325	0.074
Oleic		3.03 ± 1.28	0.278	0.409	0.197	0.147	0.301	0.331	0.017	0.211
Linoleic	**LA**	991 ± 344	0.072	−0.110	−0.099	−0.161	0.244	0.090	0.301	0.041
Gamma-Linolenic	**GLA**	11.78 ± 8.19	−0.194	−0.228	−0.308	0.083	−0.066	0.338	0.038	−0.230
Alpha-Linolenic	**ALA**	23.3 ± 113.9	0.465*	−0.036	−0.268	0.015	0.326	0.108	0.341	0.026
Dihomo-g-linolenic	**DGLA**	38.7 ± 15.6	0.023	−0.158	−0.044	0.134	0.349	0.412	0.329	0.045
Arachidonic	**AA**	230 ± 60.5	0.065	−0.202	−0.174	0.166	0.135	0.149	0.174	−0.101
Eicosapentaenoic	**EPA**	97.0 ± 60.2	0.391	0.435	0.119	0.188	0.147	−0.098	0.259	0.597**
Docosahexaenoic	**DHA**	176 ± 73.3	0.411	0.327	−0.068	0.157	0.089	−0.165	0.239	0.511*

	meat	eggs	milk	oil	cakes	preference drinks
Palmitic	0.002	−0.059	−0.334	0.356	0.040	0.456*
Oleic	−0.275	−0.165	0.015	0.147	−0.479*	−0.326
Linoleic	−0.132	0.146	−0.364	0.356	−0.040	0.287
Gamma-Linolenic	0.078	−0.015	−0.220	0.211	0.175	−0.126
Alpha-Linolenic	−0.025	0.189	−0.415	0.232	−0.014	0.053
Dihomo-g-linolenic	0.118	0.081	−0.250	0.543*	0.089	0.096
Arachidonic	−0.090	0.078	−0.394	0.310	0.006	0.287
Eicosapentaenoic	−0.168	−0.064	−0.053	0.081	−0.171	0.651**
Docosahexaenoic	−0.256	−0.377	−0.090	−0.104	−0.155	0.432

*p < 0.05, **p < 0.01.

4. Discussion

It has been said that most trans fats in the US diet are produced industrially (IP) during the partial hydrogenation of vegetable oils. Smaller amounts are present in dairy products and in meat from cows, sheep, and other ruminants, produced by bacteria in their stomachs. We found that IP-trans fatty acids were lower in Japan vs the US [9]. The reported intake of IP-TFA is 75% lower in Japan than in the US, again supporting the observed differences in biomarker levels. Circulating 18:2 trans fatty acids were shown to be most adversely associated with total mortality, mainly due to the increased risk of CVD [13]. Recent study from Germany indicated that total trans fatty acids in erythrocyte membranes were shown to be inversely associated with mortality, but this was mainly driven by the naturally occurring 16:1 trans (trans-palmitoelaidic acid) [14]. Other researchers also showed that palmitoelaidic acid is cardioprotective [11] [12]. As to relationship between IP-TFA or SFA intakes and CHD mortality, excessive intakes of both had a greater impact on risk for CHD in the US compared with Japan, whereas insufficient intakes of n6 PUFAs had about the same impact on risk in both countries [13]. As stated above, naturally occurring trans fats are consumed in smaller amounts (about 0.5 percent of total energy intake) in meats and dairy products from cows, sheep, and other ruminants; these trans fats are produced by the action of bacteria in the ruminant stomach [4]. Since trans fatty acids are not used in foods in Japan, all the trans fatty acids must come from meat or dairy products. We found that there was no relationship between various foods intakes and plasma levels of trans fatty acids in Japanese old men. Only intakes of preference drinks such as tea and coffee had significant relationship with plasma levels of palmitoelaidic acid and linoelaidic acid. These results seem to indicate that plasma levels of trans fatty acids are not derived from foods but derived by intestinal microbes. There are some reports indicating that palmitoelaidic acid is a cardioprotective factor [15] [16].

As to ω fatty acids, intakes of long chain $\omega 3$ fatty acids such as eicosapentaenoic acids (EPA), docosapentaenoic acid (DPA), and docosahexanoic acid (DHA) found in fish and fish oils has been shown to be related to the low incidence of coronary heart disease in the Inuit people of Greenland [17]. They indicated that the dietary changes in Norway and especially in Oslo during the Second World War with reduced fat intake resulted in a reduced incidence of and mortality from ischemic heart diseases. This was probably caused to a high degree by reduced platelet aggregability leading to a reduced incidence of thrombosis. They suggested that this was caused by eicosapentaenoic acid (EPA) from fish lipids. Hypocholesterolaemia due to reduced fat intake and increased consumption of polyunsaturated fatty acids may have contributed to these results by reducing platelet aggregability.

Systematic reviews have reported mortality benefits for $\omega 3$ fatty acids [18] [19], and omega-3 biomarker levels have been strongly associated with risk for fatal CHD in still other meta-analyses [20] [21]. Hence, higher omega-3 levels could at least partly explain the lower CHD risk in Japan.

As to effects of EPA and DHA they can act as a competitive inhibitor of AA conversion to PGE_2 and LTB_4, and decreased synthesis of one or both of these eicosanoids has been observed after inclusion of flaxseed oil or fish oil in the diet [22]. Release of the proinflammatory cytokines, the release of tumor necrosis factor alpha and interleukin 1beta was inhibited after dietary supplementation with fish oil [22].

It is well known that thromboxane A_2 is formed from AA. Thromboxane A_2 induces platelet activation, thus thrombosis.

Dihomo-g-linolenic acid is converted to arachidonic acid. We have indicated that plasma levels of AA and dihomo-g-linolenic acid (DHGL) were lower in Japanese than American [23]. Since oils and meat contain AA (**Figure 3**), we thought that American people intake more meat and oils than Japanese resulting in increased plasma levels of AA and dihomo-g-linolenic acid.

Table 3 indicates the amounts of arachidonic acid (AA), DHA and EPA.

There is no EPA or DHA in beef and lard. Although DHA was found in eggs no EPA was found in eggs.

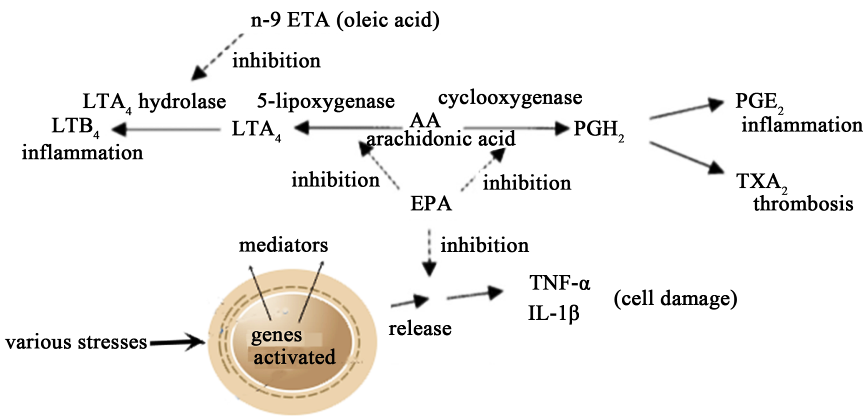

Figure 3. Summarizes the effects of EPA and DHA on inflammation and thrombosis.

Table 3. Fatty acids content in foods.

	AA	EPA	DHA
	g/100 g fatty acids		
beef, shoulder	0.1	0	0
tuna	2	3.4	15
lard	0.1	0	0
egg	1.8	0	1.4

Standard tables of food composition of Japan. Published by Kagawa Education institute of Nutrition 2015.

Figure 3 indicates the effects of AA, DHA and EPA in thrombosis and inflammation.

EPA and DHA inhibits the conversion of AA to LTB4 used for inflammation and the formation of PGE_2 and TXA_2 (thromboxane A_2) which induces thrombosis. EPA and DHA also inhibit release of TNF-α and IL-1β, which are cytotoxic.

The present studies indicate that fish intake results in increased plasma levels of EPA and DHA, and oil intake results in increase in plasma levels of AA and dihomo-g-linolenic acid.

These observations may partly explain different mortality rations by cardiovascular disease between Japanese and American.

5. Ethics

This work has been approved by the Ethical committees of Showa Women's University and NPO (non-profit organization) "International projects on food and health" and has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments.

6. Statistics

The results are presented as means ± SD. Statistical significance of the differences between groups was calculated according to one-way ANOVA. When ANOVA indicated a significant difference ($p < 0.05$), the mean values were compared using Tukey's least significant difference test at $p < 0.05$. Spearman's correlation tests were used to examine statistical significance.

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Experiments were designed and performed by all of the authors. AT wrote a manuscript. Statistical analyses were done by FS. All authors read the manuscript and approved the final version. All the authors had responsibilities for the final content. No conflicts of interest for any author.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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