Project Title: **Effect of a fish-based diet on biochemical parameters relevant to thrombotic and inflammatory diseases.**

Lay Title: **Health effects of fish which are relevant to heart disease and arthritis.**

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OBJECTIVES:

1. To examine the usefulness of diets rich in local fish for elevating tissue levels of omega-3 fats and for suppressing production of inflammatory and thrombotic chemical messengers in healthy human volunteers.
2. To examine effects of the individual omega-3 fats, EPA and DHA, in healthy human volunteers.
3. To determine the levels of fish intake in arthritis patients.
4. To determine common attitudes to fish which might affect its inclusion in the diet.

NON TECHNICAL SUMMARY

Fish contain omega-3 fats which have the potential to provide widespread health benefits. Previous studies with fish oil capsules by ourselves and others have shown a beneficial effect of fish oil in rheumatoid arthritis which is an inflammatory joint disorder. However, these results were obtained with fish oil capsules where the fish oil derives mainly from Menhaden, a North Atlantic species. Findings with Menhaden oil do not necessarily translate to the use of local fish. This is because local fish generally have a different mix of omega-3 fats from that present in Menhaden. There are two principal omega-3 fats in fish; these are EPA and DHA. In Menhaden oil, EPA predominates over DHA whereas in most local fish, the ratio is reversed in favour of DHA. Therefore, it was important to conduct studies to determine if beneficial effects similar to those seen with Menhaden oil capsules (e.g. Maxepa) might be seen also with fish (or fish oil) sourced locally, i.e. from fish in Southern Australian waters.

The first study in this report addressed the potential for local fish to elevate omega-3 fatty acid levels in human volunteers and to decrease the production of inflammatory messenger molecules by the white blood cells. This was successful. The second study also used healthy volunteers to determine if the two omega-3 fats, EPA and DHA, had similar effects on the production of inflammatory messengers. The results showed that dietary EPA and DHA, when ingested individually, accumulate in tissues with similar efficiency and suppress inflammatory messenger production with similar efficiency. However, the results also suggest that EPA and

DHA taken together (as happens when fish oil is used) may be better for suppressing more inflammatory messengers. *Overall, these results suggest that Southern Australian fish will have similar beneficial effects in rheumatoid arthritis and other inflammatory diseases as those which have been demonstrated with Menhaden fish oil capsules.*

However, simple recommendations to rheumatoid arthritis patients to increase fish intake are unlikely to be successful. What is necessary are dietary recommendations which will increase omega-3 fat intake, but which are also practical, easy and suitable for lifetime use. To this end, we conducted two further studies. The first was to document the fish intake in arthritis patients. The results indicated an average intake of one fish meal every two weeks. This would not achieve tissue levels of omega-3 fats which are expected to be beneficial in inflammatory disease.

In order to develop strategies to increase fish intake, we conducted a study of factory workers to elicit attitudes to fish which might affect fish intake adversely. The results indicate that there are several issues which could be addressed in attempts to increase fish intake. These centre around availability, ease of preparation (especially when young children are present), avoidance of bones, and perhaps use of appropriate sauces when odour is perceived to be an adverse factor. Also, the results indicate that the level of fish intake is reflected in the level of omega-3 fats in the blood, implying that higher intakes can provide greater health benefits (up to a limit).

Our conclusions are that Southern Australian fish can be useful components of diets which could be recommended to arthritis patients. However, successful strategies suitable for life-time use will require further developments in the industry. Firstly, fish retailing could be altered by broadening the forms in which fish is presented for sale. Secondly, there is potential for development of fish oil production from local fish. The oil could be used in capsules, but our most recent studies (not reported here) indicate that fish oil can be used as an additive in manufacture of a great array of foods (note that fish oil containing breads have been marketed recently). Development of a variety of foods enriched in omega-3 fats from fish oil (sourced locally) will allow subsequent development of dietary recommendations for arthritis patients (and the general community) which can be adhered to easily and which are suitable for lifetime use.

Summary: Fish contain omega-3 fats which have the potential to provide widespread health benefits. Previous studies with fish oil capsules by ourselves and others have shown a beneficial effect of fish oil in rheumatoid arthritis which is an inflammatory joint disorder. However, these results were obtained with fish oil capsules where the fish oil derives mainly from Menhaden, a North Atlantic species. Findings with Menhaden oil do not necessarily translate to the use of local fish. This is because local fish generally have a different mix of omega-3 fats from that present in Menhaden. There are two principal omega-3 fats in fish; these are EPA and DHA. In Menhaden oil, EPA predominates over DHA whereas in most local fish, the ratio is reversed in favour of DHA. Therefore, it was important to conduct studies to determine if beneficial effects similar to those seen with Menhaden oil capsules (e.g. Maxepa) might be seen also with fish (or fish oil) sourced locally, i.e. from fish in Southern Australian waters.

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Goal: To examine the usefulness of local fish or fish oil as sources of omega-3 fats in diets aimed at the suppression of arthritis and heart disease.

Current Objectives:

(a) To examine the usefulness of diets rich in local fish for elevating tissue levels of omega-3 fats and for suppressing production of inflammatory and thrombotic chemical messengers in healthy human volunteers.

(b) To examine effects of the individual omega-3 fats, EPA and DHA, in healthy human volunteers.

(c) To determine the levels of fish intake in arthritis patients.

(d) To determine common attitudes to fish which might affect its inclusion in the diet.

Significance: The chemical messengers under study are involved in inflammatory diseases (arthritis and heart disease) and thrombosis (unwanted blood clotting as might occur in heart disease). Thus the project involves studying the effects of increasing fish in the diet on markers relevant to arthritis and heart disease.

The project forms a section of ongoing studies on the effects of omega-3 fats on arthritis and heart disease. Because fish contains omega-3 fats, there is potential for use of fish as one of the beneficial foodstuffs in a complete diet which is designed to increase intake of omega-3 fats in arthritis patients and in the general community.

Background: Studies of various communities have pointed to a beneficial effect of dietary omega-3 fats in primary and secondary prevention of coronary heart disease. This evidence came from measurement of fish intake, but the effect was correlated later with intake of plant omega-3 fats as well. Evidence for beneficial effects of omega-3 fats extends also to studies with rheumatoid arthritis, but in this case only fish oil capsules have been used. Interestingly, both rheumatoid arthritis and coronary heart disease involve inappropriate inflammation in their origin. *Thus, there is evidence for health benefits in inflammatory disease deriving from ingestion of omega-3 fats, whether from fish, fish oil, or vegetable oils.*

Because these sources have different omega-3 fats in different amounts and ratios, it is important to understand which of the omega-3 fats are important, and to understand their biochemical effects. Without this understanding, refinements that increase the beneficial effects of omega-3 fats at a community-wide level are unlikely to occur.

Omega-3 Fats and their Sources

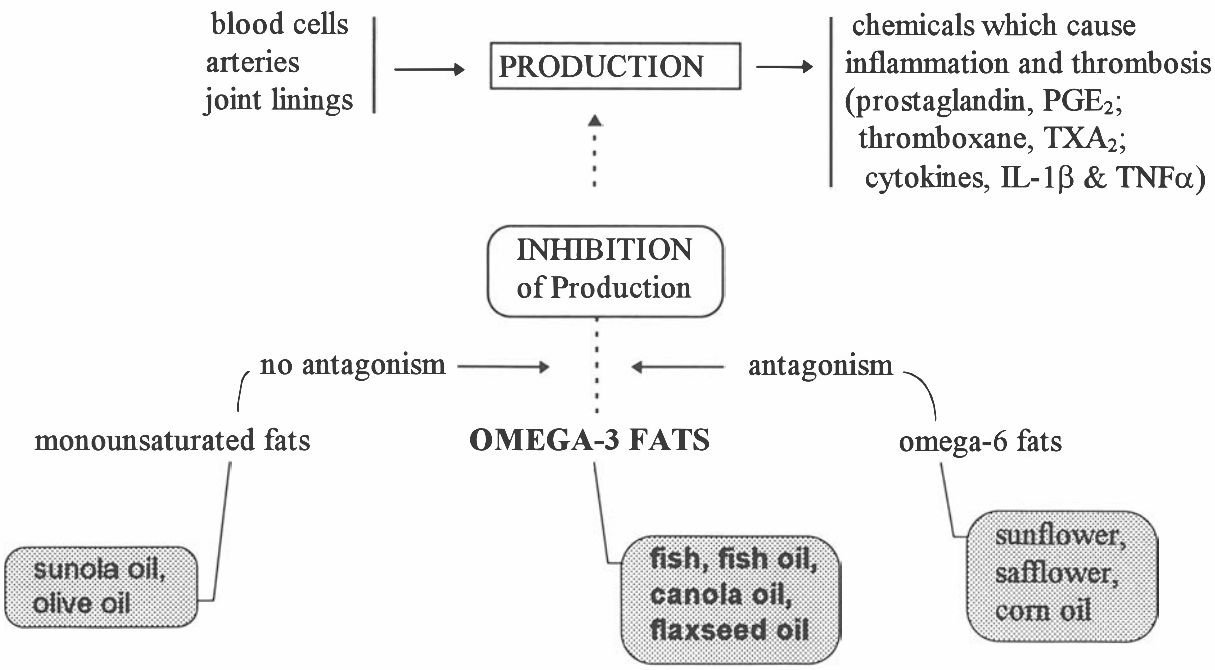
α-LNA (α-linolenic acid)	canola oil, flaxseed oil
EPA (eicosapentaenoic acid)	fish, fish oil
DHA (docosahexaenoic acid)	fish, fish oil

With regard to the biochemical effects of omega-3 fats which might be beneficial, they can suppress production of chemical messengers which are probably involved in the inflammatory changes seen in arthritic joints and atherosclerotic arteries.

The inflammatory chemicals which are suppressed by omega-3 fats are known as prostaglandins, thromboxane and cytokines and they are produced by white blood cells, joint linings, and artery linings. Our previous studies have shown that when the white blood cell level of the omega-3 fatty acid, EPA, increases, then synthesis of inflammatory chemical messengers (the cytokines) is inhibited. In addition, our studies showed that the inhibitory effect was essentially maximal when cellular levels of EPA reached 1 to 1.5% of total fatty acids (1,2). *Therefore, this level of white blood cell EPA provides us with a target level to aim for in studies which are designed to increase cellular EPA through increased intake of dietary omega-3 fats.*

We have conducted a range of dietary interventions over several years, all aimed at increasing omega-3 fat intake and elevating cellular EPA levels. These studies utilised omega-3 rich / omega-6 poor vegetable oils as well as fish and fish oils. Results indicate that the suggested target level of cellular EPA is achievable if a variety of omega-3 rich, and omega-6 poor foodstuffs are made available. Because omega-6 fats such as those found in commonly used polyunsaturated products are antagonists of omega-3 fats at several levels, reduction of omega-6 fat intake will enhance the effectiveness of dietary omega-3 fats and should be a complementary strategy (see scheme below) (3). Monounsaturated oils such as olive oil and sunola oil are suited ideally as substitutes for omega-6 (polyunsaturated) oils because because they do not have the negative health effects of saturates and they are not antagonistic to the absorption and action of omega-3 fats. *Therefore, strategies for increasing omega-3 fats should incorporate use of monounsaturated background dietary fats; currently, olive oil or sunola oil are suitable for this purpose.*

SCHEME SHOWING HOW DIETARY OMEGA-3 FATS CAN SUPPRESS INFLAMMATION AND THROMBOSIS



When considering whether there should be a dietary recommendation to increase fish intake as therapy or prevention for inflammatory diseases, the rationale is based on published studies with fish oil capsules and rheumatoid arthritis. However, there is a complication because the majority of the studies used capsules containing Menhaden oil. *However, effects obtained with Menhaden oil capsules may not be mimicked by ingestion of local fish supplying an equivalent amount of dietary omega-3 fat. This possibility exists because there is a marked disparity between the DHA:EPA ratios in commonly used commercial fish oil capsules such as Maxepa, which has a ratio of 0.7, and the DHA:EPA ratios in Australian fish.* Some DHA:EPA ratios for Australian fish are: kingfish, 10.6; garfish and dory, 7.9; mackerel and tuna, 7.0; flathead and red snapper, 6.0; school shark, 4.7; Australian salmon, 3.7; King George whiting, 1.6; mullet, 0.7 (calculated from refs. 4,5). Thus, it is essential to ascertain the equivalence, or otherwise, of DHA and EPA with regard to the suppressive effects of omega-3 fats on the synthesis of inflammatory chemicals such as prostaglandins, thromboxane, and cytokines. If fish is to be examined and recommended for this purpose, the type of fish examined and recommended may be determined by their DHA:EPA ratios.

Overall, there are many issues to be addressed. The following were examined within this project:

A. Can fish in the diet raise the cellular content of the omega-3 fat, EPA, to a target level of 1.5% of total fatty acids and is there a suppression of inflammatory chemical messenger production by the white blood cells?

B. Of the two omega-3 fats in fish, EPA and DHA, which one is the most active in altering inflammatory chemical messenger production?

C. How much fish do people (in particular, arthritis patients) eat?

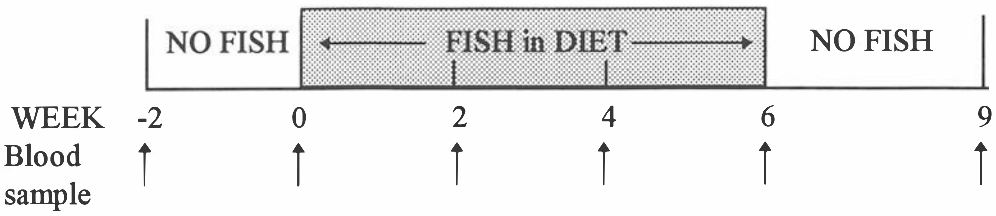
D. What are commonly held attitudes to fish which might be barriers to increasing fish intake?

RESULTS

Question A. Can fish in the diet raise the cellular content of the omega-3 fat, EPA, to a target level of 1.5% of total fatty acids and is there a suppression of inflammatory chemical messenger production by the white blood cells?

Method We conducted a longitudinal study with healthy volunteers. They consumed at least five fish meals / week. Fresh fish (mullet, mulloway, trevalley, snook) were provided by a local producer. Canned fish were provided by Safcol (tuna, salmon). Subjects were provided with Sunola oil, margarine, salad dressing and mayonnaise and these products were provided by Meadow Lea Foods. Diets were monitored by a dietitian and dietary records were kept. Blood was taken for analysis of the white blood cells for fatty acid profile and production of inflammatory chemical messengers (cytokines).

Study Design



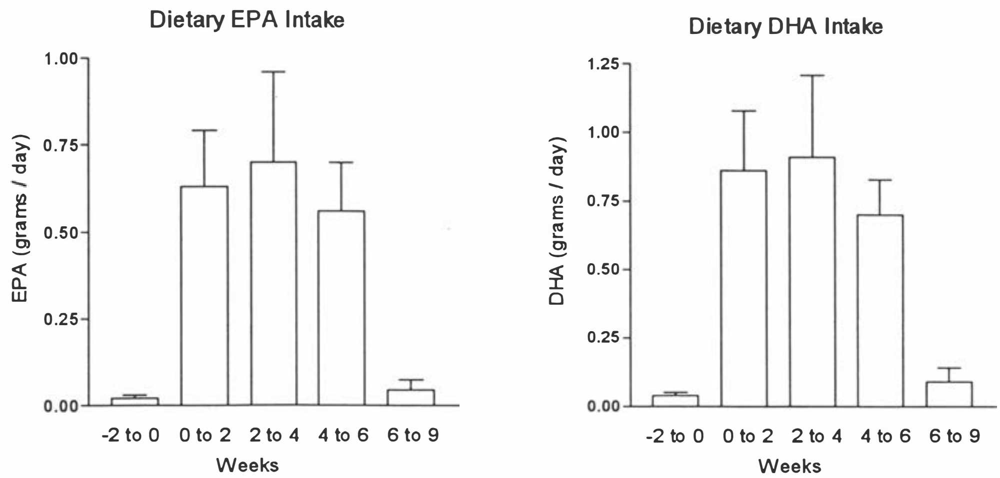
Results

A full dietary analysis from each period revealed that there was no statistically significant change in total energy intake, protein, carbohydrate or total fat intake between the five visits (Table 1). However, during the period where fish was included in the diet, there was a substantial increase in the intake of the omega-3 fats, EPA and DHA (Fig. 1).

Table 1. Estimated macronutrient intake from diet diary analysis for the five dietary periods described above.

	Diet Period (weeks)				
	-2 to 0	0 to 2	2 to 4	4 to 6	6 to 9
Energy Intake (kj/day)	9576 ± 1000	8944 ± 1218	9041 ± 1256	9556 ± 1461	9384 ± 1331
Protein g/day	91.7 ± 15.3	106 ± 32.5	103 ± 25.4	106 ± 31.2	100 ± 16.4
Fat g/day	96.8 ± 15	76.7 ± 15.3	79.5 ± 13.9	89 ± 17.9	93 ± 14.7
Carbohydrate g/day	249 ± 30.7	238 ± 47.3	239 ± 54.3	240 ± 53.9	238 ± 47.3

Fig. 1. Estimated intake of the omega-3 fatty acids, EPA and DHA, from diet diary analysis for the five dietary periods described above.



Fish in the diet also increased also white blood cell (mononuclear cell) content of the omega-3 fat, EPA, to levels close to our target of 1.5% (Fig. 2). The cellular content of the omega-3 fat, DHA, was increased also (Fig. 2).

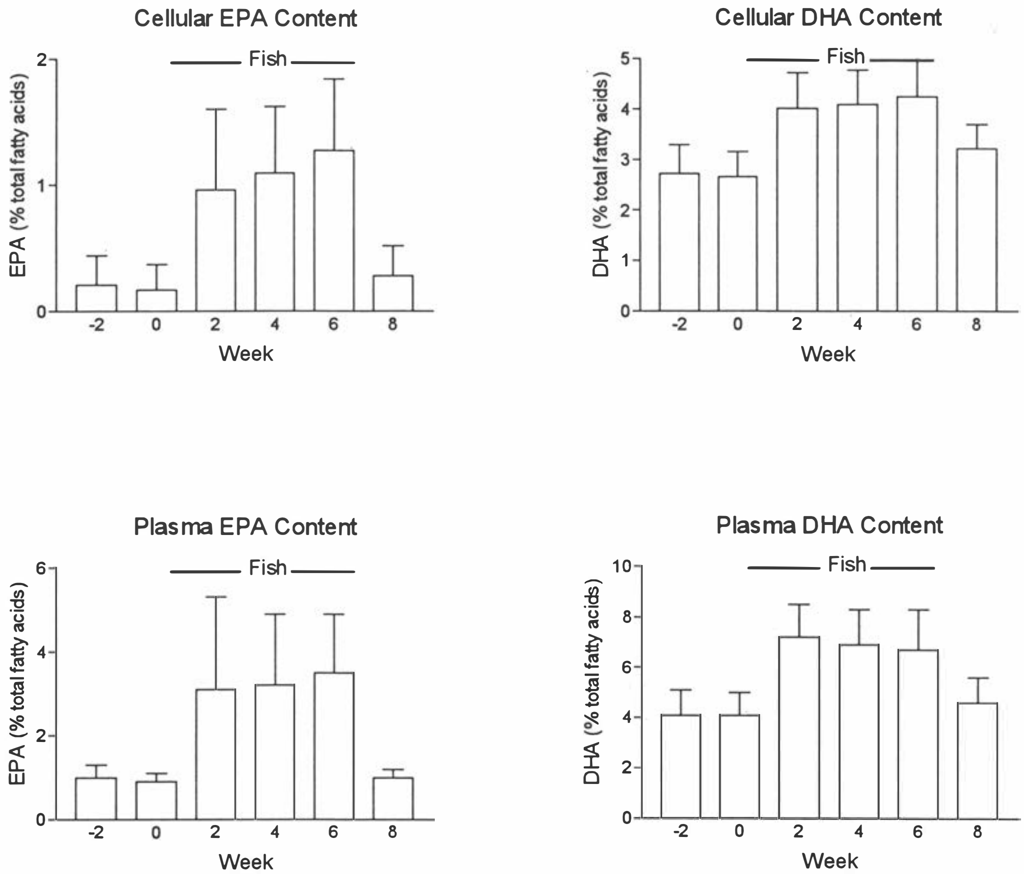


Fig. 2. White blood cell (mononuclear cell) and plasma content of the omega-3 fatty acids, EPA and DHA, for the five dietary periods described above.

The increased cellular levels of omega-3 fats was accompanied by a 33% suppression of the production of the inflammatory chemical messenger, IL-1β, and this suppression was statistically significant (Fig. 3). Production of another inflammatory chemical messenger, TNFα, was supressed by 18%, but this was not statistically significant (Fig. 3).

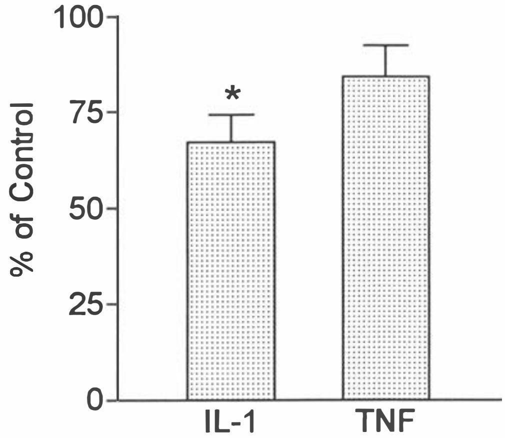


Fig. 3. Effect of fish ingestion on production of inflammatory messengers (the cytokines IL-1 and TNF) by white blood cells. Results represent the average reduction in cytokine production for the entire period of fish oil ingestion. Mean ± SEM (n=6 subjects).

Within our ongoing programme of dietary intervention studies, we have previously examined fish oil in capsules, as well as various vegetable oils. It can be seen that using fish was almost as effective as ingesting 9 capsules (9 g) of fish oil / day (Table 2).

Table 2. Plasma phospholipid levels of omega-3 fatty acids arising from use of diets based on sunflower oil, flaxseed oil, local fish, or supplemented with fish oil capsules (Maxepa).

	Sunflower oil	Flaxseed oil	**Fish**	Fish oil capsules (9 g)	Fish oil capsules (9 g) + Flaxseed oil
	% of total fatty acids				
EPA	0.6	1.9	**3.5**	4.4	5.4
DHA	3.7	3.3	**6.7**	7.6	7.0

<u>Conclusion</u> Australian fish can be a useful component of a diet designed to increase omega-3 fat intake, increase the cellular content of omega-3 fats, and suppress production of potentially harmful inflammatory chemical messengers. Dietary fish alone increased white blood cell EPA levels into the range 1 - 1.3% of total fatty acids. This was associated with modest suppression of one of the inflammatory messengers, IL-1β. This is a creditable outcome for a single foodstuff (fish) and is normally achievable only with fish oil capsules. It is an indicator that, in an omega-3 rich diet where omega-3 fats are supplied from a variety of sources such as canola oil and flaxseed oil products, fish will be an important component.

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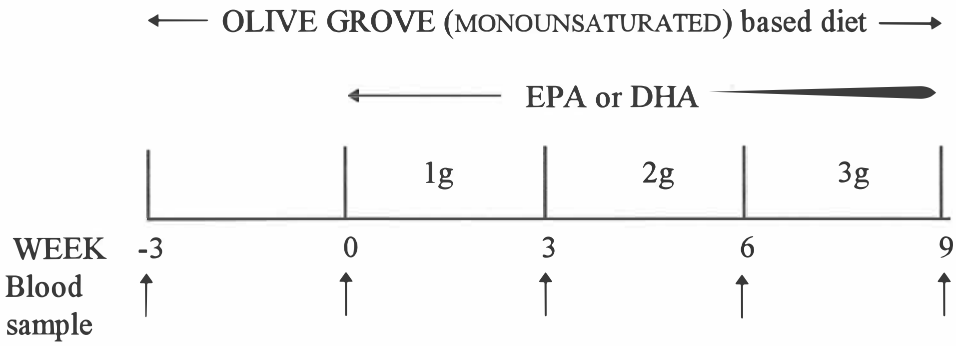
Question B. Of the two omega-3 fats in fish, EPA and DHA, which one is the most active in altering inflammatory chemical messenger production?

Methods

The two omega-3 fats in fish, EPA and DHA, were obtained in pure form in capsules from the US Fish Oil Tests Materials Program which is run from the US National Institutes of Health in Bethesda, Maryland, USA. Healthy volunteers were recruited and consumed in increasing doses 1, 2 and 3g / day of EPA or DHA for 3 weeks at each dose. Subjects were provided with Olive oil, olive oil based margarine, salad dressing and mayonnaise (Olive Grove Brand) and these products were provided by Meadow Lea Foods. Diets were monitored by a dietitian and dietary records were kept. Blood was taken for analysis of the white blood cells for fatty acid profile and production of inflammatory chemical messengers (cytokines).

Study Design



Results

When subjects ingested EPA, there was a dose-dependent increase in EPA in various plasma fractions (phospholipids, cholesterol esters, triglycerides) and blood cells (mononuclear cells and platelets) (Fig. 4).

Because docosapentaenoic acid (DPA) and docosahexaenoic acid (DHA) are both metabolites of EPA, it could be expected that the blood levels and cellular levels of these omega-3 fatty acids would increase in response to the increases in their precursor fatty acid, EPA. While DPA levels were elevated in plasma phospholipid and triglyceride fractions and in both platelets and mononuclear cells, DHA levels were not increased (Fig. 4).

When subjects ingested DHA, there was a dose-dependent increase in DHA in the plasma fractions and the blood cells (Fig. 5). Also, there was an easily discernible increase in EPA in the plasma cholesterol ester fraction, but only modest increases in plasma phospholipids and the blood cells. This is evidence of modest 'retrograde' conversion of DHA to EPA. By contrast, DPA levels declined markedly in the blood cells, an effect due probably to displacement by DHA (Fig. 5).

There was little difference between EPA and DHA in their effects on inflammatory messenger production. Both fatty acids decreased PGE_2 and TXA_2 synthesis by white blood cells (Fig. 6). Also both fatty acids decreased

IL-1β synthesis. In contrast, TNFα synthesis increased in response to ingestion of EPA or DHA (Fig. 6).

Fig. 4. Effect of increasing amounts of dietary ***EPA*** *on the omega-3 fatty acids, EPA, DPA, and DHA in plasma lipid fractions and blood cells.*

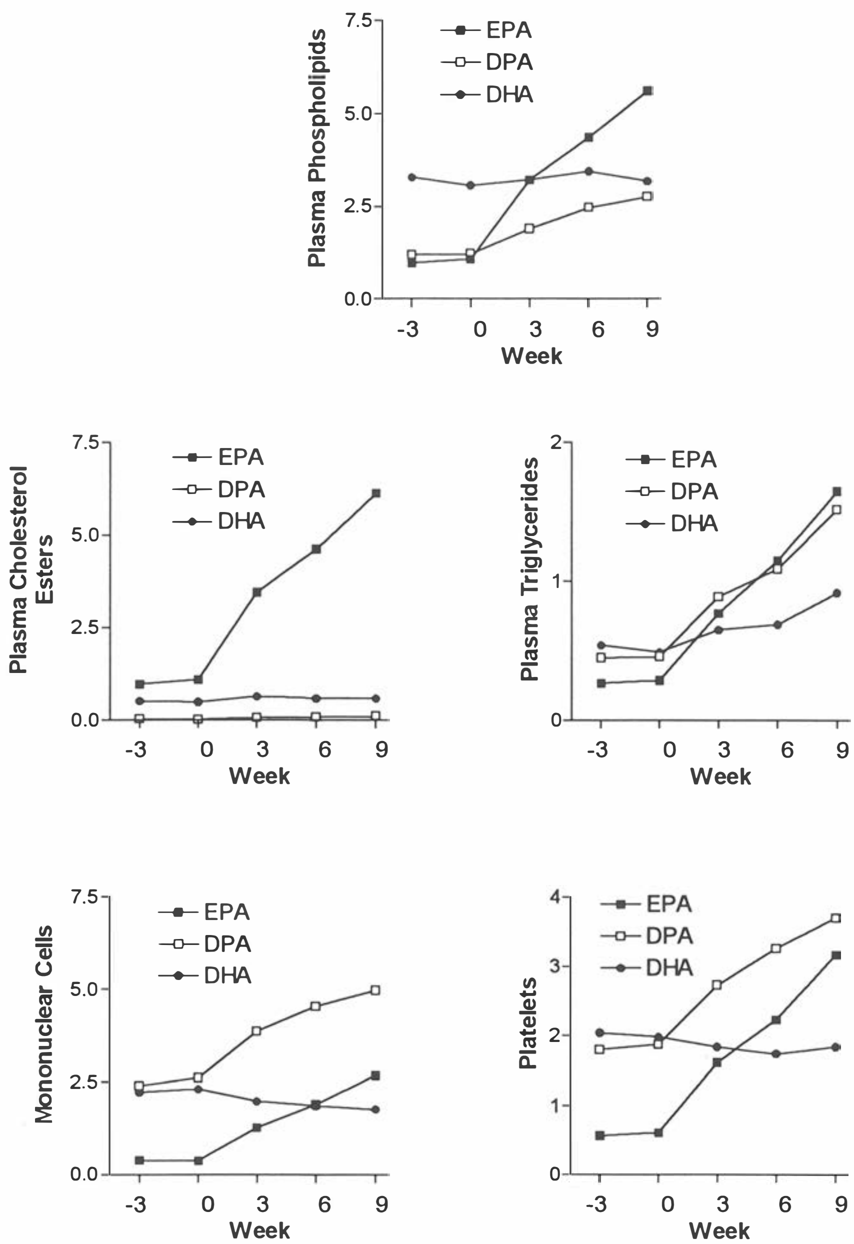


Fig. 5. Effect of increasing amounts of dietary ***DHA*** *on the omega-3 fatty acids, EPA, DPA, and DHA in plasma lipid fractions and blood cells.*

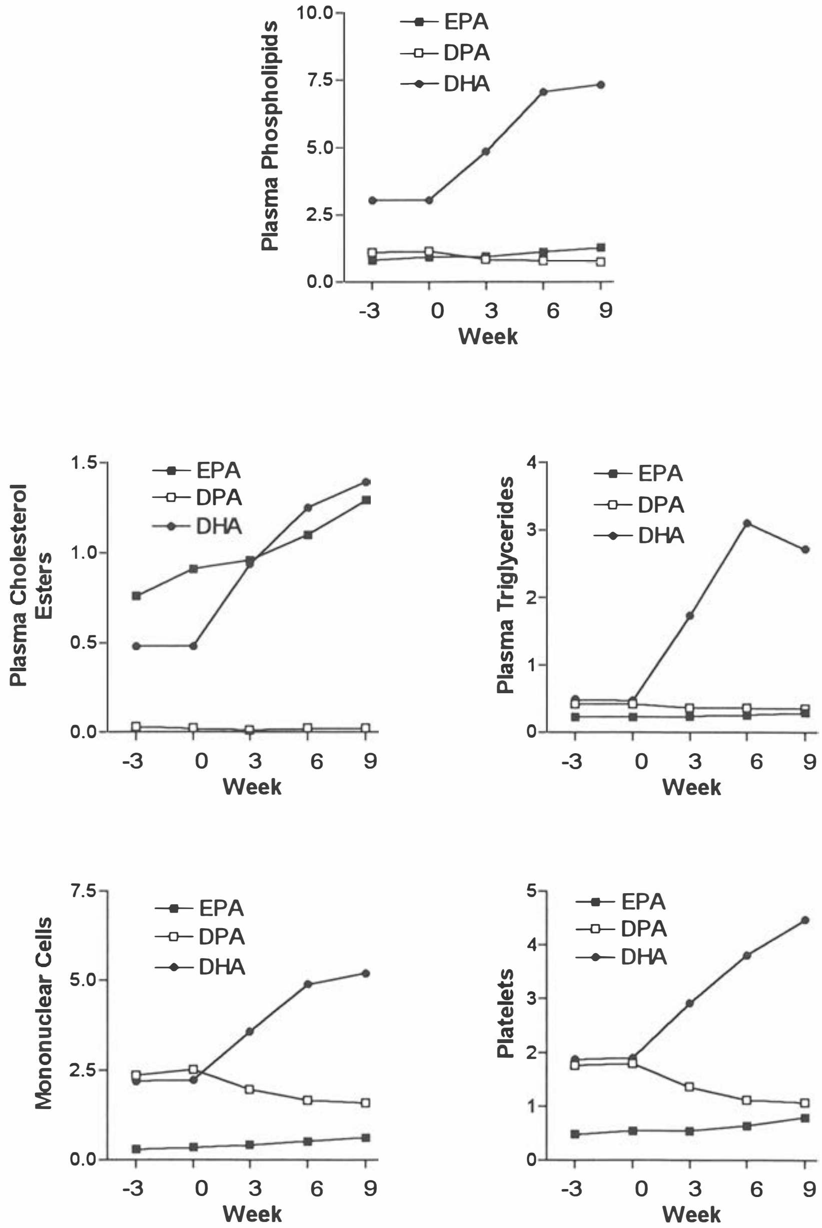
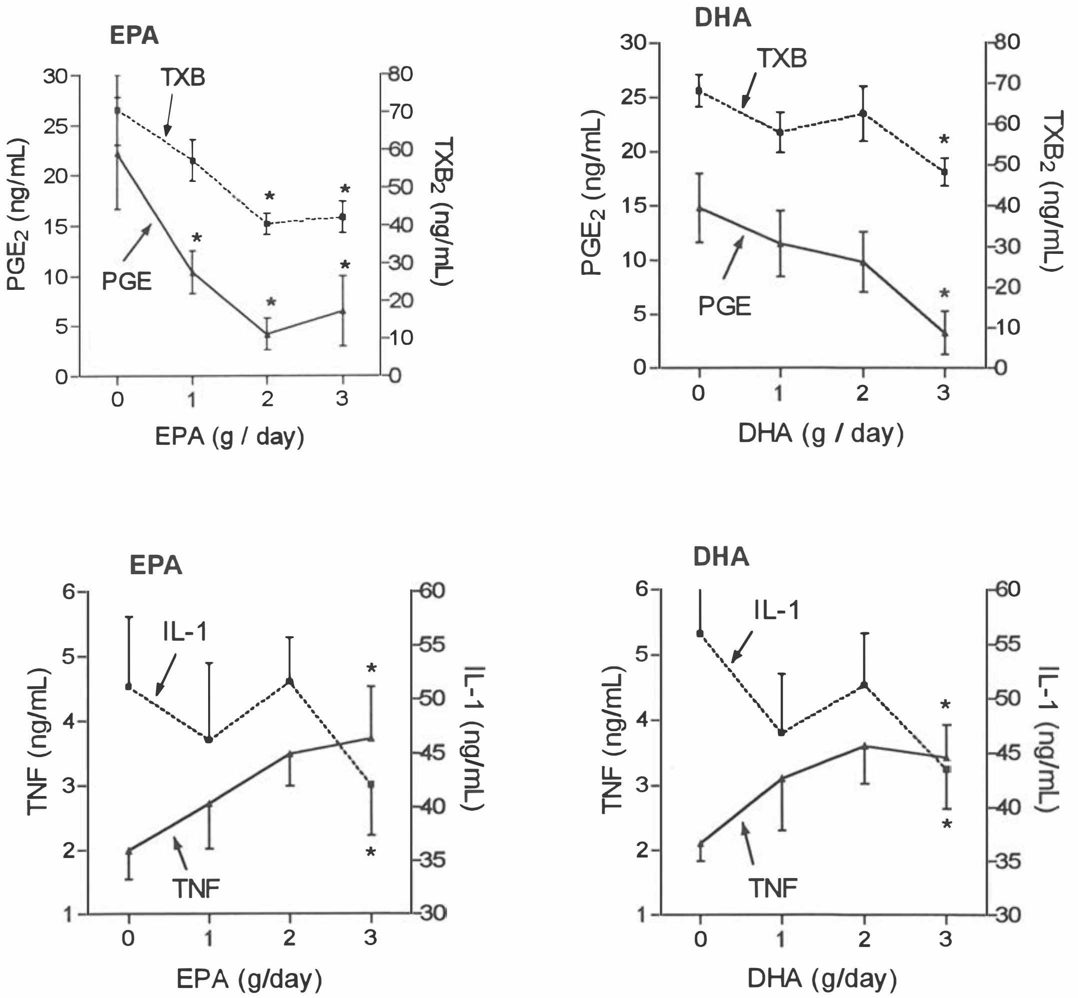


Fig. 6. Effect of dietary EPA or DHA on production of the inflammatory messenger molecules, thromboxane A_2 (TXA_2) and prostaglandin E_2 (PGE_2) (top row of graphs) and interleukin-1 (IL-1) and tumor necrosis factor(TNF) (second row of graphs).



Discussion The suppressive effects of the individual omega-3 fatty acids on PGE_2, TXA_2, and IL-1β are consistent with those seen previously with ingestion of fish oil capsules. However, the effects of both EPA and DHA on TNFα are different in that stimulation was observed whereas use of fish oil capsules is associated with inhibition in previous studies. It is possible that slightly different methodology used in the present experiment is responsible for the different findings. In the present experiment, the white blood cells were incubated in culture medium containing autologous human serum, i.e. serum prepared from the same donor as the cells. In our past studies with fish oil capsules, fetal calf serum was used in the culture medium (1). However, others have used autologous serum and reported inhibition of TNFα production after fish oil ingestion (6). Another disparity with the TNFα results from previous studies is the low baseline levels of TNFα production. The reasons for this are unknown. In addition, differently sourced reagents were used in the TNFα assays. In the present experiment, the primary and secondary antibodies to TNFα were purchased as 'matched pairs' and were of different origins from those previously used by us. It is possible that the different antibodies used in the different studies detect different forms of TNFα, e.g. the precursor forms and the mature froms.

Finally, it is possible that, with regard to supression of TNFα production, complete fish oil or a mixture of EPA and DHA, is superior to EPA and DHA used in isolation.

Conclusion

Both omega-3 fatty acids, EPA and DHA, are accumulated into tissues from the diet in a dose-dependent manner. There is little or no difference between the two fatty acids in suppression of white blood cell production of the inflammatory messenger molecules, TXA_2, PGE_2, and IL-1β. This implies that the variable ratios of EPA:DHA in fish oils and fish from various sources will not influence their potential anti-inflammatory effects.

This is a useful finding because most studies have been conducted with fish oil derived from the North Atlantic fish, Menhaden. This oil has a preponderance of EPA over DHA. However, most local fish in Southern Australian waters have the opposite mix, i.e. a preponderance of DHA over EPA. However, this should not alter the potential benefits deriving from fish oil or fish sourced locally.

Because studies with Menhaden oil capsules have shown benefits in rheumatoid arthritis and because the present study suggests that fish or fish oil from Southern Australian fish should have a similar effect, it is now important to consider strategies which could be useful for arthritis patients in allowing them to practically and easily increase their omega-3 fat intake. While we are planning further studies on introduction of fish oil into common foods (NB fish oil containing bread is available already), it is important also to encourage increased intake of fish in arthritis patients. The latter course requires some knowledge of current fish intakes in arthritis patients and what factors might influence fish intake. These are addressed below.

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Question C. How much fish do people eat?

Method

A question on fish consumption was included in a questionnaire on other health matters which was administered to 236 subjects (approximately half had rheumatoid arthritis and the remainder had other types of arthritis). The questions on fish consumption did not distinguish between fresh, canned, or frozen fish.

Results

In summary, 83% of respondents ate fish once, or less than once per week. The average consumption was one fish meal every two weeks.

Conclusions The average rate of consumption of fish is low and is less than that which would be required to suppress production of inflammatory chemical messengers.

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Question D. What are commonly held attitudes to fish which might be barriers to increasing fish intake?

Method A questionnaire was designed which assessed fish intake and attitudes towards fish intake. In choosing issues to be addressed, 22 people were interviewed at a horticultural show to elicit issues which might be determinants of fish consumption. Issues which were raised by at least 3 people were addressed in the questionnaire. After constructing questions to address these issues, the questionnaire was trialled on volunteers and questions were modified further in response to their replies. Validity of the fish intake questions were addressed by comparing answers with the level of omega-3 fats in the blood of respondents (determined by gas-liquid chromatography).

The intent was to administer the questionnaire to fish factory workers and to similar workers not in fish factories in order to assess attitudes in workers who might have widely varying levels of fish intake.

Forty seven fish factory workers completed the questionnaire. A group from Gerard industries was to provide the non-fish factory workers and although they completed questionnaires, these were misplaced by management. Therefore, a group from the Australian Submarine Corp. was recruited also to complete questionnaires.

Results Fish factory workers consumed fish at home more often than the other group (average fish meals per week at home was 1.3 vs. 0.8, respectively). The blood levels of omega-3 fats varied according to the levels of fish intake claimed in the questionnaires, thereby validating the questions and answers on frequency of fish intake.

Approximately half of the fish factory workers and the other group rated fish as moderately expensive or expensive. But similar proportions of respondents also rated beef and lamb as moderately expensive or expensive while chicken was rated moderately expensive or expensive by a greater number of respondents.

Approximately 66% of respondents indicated fresh fish was easily available, but 85 - 98% of respondents indicated that other meats were more easily available.

In the non-fish factory group, the presence of young children in the household correlated with lower fish intake while this was not a factor in the fish factory group. There were differences in the ethnic origins of both groups where in the fish factory workers, it was more common for one or both parents to have been born in Greece and this correlated with higher fish intake as well.

The majority of both groups agreed that they 'liked the taste of fish'. 76% of the non-fish factory group 'disliked the bones in fish' while this was true for only 40% of the fish factory workers. 36% of the non-fish factory group 'disliked the smell of fish' while this was true for only 19% of the fish factory workers. 86 to 94% of respondents believed 'that fish is healthy'.

Conclusion

It is probable that the group from the Aust. Submarine Corp. was not a typical 'non-fish factory' group because they had above average incomes and an enclosed work environment where hot meals were provided along healthy guidelines. It would be preferable to try again to obtain a different 'non-fish factory' group.

Nevertheless, the results indicate that there are several issues which could be addressed in attempts to increase fish intake and these probably centre around availability, ease of preparation (especially when young children are present) and avoidance of bones, and perhaps use of appropriate sauces when odour is perceived to be an adverse factor. Also, the results indicate that the level of fish intake is reflected in the level of omega-3 fats in the blood, implying that higher intakes can provide greater health benefits (up to a limit).

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Benefits: The results of these research projects have important long-term implications. They contribute to an ongoing programme which has the ultimate aim of increasing omega-3 fat intake in arthritis patients and in the general community. The current research projects suggests that beneficial health effects which have been observed with Menhaden oil capsules will be comparable with dietary omega-3 fats derived from the local fish industry. These may be in two forms, whole fish or fish oil.

Thus, benefits can flow to the retailing sector if fish is promoted as a useful component of a diet designed to increase omega-3 fat intake AND it is presented in ways more amenable to busy life styles and a culture generally not attuned to preparation of meals centred on fresh fish.

Also, benefits can flow to the industrial sector if high quality fish oil production is established to make use of fish by-products. Fish oil produced from local fish can be promoted also as a useful component of a diet designed to increase omega-3 fat intake.

Intellectual Property: There are no patentable products identified in this research project. However, the concepts arising from the findings can be useful in increasing fish consumption and in value adding to the manufacturing process.

Further Development: New strategies in retail marketing of fish should be developed and examined for their practicality and acceptance in a study using healthy volunteers. This should have qualitative end-point measures to gauge consumer acceptance and quantitative end-point measures of the kind used in the studies in this project.

In addition, the range of omega-3 rich foods should be expanded by use of fish oil addition in their manufacture. We have conducted preliminary experiments in this area and believe that it has a high chance of success. It allows people to increase their omega-3 fat intake with minimal disruption to their normal food habits. Ultimately, the fish oil should be produced locally. As well as being included in foods, locally produced fish oil could be encapsulated and used as a dietary supplement for people who wish to use this strategy as well.

In any case, opportunities exist for the processing of nutritionally valuable components of the fish harvest which are currently discarded or under-utilized. Value can potentially be added to the primary catch by using fish organs and fish meat which may have unattractive taste and texture, but which contains health enhancing fats.

Staff engaged on project 94/116:

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