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Barbara J. Meyer

University of Wollongong, bmeyer@uow.edu.au

A E. Lane

University of Wollongong, al198@uowmail.edu.au

N J. Mann

RMIT University

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Abstract

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Disciplines

Arts and Humanities | Life Sciences | Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

Meyer, B. J., Lane, A. E. & Mann, N. J. (2009). Comparison of seal oil to tuna oil on plasma lipid levels and blood pressure in hypertriglyceridaemic subjects. *Lipids*, 44 (9), 827-835.

Comparison of seal oil to tuna oil on plasma lipid levels and blood pressure in
hypertriglyceridaemic subjects

Meyer BJ*¹, Lane AE¹, Mann NJ²

¹School of Health Sciences, Metabolic Research Centre, Smart Foods Centre, University of
Wollongong, NSW 2522, Australia.

²School of Applied Sciences, RMIT University, Melbourne, Vic, 3000, Australia

*Corresponding Author:

A/Prof Barbara Meyer

School of Health Sciences,

University of Wollongong,

Wollongong,

NSW 2522

Phone: +61 (0)2 4221 3459

Fax: +61 (0)2 4221 3486

Email: bmeyer@uow.edu.au

Running Head: DPA and plasma lipids and blood pressure

Abstract

As meat is a rich source of the omega-3 fatty acid docosapentaenoic acid (DPA) and Australians consume 6 times more meat than fish, investigation of the potential health benefit of DPA is warranted. The aims were to compare the effects of seal oil supplementation with fish oil, on measures of plasma lipids and blood pressure in hypertriglyceridaemic subjects. Forty-eight volunteers were recruited from the Wollongong community and were randomly allocated to one of three groups receiving 1g/d of long chain omega-3 polyunsaturated fatty acids (LC n-3 PUFA) using one of three oils: seal oil capsules (340mg eicosapentaenoic acid (EPA), 230mg DPA, 450mg DHA), fish oil capsules (210mg EPA, 30mg DPA, 810mg DHA) or placebo capsules (containing sunola oil) for 6 weeks. Plasma triglycerides remained unchanged in the placebo group, whilst reductions of 7% and 14% ($p<0.05$) were seen in the fish oil and seal oil groups respectively. Systolic blood pressure improved by 8 and 5 mmHg with seal oil and fish oil respectively ($p<0.05$). The mean arterial pressure was significantly lower after seal oil supplementation ($p<0.005$) compared with the placebo group. These results indicate that seal oil is as effective as fish oil in lowering plasma triglycerides and blood pressure.

Keywords: Docosapentaenoic acid, omega-3 polyunsaturated fatty acids, cardiovascular disease, blood pressure, dyslipidaemia

Introduction

Cardiovascular disease (CVD) is the greatest single cause of mortality in Australia, accounting for 34% and 39% of male and female deaths, respectively (1). Numerous clinical trials have shown that highly unsaturated long chain omega-3 polyunsaturated fatty acids (LC n-3 PUFA) such as eicosapentaenoic acid (EPA; 20:5n-3) and docosahexaenoic acid (DHA; 22:6n-3) benefit cardiovascular disease outcomes in primary and secondary prevention (2). Risk factors for CVD include hypertension and dyslipidaemia, with increased plasma triglycerides emerging as an independent risk factor (3). EPA and DHA are effective in lowering plasma triglyceride levels (4). Yet there is almost no data available regarding the potential health benefits of the only other common highly unsaturated LC n-3 PUFA, docosapentaenoic acid (DPA; 22:5n-3).

Epidemiological evidence indicates that intakes of all three of the LC n-3 PUFA (EPA, DHA, DPA) are significantly and inversely related to carotid intimal-medial thickness (IMT) (5). The quartiles of gram EPA intakes (0.00-0.15; 0.16-0.29; 0.30-0.41; 0.42+); of gram DHA intakes (0.01-0.27; 0.28-0.45; 0.46-0.63; 0.64+) and of gram DPA intakes (0.02-0.04; 0.05-0.07; 0.08-0.10; 0.11+) all correlated with negatively with IMT, which suggests that the cardiovascular benefits attributed to LC n-3 PUFA are not just attributable to EPA and DHA, but also to DPA (5). Furthermore, the Kuopio Ischaemic Heart Disease Risk Factor Study showed that the men with the highest quintile of serum DHA plus DPA (>3.58% of total fatty acids) had a 44% reduced risk of acute coronary events compared with men in the lowest quintile (<2.38% of total fatty acids), and there were no associations with EPA levels (6). The significance was due to DHA plus DPA, not just DHA alone. Hence there is scientific evidence that DPA has cardiovascular health benefits but this evidence is limited.

DPA can be found in relative abundance in most red meat. Australian grass fed beef contains 32mg EPA, 49mg DPA and 6mg DHA per 100g lean beef, as opposed to grain fed beef which contains much lower values (16mg EPA, 37mg DPA and 5mg DHA per 100g) (7). This is consistent with beef from USA with range fed beef containing 0.62% EPA, 0.71% DPA and 0.09% DHA as percent of total fatty acids compared with only 0.13% EPA, 0.26% DPA and 0.04% DHA in feed-lot (grain fed) beef (8). Hence meat contains more DPA and EPA, whereas fish/seafood contains more DHA and much less DPA.

Actual DPA intakes have been reported as 90mg/d for men and 52mg/d for women in Australia (9) which is comparable to that of France (75mg/d for men and 56mg/d for women, (10)) and Japan (90mg/d for both men and women in Japan (5)), but both France and Japan consume more fish/seafood than Australians and hence their EPA and DHA intakes are higher than Australian intakes (5,9,10). As Australians consume more meat than fish/seafood, in the Australian diet, meat contributes up to 42.7% of LC n-3 PUFA intake which is similar to the new estimate of fish and seafood of 48% (9,11). This would indicate that DPA intakes are 3-fold higher than previously thought (9,11). Importantly, DPA intakes contribute up to 30% towards the intakes of LC n-3 PUFA in the Australian adult diet (9). Given this level of DPA in the Australian diet, it is pertinent to understand its potential health benefit.

However for research studies on DPA, no purified or enriched form is commercially available. The richest commercial source of DPA is seal oil. There have been limited trials assessing the effect of seal oil supplementation on cardiovascular disease risk factors. One study showed a significant reduction in plasma triglycerides after seal oil supplementation for 6 weeks in healthy people (12), whilst another similar study showed no significant lowering of plasma triglycerides (13). However these studies were conducted in people with normal plasma triglyceride levels. Therefore the aim of this study was to assess the ability of seal oil supplementation to lower plasma triglyceride levels

and blood pressure in people with hypertriglyceridaemia in comparison to fish oil containing similar levels of EPA and DHA in a placebo controlled double blind intervention trial.

Experimental Procedures

Notification of Clinical Trial and Ethics Approval

The study on the cardiovascular effects of DPA was registered with the Australian Clinical Trial Register, number ACTRNO12605000641695 and notification forwarded to the Therapeutics Goods Administration. Ethics approval was granted from the University of Wollongong (UoW) Human Research Ethics Committee and informed consent was obtained from all study participants prior to commencement of the clinical trial.

Recruitment and study population

Hypertriglyceridaemic subjects were recruited via newspaper advertisements, email to UoW community, social clubs and on local ABC radio. The UoW media release unit also generated interest from the media. Fifty-six volunteers were recruited and eligible for the study (i.e. plasma triglycerides $> 1.5\text{mmol/L}$) and 48 completed the study. Reasons for dropping out of the study included suffering from diarrhoea, forgetting to come to their 6 week appointment, losing their job and not being contactable for their 6 week appointment or no reasons at all. People already taking fish oil supplements were excluded from the study.

Seal Oil, Fish Oil and Placebo Capsule Supplementation

The capsules were 500mg in weight and the composition is shown in table 1. All 3 groups were provided with two separate bottles of capsules and they were asked to take 10 capsules per day; 4 capsules before breakfast and 6 capsules before dinner, such that all 3 groups were taking the same number of capsules per day. The target LC n-3 PUFA intake of the Seal Oil (BGI Atlantic Marine Product Inc, Canada) and Fish Oil (NuMega Ingredients Ltd, Sydney) groups was 1g/day.

Therefore the Seal Oil group took 10 Seal Oil capsules per day (which provided 340mg EPA, 230mg DPA, 450mg DHA per day); the Fish Oil group took 4 placebo capsules and 6 Fish Oil

capsules per day (which provided 210mg EPA, 30mg DPA, 810mg DHA per day). The third group took 10 placebo capsules per day (Sunola oil, NuMega Ingredients Ltd, Sydney, which provided no LC n-3 PUFA but did provide approximately 4g monounsaturated oil per day). The placebo group intake of monounsaturated oil in quantity is trivial compared to the dietary intake of monounsaturated fat. Furthermore as the seal oil capsules contained squalene (12.5mg/500mg capsule), the fish oil and placebo groups took one squalene capsule (875mg) per week for 6 weeks equivalent to 125mg/day, an identical intake to the seal oil group. Seal oil provided a 7.6 fold increase in the amount of DPA; a 1.6 fold increase in the amount of EPA and a 1.8 fold decrease in the amount of DHA compared to fish oil (Table 1B).

Seal oil also contains 0.3mg/100g vitamin A and 4.5mg/100g alpha-tocopherol (14). Tuna oil contained less than 10 International Units of vitamin A and 0.21% of mixed natural tocopherols (NuMega Ingredients Ltd, Sydney).

Study Design

A randomised, parallel, placebo controlled, double blind study was conducted in 56 hypertriglyceridaemic subjects, with 48 who completed the study. They were randomly allocated to one of three groups and all three groups took ten 500mg capsules per day for a 6 week intervention trial. Blood pressure and fasting blood samples were taken at baseline and at 6 week post intervention. Blood samples were assessed for erythrocyte fatty acids and plasma lipids (triglycerides, total cholesterol, LDL-cholesterol and HDL-cholesterol).

Erythrocyte Fatty Acids

Fasting blood samples were collected into tubes containing ethylenediamine tetra-acetic acid (EDTA) and placed on ice. The erythrocytes were separated from plasma by centrifugation (10 min, 2000g, 4°C). Erythrocyte and plasma samples were stored at -80°C until analysed.

Erythrocyte membranes were isolated from 400µl of packed erythrocytes and prepared for fatty acid analysis. The erythrocytes were lysed in 10ml TRIS buffer (10mM TRIS buffer, 2mM EDTA, pH 7.2) and the membranes were pelleted after ultracentrifugation (200000 g, 4°C, 30 minutes). The erythrocyte membrane pellets were resuspended in 200µl water and 150µl was transferred into glass tubes for direct transesterification as described by Lepage and Roy (15). Briefly, 2ml of methanol: toluene (4:1) was added to each sample. While vortexing, 200µl of acetyl chloride was added drop wise to each sample using a positive displacement pipette. Samples were then heated for 60 minutes at 100°C in a heating block. After the tubes had been cooled in cold water, 3ml of potassium chloride (10%) and 100µl of toluene were added to each tube before centrifugation for 10 minutes (2000g, 4°C). The fatty acid methyl esters, contained in the upper toluene phase, were removed and placed into GC vials. The fatty acid methyl esters were analysed by flame-ionisation gas chromatography (model GC-17A, Shimadzu) using a 30m x 0.25mm internal diameter capillary column (Varian). Individual fatty acids were identified upon comparison with known fatty acid standards (NuChek, Sigma, Australia, mix C10-C24 plus added DPA).

Plasma Lipids

HDL was isolated from plasma by precipitation of the apoB containing lipoproteins using dextran sulphate and magnesium chloride according to Warnick et al (16). All lipid analyses (plasma triglyceride, total cholesterol, HDL-cholesterol) were carried out using enzymatic colorimetric assays using the Konelab autoanalyser. LDL-cholesterol was calculated using the Friedewald calculation (17).

Blood Pressure

Systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) were measured using the Omron blood pressure instrument (Medisave Australasia). These measurements were taken in triplicate at baseline (duplicate days) and after 6 weeks intervention

(duplicate days). An average of the 6 baseline readings were obtained for each study participant and similarly after 6 weeks intervention.

Statistical analysis

Statistical analysis was carried out using JMP statistical analysis package (SAS Institute Inc Windows NT v5.1) and where variables were not normally distributed (plasma triglycerides), log transformation was used prior to analysis. One way ANOVA was used to assess the change in plasma triglycerides and blood pressure between the three groups. One way ANOVA was also used to assess the change in erythrocyte EPA and DHA levels and the change in plasma triglycerides per group. Pearson correlation analyses were conducted using Microsoft Excel. Statistical significance was set at $\alpha = 0.05$ for all analyses.

Results

Study Participant Characteristics and Baseline Blood Pressure and Plasma Lipids (Table 2)

The study participant baseline characteristics and baseline blood pressure and plasma lipids are shown in Table 2. There were no significant differences in age, sex, weight, body mass index (BMI) and blood pressure lowering medication used, between the three groups at baseline. On average the study population was overweight, and ranging from middle age to elderly. All subjects were hypertriglyceridaemic, but with relatively normal plasma cholesterol levels. Systolic blood pressures were greater than 140mmHg in 23% of the study population whilst diastolic blood pressures were greater than 90mmHg in 10% of the study population. The study volunteers did not change their body weight throughout the intervention (results not shown).

Erythrocyte Fatty Acids (Table 3 and figure 1)

The main erythrocyte LC PUFA measured at baseline (0 weeks) and after 6 weeks of intervention (week 6) in all 3 groups are shown in Table 3. The placebo group showed no changes over the 6 weeks period. In comparison to its own baseline value (0 weeks), fish oil supplementation resulted in decreases in arachidonic acid (AA, 20:4n-6, $p<0.01$), adrenic acid (22:4n-6, $p<0.05$) and DPA (22:5n-3, $p<0.05$) and an increase in DHA (22:6n-3, $p<0.01$). In comparison to its own baseline value (0 weeks), seal oil supplementation significantly decreased levels of AA ($p<0.05$) and adrenic acid ($p<0.05$) and significantly increased the mean levels of EPA ($p<0.001$), DPA ($p<0.001$) and DHA ($p<0.0005$).

Figure 1 shows the comparison of the percentage changes in erythrocyte fatty acids in the three groups after 6 weeks supplementation. In comparison to the change in the placebo group (0-6 weeks), there were no significant difference in AA, EPA and DPA in the fish oil group (0-6 weeks), but there were significant decreases in adrenic acid ($p<0.05$) and increases in DHA ($p<0.0005$). In

comparison to the change in the placebo group (0-6 weeks), there was no significant difference in AA in the seal oil group (0-6 weeks), but there were significant decreases in adrenic acid ($p<0.05$) and significant increases in EPA ($p<0.001$), DPA ($p<0.001$) and DHA ($p<0.0001$).

Plasma Lipids (Figure 2)

The change in plasma lipids (mmol/L) from baseline (0 weeks) to 6 weeks for all 3 groups are shown in Figure 2. Plasma triglycerides remained unchanged in the placebo group (2.31 versus 2.36mmol/L), but were reduced by 7% in the fish oil group (2.24 versus 2.09mmol/L, $p>0.05$) and 14% in the seal oil group (2.54 versus 2.19mmol/L) ($p<0.05$) and these changes were significantly different to the changes in the placebo group. No differences were seen in the total cholesterol, LDL-cholesterol or HDL-cholesterol between any of the groups.

Blood Pressure (Figure 3)

The changes in blood pressure results are shown in figure 3. Systolic blood pressure (SBP) decreased significantly in both the fish oil (-5.3mmHg, $p<0.05$) and the seal oil groups (-7.7mmHg, $p<0.01$) in comparison to the placebo group (6mmHg). The mean arterial pressure (MAP) was significantly reduced (-8.3mmHg, $p<0.01$) in the seal oil group and tended towards a reduction (-3.5mmHg, n.s.) in the fish oil versus the placebo group (3.9mmHg). There were no statistical differences in diastolic blood pressure (DBP) in the three groups.

Correlations between the change in erythrocyte EPA and DHA levels and the change in plasma triglycerides and blood pressure (Table 4)

The change in erythrocyte EPA+DHA levels correlated with the change in plasma triglycerides in the seal oil group, $r=0.52$ ($p<0.05$) but there were no correlations in the fish oil or placebo oil groups with the change in plasma triglycerides (Table 4).

There were several significant correlations (see Table 4) between the change in erythrocyte EPA and DHA levels and the change in SBP, DBP and MAP in the fish oil groups with correlation coefficients ranging from 0.56 to 0.76, ($p < 0.05$). As expected there were no correlations with erythrocyte LC n-3 PUFA and blood pressure in the placebo group (Table 4).

Discussion

The supplementation of 1g of LC n-3 PUFA per day supplied by fish oil capsules for 6 weeks resulted in a significant increase in erythrocyte DHA levels, which is in agreement with previous studies using similar doses of fish oil and similar duration of intervention (18,19). However, the supplementation of 1g of LC n-3 PUFA per day supplied by seal oil capsules for 6 weeks differed to that of fish oil, in that DPA and EPA in addition to DHA were significantly increased, which is in agreement with a previous study using the same 1g dose of seal oil for 6 weeks (12).

It has been shown previously that intakes of EPA and DHA correlate significantly with erythrocyte EPA and DHA levels respectively (20). However, there was no correlation between DPA intakes and erythrocyte DPA levels (correlation coefficient $r = 0.05$, $p=0.71$), despite quite reasonable correlations between dietary intakes and erythrocyte levels of EPA, DHA and total LC n-3 PUFA (20). Since that publication, another study assessed the validity of a PUFA questionnaire by comparison to 3 day weighed food record and erythrocyte fatty acids using the methods of triads (21). In that triangulation of DPA intakes from PUFA questionnaire versus DPA intake from 3 day weighed food record versus DPA in erythrocytes (or plasma) - a validity co-efficient could not be determined as the estimate was >1 for erythrocytes and negative for plasma. This lack of correlation between dietary intake of DPA and circulating levels of DPA has been shown by another group (22) who assessed a different questionnaire. Using the methods of triads they found a similar negative validity co-efficient when assessing plasma DPA to their questionnaire and weighed food records (22). Hence whilst there is a direct correlation between EPA and DHA intakes and EPA and DHA erythrocyte levels respectively, this does not hold true for DPA as there is no direct correlation between DPA intake and erythrocyte or plasma levels of DPA.

Therefore to interpret the DPA results in this study it is probably better to look at DPA intakes rather than erythrocyte levels of DPA. In this study the fish oil group consumed 210mg/d EPA, 30mg/d DPA and 810mg/d DHA, whilst the seal oil group consumed 340mg/d EPA, 230mg/d DPA and 450mg/d DHA. The difference between the fish oil and seal oil groups is the seal oil group consumed 130mg/d more EPA; 200mg/d more DPA and 360mg/d less DHA than the fish oil group. This difference corresponds to a 1.6 fold increase in EPA; a 7.6 fold increase in DPA and a 1.8 fold decrease in DHA, where the magnitude of dietary change is greatest in DPA.

This study showed a trend towards a 7% reduction plasma triglyceride levels with 1g LC n-3 PUFA per day fish oil supplementation, which is less than a recently published study that assessed a dose response with DHA rich fish oil supplementation which showed 6% (n.s.), 20% and 25% reductions with approx 0.7g, 1.3g and 2g of fish oil supplementation per day for 6 weeks (19). The seal oil 1g LC n-3 PUFA per day supplementation for 6 weeks resulted in 14% reduction in plasma triglyceride which was also less than 21% reduction previously reported (12), however another seal oil study showed no significant lowering of plasma triglycerides (13). Both Bonefeld-Jorgensen et al (12) and Conquer et al (13) were conducted in healthy people with normal plasma triglyceride levels which could explain the lack of effect in the latter study. The Bonefeld-Jorgensen et al study (12) was not a placebo controlled study and the reductions in plasma triglyceride seen could have been due to other factors.

In terms of the mechanism in plasma triglyceride lowering effect, a decrease in hepatic VLDL output has been attributed to increased hepatic fatty acid oxidation and a decreased rate of lipogenesis (23,24). EPA and DHA have been shown to be ligands for nuclear receptors such as PPAR-alpha (23,24,25) and sterol regulatory element binding proteins (23,26), which modulate the expression of key genes in these metabolic processes. Now DPA may also be involved in these processes. Certainly in a well controlled rat study (where seal oil and fish oil supplemented rat

groups had constant PUFA/MUFA/SAFA levels and the control rat group had linoleic acid as their sole PUFA in the diet), the seal oil was more effective than fish oil in lowering serum triglyceride levels (27). In this rat model the activities of fatty acid synthase, glucose-6-phosphate dehydrogenase and hepatic lipase were all lower in the seal oil group compared to the control group, whereas only the activity of hepatic lipase was lower in the fish oil group compared to the control group. However, the activities of peroxisomal beta-oxidation and lipoprotein lipase in adipose tissue were significantly higher in the fish oil group compared to the controls (27). Hence the hypotriglyceridaemic effect of the seal oil was attributed to suppression in fatty acid synthesis. As the main difference between seal oil and fish oil is the 8 fold increased level of DPA in seal oil, the authors surmised that this higher DPA content could be the primary agent responsible for triglyceride lowering.

Moreover, a study comparing the effects of EPA rich oil versus DHA rich oil on circulating plasma triglyceride levels in humans found that the DHA rich oil was more effective than EPA rich oil and remained significant when compared to the olive-oil placebo group, whereas the EPA rich oil did not (28). Interestingly, the authors pointed out that the DHA rich oil contained a 6 fold greater amount of DPA than the EPA rich oil, but the hypotriglyceridaemic effect of DPA was unknown and that it warranted further study (28).

In the present study both fish oil and seal oil supplementation resulted in improvements in blood pressure. The reduction in blood pressure as a result of fish oil supplementation are well documented with several meta-analyses showing benefits as described in the review by Mori (29). However, most of these trials required doses of 3-4g per day to achieve the blood pressure lowering benefits. This study showed significant reductions in SBP (fish oil and seal oil groups) and MAP (seal oil group) but no significant reductions in DBP (all groups) using 1g dose of LC n-3 PUFA per day for 6 weeks. There was an increase in SBP in the placebo group, however, upon re-

analysis with estimating zero change in SBP in the placebo group, the changes in SBP in the seal oil and fish oil groups remained significantly lower compared to placebo.

However the increase in erythrocyte EPA+DHA after fish oil but not seal oil supplementation correlated with the change in blood pressure. EPA correlated with SBP whilst DHA correlated with DBP (Table 4). Mori et al (30) showed that purified DHA capsules lowered 24 hour ambulatory blood pressure in mild hyperlipidaemic subjects, whilst purified EPA capsules had no effect. Even though similar study populations were assessed, it is not clear why the differential effect of EPA on SBP and DHA on DBP is seen in this current study. However, other studies have shown limited effect of EPA and DHA on blood pressure in normotensive people (31) and in study populations taking multiple medications (29).

Even though there was no correlation between the changes in erythrocyte EPA+DHA levels and the change in blood pressure in the seal oil treated group, in this study, seal oil resulted in a significant 8mmHg reduction in SBP. Usually high doses of EPA+DHA of 3-4g per day are needed to reduce blood pressure as shown by meta-analyses (32,33). It is conceivable that the significant reduction in SBP in the current study could be due to 1) the study population having an average blood pressure of 130/75mmHg of which 23% had SBP greater than 140mmHg and 10% had DBP greater than 90mmHg and 2) less than 20% of the study population were taking medication to lower their blood pressure, thereby allowing the omega-3 PUFA to be effective. A study by Vericel et al (34) showed that supplementation for 42 days with 150mg DHA and 30mg EPA per day in an elderly un-medicated population resulted in 14mmHg reduction in SBP, which is consistent with the current study showing the effect of low dose omega-3 PUFA and reduction in SBP.

The mechanisms of action of LC n-3 PUFA on blood lowering effects have been described by Mori et al (29). The mechanisms include 1) the LC n-3 PUFA having vasodilatory effects by increasing the release of nitric oxide; 2) modifying the release of ADP, vasoactive prostanoids (such as thromboxane A₂ and prostacyclin I₂) 3) and the LC n-3 PUFA incorporation into plasma and cellular membranes, altering the physicochemical structure of the membrane and leading to changes in fluidity, permeability and function of the membrane and membrane-bound proteins (29).

Given the health benefits of seal oil containing DPA, what are some DPA rich containing foods? Australian red meat is a relatively rich source of DPA (9,11) and Australians consume six times more meat (158g per day (35), 164g per day (36)) than fish/seafood (26g per day (35), 28g per day (36)). Abalone is another DPA rich food (37) but the consumption is also much lower than meat. The National Health and Medical Research Council (NHMRC) in Australia has released Nutrient Reference Values (NRV) for LC n-3 PUFA intakes which includes EPA, DPA and DHA (38). However, DPA is not included in the LC n-3 PUFA nutrient claim in the current Food Standards Australia and New Zealand (FSANZ) Code (39). The exclusion of DPA precludes many cuts of meat qualifying for this LC n-3 PUFA nutrient claim. Hence these standards favour fish and seafood as well as fortified foods containing LC n-3 PUFA over those with intrinsic DPA content (40). The rationale for the exclusion of DPA is a lack of scientific evidence. Hence more research is warranted to ascertain the potential health benefits of DPA. Therefore larger trials with more pure forms of DPA are warranted.

In conclusion, 1g/d of LC n-3 PUFA from seal oil is just as effective as 1g/d of LC n-3 PUFA from fish oil in reducing plasma triglyceride levels and SBP in hypertriglyceridaemic subjects; however, studies using (as yet unavailable) purified DPA are warranted.

Acknowledgements

The authors would like to acknowledge the time and effort of all the study participants as well as funding from the Meat & Livestock Australia.

Figure legends

Figure 1

The percent change in erythrocyte fatty acids (6 weeks minus baseline) from the three groups from left to right: placebo, fish oil and seal oil group. The fatty acid abbreviations: 20:5n-3 is eicosapentaenoic acid, 22:5n-3 is docosapentaenoic acid, 22:6n-3 is docosahexaenoic acid, 20:4n-6 is arachidonic acid and 22:4n-6 is adrenic acid.

* significantly different from the change in the placebo group ($p < 0.05$).

Figure 2

The change in plasma lipids (mmol/L) in the three groups from left to right: placebo, fish oil and seal oil group. Plasma lipid abbreviations: TG triglycerides, TC total cholesterol, LDL-C low density lipoprotein cholesterol and HDL-C high density lipoprotein cholesterol.

* significantly different from the change in the placebo group ($p < 0.05$)

Figure 3

The change in blood pressure (mmHg) in the three groups from left to right: placebo, fish oil and seal oil group. Blood pressure abbreviations; SBP systolic blood pressure, DBP diastolic blood pressure and MAP mean arterial pressure

* significantly different from the change in the placebo group ($p < 0.05$)

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Table 1A Individual capsule composition by principal fatty acid (mg per 500mg capsule).

Fatty acid	Sunola Oil Capsules (mg/500mg)	Fish Oil Capsules (mg/500mg)	Seal Oil Capsules (mg/500mg)
C18:1n-9	425	61	142
C20:5n-3	0	35	34
C22:5n-3	0	5	23
C22:6n-3	0	135	45

Table 1B Amount of principal fatty acids supplemented per group per day (mg per day)

Fatty acid	Sunola Oil Group (placebo) (mg per day)	Fish Oil Group (mg per day)	Seal Oil Group (mg per day)
C18:1n-9	4250	1944	1420
C20:5n-3	0	210	340
C22:5n-3	0	30	230
C22:6n-3	0	810	450
Total LC n-3 PUFA	0	1050	1020

Placebo group consumed 10 placebo capsules per day; Fish Oil group consumed 6 fish oil capsules per day plus 4 placebo capsules per day; Seal Oil group consumed 10 seal oil capsules per day

Table 2 Study Participant Characteristics, plasma lipids and blood pressure at baseline (n=48)

	Placebo (n=17)	Fish Oil (n=15)	Seal Oil (n=16)
Male/Female (n)	9/8	6/9	9/7
Age (years)	57 ± 7 ^a (42-70)	59 ± 7 (49-73)	54 ± 7 (45-69)
Weight (kg)	86 ± 12 (63-114)	79 ± 18 (53-108)	79 ± 11 (62-107)
Body Mass Index (kg/m ²)	29 ± 3 (25-37)	28 ± 5 (19-36)	27 ± 3 (22-34)
Plasma triglycerides (mmol/L)	2.31 ± 0.73 (1.69-3.61)	2.24 ± 0.18 (1.57-3.67)	2.54 ± 0.27 (1.57-5.26)
Total cholesterol (mmol/L)	5.14 ± 0.22 (3.61-6.52)	5.31 ± 0.18 (3.68-6.82)	5.60 ± 0.25 (4.13-6.67)
LDL-cholesterol* (mmol/L)	3.06 ± 0.18 (1.93-4.23)	3.38 ± 0.18 (2.34-4.40)	3.63 ± 0.22 (2.41-4.83)
HDL-cholesterol (mmol/L)	1.12 ± 0.07 (0.75-1.91)	1.12 ± 0.10 (0.63-1.90)	1.03 ± 0.05 (0.65-1.34)
Systolic Blood Pressure (mmHg)	126 ± 13 (99-151)	131 ± 14 (100-147)	137 ± 21 (119-189)
Diastolic Blood Pressure (mmHg)	73 ± 9 (60-85)	74 ± 11 (57-93)	79 ± 9 (70-92)
Mean Arterial Pressure (mmHg)	93 ± 10 (73-107)	95 ± 10 (77-106)	102 ± 14 (88-129)

Blood pressure

medication (M/F)

2/1

2/2

0/2

n is number of participants as males and females

^a Values are mean \pm SD (range)

*LDL-C was calculated using the Friedewald calculation (17)

Table 3 Red Blood Cell Fatty Acids (expressed as % of total fatty acids)

	20:4n-6	22:4n-6	20:5n-3	22:5n-3	22:6n-3
Placebo					
(n=17)					
0 weeks	12.8±0.3 ^a	2.3±0.1	1.1±0.1	2.5±0.1	5.0±0.2
6 weeks	12.5±0.3	2.3±0.1	1.1±0.1	2.4±0.2	5.0±0.2
Fish Oil					
(n=13)					
0 weeks	12.6±0.2	2.5±0.2	1.1±0.2	2.6±0.1	5.2±0.3
6 weeks	12.1±0.2**	2.1±0.1*	1.3±0.1	2.4±0.1*	6.4±0.3***
Seal Oil					
(n=16)					
0 weeks	12.6±0.2	2.2±0.1	1.0±0.1	2.5±0.1	4.8±0.2
6 weeks	12.0±0.2*	2.0±0.2*	1.8±0.1****	2.7±0.1****	5.8±0.1***

^a Values are mean ± SEM

* p<0.05, ** p<0.01, *** p<0.005, ****p<0.0001, differences between 0 and 6 weeks

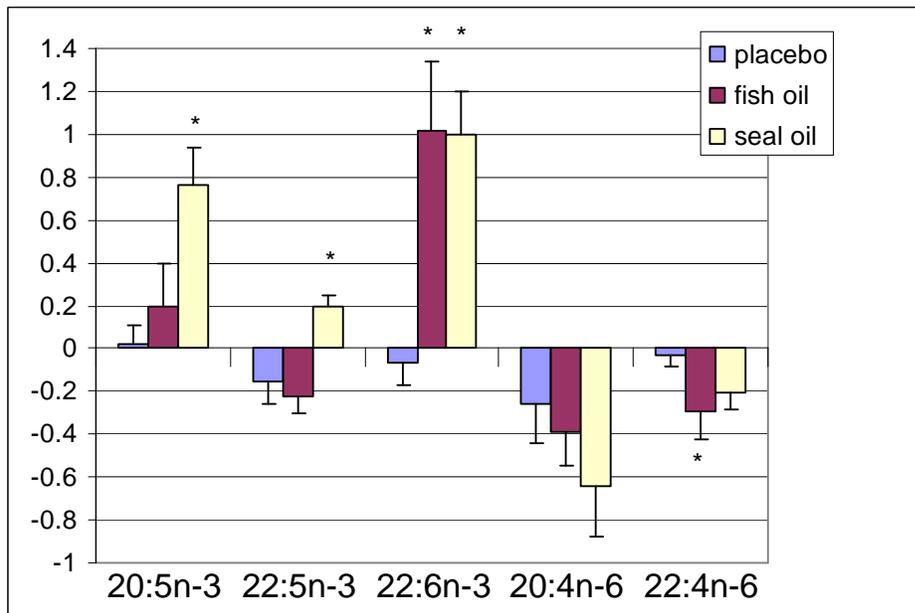
Table 4 Correlations between the changes in erythrocyte LC n-3 PUFA and changes in plasma triglyceride and changes in blood pressure.

		Placebo	Fish Oil	Seal Oil
		(n=17)	(n=15)	(n=16)
		r	r	r
Change in TG (6-0)	Change in EPA	0.094	0.028	0.283
	Change in DPA	-0.106	0.131	-0.210
	Change in DHA	-0.127	0.077	0.381
	Change in EPA+DHA	-0.024	0.067	0.520*
	Change in EPA+DPA+DHA	-0.099	0.089	0.442
Change in SBP (6-0)	Change in EPA	0.055	0.634*	-0.165
	Change in DPA	-0.270	0.065	0.023
	Change in DHA	-0.156	0.451	-0.181
	Change in EPA+DHA	-0.080	0.556*	-0.282
	Change in	-0.290	0.558*	-0.264

EPA+DPA+DHA				
Change in DBP (6-0)	Change in EPA	-0.201	0.330	-0.190
	Change in DPA	0.286	-0.444	0.222
	Change in DHA	-0.398	0.756*	0.428
	Change in EPA+DHA	-0.421	0.714*	0.299
	Change in EPA+DPA+DHA	-0.148	0.651*	0.330
Change in MAP (6-0)	Change in EPA	-0.090	0.446	-0.282
	Change in DPA	-0.056	-0.010	0.255
	Change in DHA	-0.203	0.608*	0.103
	Change in EPA+DHA	-0.206	0.628*	-0.078
	Change in EPA+DPA+DHA	-0.232	0.647*	-0.023

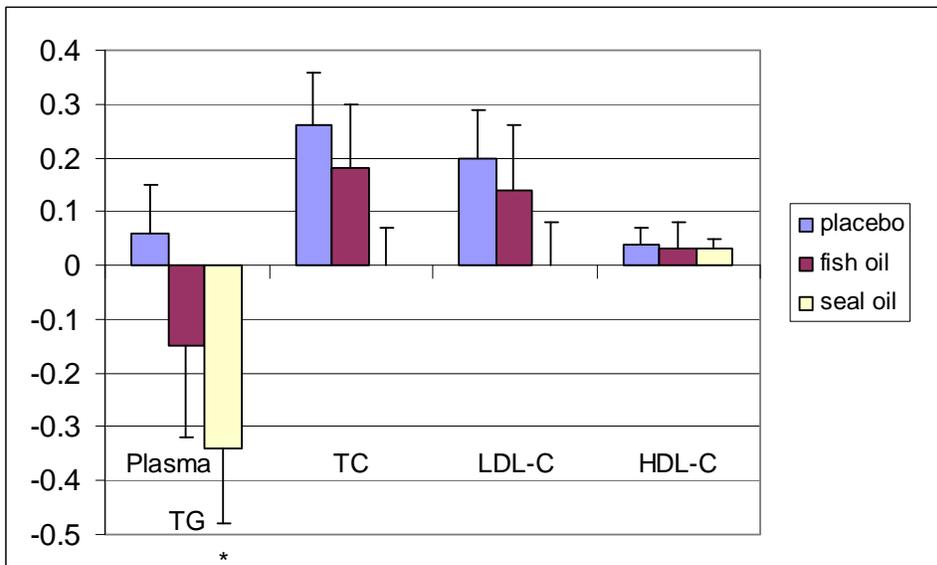
* p < 0.05

Figure 1 The percent change in erythrocyte fatty acids (6 weeks minus baseline).



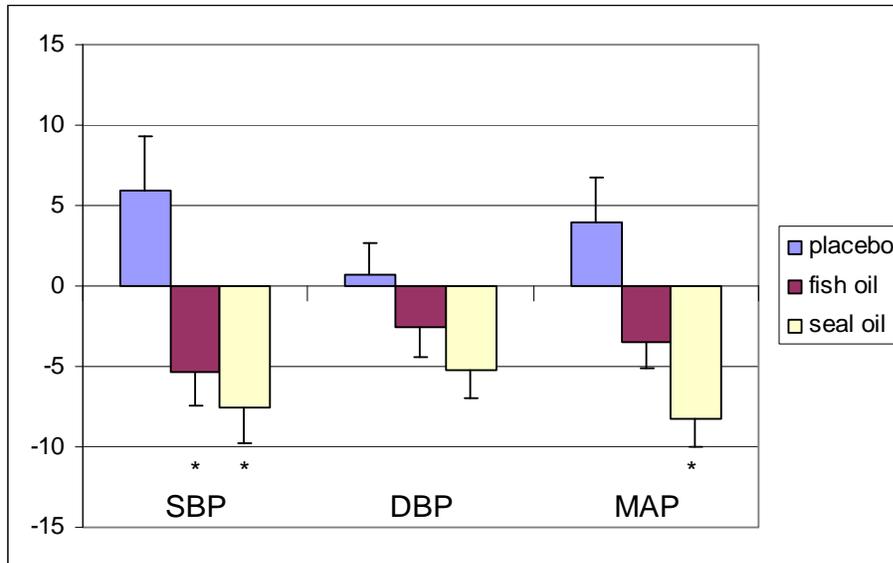
* significantly different from the change in the placebo group (p<0.05)

Figure 2 The change in plasma lipids (mmol/L) in the placebo, fish oil and seal oil groups.



* significantly different from the change in the placebo group ($p < 0.05$)

Figure 3 The change in blood pressure (mmHg) in the placebo, fish oil and seal oil groups.



* significantly different from the change in the placebo group ($p < 0.05$)