Fish or n3-PUFA intake and body composition:
A systematic review and meta-analysis

Nicole Bender¹,², Marc Portmann¹, Zina Heg¹, Karen Hofmann¹, Marcel Zwahlen¹, Matthias Egger¹

¹Institute of Social and Preventive Medicine, University of Bern, Finkenhubelweg 11, 3012 Bern
²Institute for Human Evolution, University of the Witwatersrand, 1 Yale Road, Johannesburg, South Africa

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Running title: fish and body composition

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Corresponding author: Nicole Bender, ISPM Bern, Finkenhubelweg 11, 3012 Bern, Switzerland,
nbender@ispm.unibe.ch

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Abstract

Obesity is a major public health issue and an important contributor to the global burden of chronic disease and disability. Studies indicate that fish and omega 3 polyunsaturated fatty acids (n3-PUFA) supplements may help prevent cardiovascular and metabolic diseases. However, the effect of fish-oil on body composition is still uncertain, so we performed a systematic review of randomized controlled trials and the first meta-analysis on the association between fish or fish oil intake and body composition measures. We found evidence that participants taking fish or fish oil lost 0.59 kg more body weight than controls (95% CI: -0.96 to -0.21). Treatment groups lost 0.24 kg/m² (BMI) more than controls (-0.40 to -0.08), and 0.49 % more body fat than controls (-0.97 to -0.01). Fish or fish oil reduced waist circumference by 0.81 cm (-1.34 to -0.28) compared to control. There was no difference for fat mass and lean body mass. Further research is needed to confirm or refute our findings and to reveal possible mechanisms by which n3-PUFAs might reduce weight.
Introduction

Obesity is a major public health issue and an important contributor to the global burden of chronic disease and disability (1). For more than two decades, the prevalence and incidence of obesity worldwide has reached pandemic proportions (1, 2). Its association with deleterious outcomes such as type 2 diabetes, heart disease, and depression, and its direct relation to increased all-cause mortality and reduced life expectancy (1, 3, 4) make it a pressing global health problem.

Attempts to control the epidemic of obesity usually target behaviour and environmental aspects of the problem. World Health Organization strategy consists of a range of long-term measures, including primary prevention, weight maintenance, management of complications and weight loss (5). However, the global obesity epidemic continues despite these measures, indicating that new approaches are needed.

A much-debated approach is consumption of omega 3 polyunsaturated fatty acids (n3-PUFA, including eicosapentaenoic acid, EPA, and docosahexanoic acid, DHA), either through eating fish (which contain n3-PUFA) or taking supplements in the form of fish oil capsules. There is a growing evidence that n3-PUFA have beneficial effects on health, including prevention of cardiovascular diseases like stroke and coronary heart disease (6, 7), and metabolic diseases like dyslipidemia (8, 9). However, the influence of n3-PUFA on body composition is unclear.

Ecological studies in several countries indicate that a diet rich in fish is associated with low body weight (10). Several clinical studies suggest that fish oils and n3-supplements support weight-loss diets (11, 12), but the benefit was not evident in other studies (13, 14). A narrative review of these studies supported the argument that n3-PUFA may reduce obesity (15), while a systematic review of clinical trials that assessed the effects of dietary n3-PUFA on body weight in adults reported that four out of five studies did not show any important change (16). Only few randomized controlled trials assessed the influence of whole fish, and therefore a combination of fish oil and fish protein, on weight loss. These studies showed a similar effect of whole fish compared to fish oil, even when lean
fish was used, suggesting a potential role of fish protein in weight loss (17-19). To date, no meta-
analysis on this subject has been done.

We undertook a systematic review and meta-analysis of randomized controlled trials to assess the
evidence for an effect of fish or fish-oil on body composition.

**Methods**

**Databases and search strategy**

We conducted and reported the present meta-analysis according to the Cochrane Handbook of
Systematic Reviews on Interventions (20) and the PRISMA guideline (21). We searched the electronic
databases Medline, Embase and the Cochrane Central Register of Controlled Trials (CENTRAL)
(search last updated on 1 May 2013). The search strategy was combined for all exposures and
outcomes of interest. Search terms included *Fish, seafood, salmon, tuna, cod, anchovy, bass, bream,
dogfish, eel, haddock, halibut, herring, huss, mackerel, monkfish, mullet, plaice, red snapper, rock,
sardines, pilchards, skate, sole, swordfish, trout, turbot, n3 fatty acid, n3 supplement*, n3 pufa, n3
polyunsaturated fatty acid, omega-3, eicosapentaenoic acid, EPA, docosahexanoic acid, DHA, and
were combined with terms related to body composition: *obesity, adiposity, body mass index, BMI,
weight, waist, waist-to-hip ratio, WHR, fat, adipose, overweight, Quetelet index, diet, body
composition*. Where possible, we used MeSH headings (or other standardized indexing terms). The
search was restricted to humans, but unrestricted for publication date or language (see supporting
information document S1 for Medline search strategy. Search strategies for Embase and CENTRAL
were similar). The reference lists of all included studies were examined to identify studies not found
by the search of electronic databases. The references of all studies found were entered into an
electronic database (Reference Manager, version 12, Thompson Reuters) and duplicates were
removed.
Eligibility criteria

The titles and abstracts of retrieved references were checked for inclusion or exclusion, according to the following pre-established criteria. We included randomized controlled trials in men or women and individuals of any ethnicity that reported body composition measures as primary or secondary outcomes. The exposures were fish or n3-PUFA derived exclusively from fish. Outcome measures were BMI, body fat percentage, body weight, waist circumference, hip circumference, waist-to-hip-ratio, lean body mass, or other measures of body composition. We excluded studies that used n3-PUFA from vegetal sources, and RCTs with a crossover design that did not report results at crossover. We also excluded studies that aimed to increase body weight for cachectic patients (22, 23) or newborns (24, 25). See flowchart in Figure 1 for details on the identification of eligible studies. Two independent reviewers (NB, MP) assessed eligibility and reached consensus by discussion.

Data extraction

Two independent reviewers (NB, MP, ZH or KH) extracted data from the full text papers on all studies included. The reviewers used a standard data extraction sheet, entered in duplicate into an electronic database (EpiData, version 3.1, Copenhagen, Denmark). Discrepancies were resolved by discussion. Bibliographic details (author, publication year), details of the population (e.g., sex, age, setting), sample size per comparison group and number of people lost to follow up, exposure (fish or n-3 capsules) and daily dosage, obesity-related phenotypes (e.g. BMI, waist circumference) before and after the intervention were all extracted. Furthermore, potential confounders accounted for and quality criteria like type of randomization or blinding of participants and outcome assessors were extracted.

Study quality

To assess the internal validity of the studies and the accuracy of reporting we followed published guidelines to *a priori* identify criteria that may be related to the risk of bias (26, 27): sequence generation, concealment of allocation, blinding of participants, blinding of clinicians, blinding of
outcome assessor, and intention-to-treat analyses. For each included study we noted whether the quality criteria were met or not, or if they were not described.

**Data analysis**

We combined data using fixed effects meta-analyses. We calculated mean differences in changes from baseline between the two comparison groups, with 95% confidence intervals. Standard deviations of changes from baseline were consistently reported only in three studies (18, 28, 29). Where standard deviations of changes from baseline were missing, we used the formula provided in the Cochrane Handbook of Systematic Reviews (20) to calculate standard errors and then converted them into standard deviations. In this formula we used a correlation coefficient of 0.8 for the outcome lean body mass, and 0.9 for the other outcomes, as reported in the studies.

Statistical evidence for heterogeneity between studies was assessed by the I² statistic (30). Funnel plots were used to examine possible small study bias; we used a regression test to test for funnel plot asymmetry (31). We also performed stratified analyses and random-effects meta-regressions to assess the effect of study quality criteria, patient characteristics and intervention characteristics on the results. The statistical package Stata (version 11.2, Stata Corp. College Station, TX) was used for all analyses.

**Results**

**Study selection**

We found 988 unique studies. After exclusions according to our criteria, we retrieved 38 studies as full text. Of these, 17 studies met the inclusion criteria, and we used 15 in the meta-analyses. We excluded two studies that reported results not in a format suited for meta-analysis. One (17) reported the outcomes as percentage of changes from baseline. This study showed no difference in body weight, waist circumference, fat mass and lean body mass between the fish-group and the control-group after a 8-week diet. The other study (32) reported outcome data (BMI and waist circumference) as median and interquartile ranges. It showed no difference between intervention and control group after three years of follow-up.
Study characteristics of included studies

Most studies were conducted in European countries (8 studies). Three were carried out in Australia, two in North America, two in Asia and one each in South America and in Africa (see Table 1 for a description of included studies). The populations studied were mainly Caucasian. Most participants were recruited from general populations; four were from hospital or outpatient populations. Sample sizes varied between 18 and 563, but were mostly smaller than 100. A total of 934 participants were included. Study duration varied between three weeks and three years; most studies lasted two to three months. Exposure was mostly through n3-PUFA capsules, which contained both EPA and DHA in different ratios. The daily dosage of total n3-PUFA varied between 157 mg and 3360 mg.

Quality criteria (sequence generation, concealment of allocation, blinding of participants, clinician or outcome assessor, intention-to-treat analysis) appeared to have no effect on results. But the reporting quality of most studies was low (see Table 2), which made it difficult to determine the impact of study quality on our results. Only six studies reported on sequence generation, five on concealment of allocation, no study reported whether or not outcome assessors were blinded, and only three studies reported that they performed an intention-to-treat analysis.

We did not find evidence for publication bias (see supporting information document S2). The regression test (body weight: \( p=0.31 \); BMI: \( p=0.63 \)) did not indicate publication bias.

Results of meta-analyses

We gathered data suitable for meta-analyses for six different outcomes (body weight, BMI, body fat percentage, fat mass, waist circumference, and lean body mass). In general, meta-analyses showed a more pronounced change in body composition in intervention groups than in control groups (Figure 2 and supporting information document S3). The heterogeneity between studies assessed by \( I^2 \) statistics was 0% for all meta-analyses performed.

The meta-analysis of outcome body weight (12 studies) showed more weight loss in the intervention groups than in the control groups (-0.59 kg, 95% CI: -0.96 to -0.21, \( p=0.002 \)). For the outcome BMI
The meta-analysis showed a greater decrease in BMI in the intervention groups than in the control groups (-0.24 kg/m², 95% CI: -0.40 to -0.08, p=0.003). Similarly, for the outcome body fat percentage (7 studies), the meta-analysis showed a greater decrease in the intervention groups than in the control groups (-0.49%, 95% CI: -0.97 to -0.01, P=0.047). Outcome waist circumference (7 studies) was also reduced more in the intervention groups than in the control groups (-0.81 cm, 95% CI: -1.34 to -0.28, p=0.003).

For the outcome fat mass (3 studies), the meta-analysis showed no statistically significant difference between intervention and control groups (-0.36 kg, 95% CI: -0.96 to 0.24, p=0.24). Similarly, for the outcome lean body mass (3 studies), the meta-analysis showed no statistically significant difference between intervention and control groups (-0.19 kg, 95% CI: -0.72 to 0.33, p=0.47).

**Sensitivity analyses and meta-regressions**

Results were not modified by exposure characteristics (type of exposure (fish or fish oil), EPA/DHA ratio, dose per day, study time or additional interventions like calorie restricted diet or exercise), or participant characteristics (ethnicity, setting, age, nutritional stage, health condition, sex). We found that length of study (less than 60 days versus more than 60 days) had a significant effect in the meta-regression for the outcome BMI (p=0.028): the effect was stronger in shorter studies (see also Figure 3). Stratified analyses by sex showed stronger effects of n3-PUFA on reduction of obesity related measures in males than in females, but this difference generally did not reach statistical significance (p>0.17). An exception was waist circumference (p=0.050): the meta-regression showed a stronger effect in men than in women (based on 3 studies).

**Discussion**

We found evidence that intake of fish or fish oil capsules can decrease weight in adults. When considered on their own, most studies did not show a statistically significant difference: our meta-analyses documented effects that previous reviews had not detected (15, 16). We included only RCTs that explicitly examined body composition related measures as primary or secondary outcomes and
used n3-PUFA of fish provenience. Our analysis was therefore not compromised by the possibility
that n3-PUFA derived from vegetal sources had different effects than n3-PUFA derived from fish
(33). Our study was, however, limited by poor reporting in the studies we examined. This made it
difficult to assess the impact of study quality on results.

The effect found in our meta-analyses was modest: 590 grams mean difference in body weight
between intervention and control groups. This finding was consistent for other body composition
related outcomes like BMI, body fat percentage and waist circumference. For outcomes body fat mass
and lean body mass, the direction of results was the same. However, results were not statistically
significant, probably because of a lack of statistical power, as only few studies reported on these
outcomes.

A modest weight loss of 5-10% body weight has been shown to be effective in improving risk factors
like hyperinsulinemia, hypertension and dyslipidemia (34-36). Indeed, Klein concluded that modest
weight loss can affect the whole cluster of cardiovascular risk factors simultaneously (37). Troseid and
colleagues (32) found that despite small to moderate decreases in BMI, triglycerides and inflammatory
markers such as IL-18 decreased after an n3-PUFA intervention, and an overall positive effect was
obtained, probably by a combination of mechanisms. As obesity is associated with a low-grade
inflammation state with mild elevation of several inflammatory markers expressed in adipose tissue,
like TNF-α or IL-6 (38-40), the anti-inflammatory effect of n3-PUFA might have a beneficial effect.
In fact, n3-PUFA was shown to reduce insulin resistance in rats and humans (41, 42) and proposed as
a potential anti-inflammatory strategy to decrease obesity-related disease (43).

At a population level the effect of a small change in a risk factor on an outcome can be substantial.
This phenomenon is known as the “prevention paradox” (44) and relates to the fact that a large number
of people exposed to a low risk produce more cases of disease than a small number of people exposed
to a high risk. In fact, the population attributable risk depends on the individual attributable risk and
the prevalence of the risk factor in the population. It is therefore more effective to shift the distribution
of the risk factor (in this case overweight) in the whole population, than to treat only those at high risk
(obese people), even if the shift in the population is modest. We found that taking n3-PUFA for less
than two months may be more effective than longer interventions. This finding questions the long term
effect of n3-PUFA on body composition, but as only few studies lasted longer than two months and
only one study lasted more than a year (32), more long-term studies are needed to clarify this point.

In the present study, we found some indications that the effect might be greater in males than in
females for the outcome waist circumference, which is a measure for visceral adiposity. This is
relevant, as visceral fat is strongly associated with metabolic disease risks (45-47). Several studies
reported that n3-PUFA had a stronger effect on weight loss in males than in females (e.g. (18)), while
other studies found stronger effects in women (12). Difference between the sexes in the physiological
response to n3-PUFA is plausible because men and women have a different fat tissue anatomy and
physiology. For example, women may convert more alpha-linoleic acid into DHA than men do (48,
49). A population based study in New Zealand showed higher DHA levels and lower EPA levels in
serum lipids in females compared to males (50). Future studies on the effect of n3-PUFA on body
composition should examine gender differences in order to clarify possible differences in health
benefits.

A further question is the relative importance of EPA and DHA. We did not find a dose-response
relationship or an effect modification depending on the EPA / DHA ratio, despite both animal studies
(51, 52) and human studies (28) suggesting this possibility. Several mechanisms have been proposed
to explain the weight loss effect of n3-PUFA, for example increased lipolysis and reduced lipogenesis.
In rodents (53) and in humans (54) n3-PUFA stimulate beta-oxidation, and inhibit fatty acid synthesis
and VLDL secretion, partially by regulating gene expression. In rats, there is indication that n3-PUFA
might reduce lipogenesis in adipose cells by reducing lipoprotein lipase (LPL) activity (55). In
addition to n3-PUFA, fish protein might have an effect on body weight. For example, the amino acid
taurine, which is abundant in fish protein, showed a weight lowering effect in mice (56, 57) and
humans (58). In our meta-regressions, we did not find a difference between the effects of whole fish or
of fish oil on body composition. However, only three studies included in our analysis used whole fish
as exposure (17, 18, 59), so that more studies are needed using whole fish or fish protein to clarify the
possible specific roles of fish oil and fish protein, and the different components of fish protein.
Our meta-analysis and other studies showed that n3-PUFA might influence body composition and health in a favorable way. Evolutionary considerations are also relevant in this context. Based on estimates from studies on Paleolithic nutrition and modern-day hunter-gatherer populations it seems likely that humans have evolved with a diet that contained small and approximately equal amounts of n6 and n3-PUFA and lower amounts of trans-fatty acids and linoleic acid (60). A nutrition rich in n3-PUFA and other nutrients typical for the Paleolithic diet, such as polyphenols, fiber, and plant sterols, was therefore proposed to improve health outcomes (61). Of several early Homo species (such as Homo habilis, Homo erectus and early Homo sapiens) it is assumed that they consumed fish and seafood (62-64). However, the exploitation of aquatic food resources is still a neglected field in paleoanthropology (65, 66) and more research on the reconstruction of our ancient natural nutrition, including aquatic food, is needed (67). This knowledge should contribute to a better understanding of modern human nutrition and health.

Conclusions

Our meta-analysis showed that consumption of n3-PUFA can decrease weight in adults. Further research is needed to reveal which components of fish and fish oil are most beneficial. In particular, the documented positive effects of n3-PUFA on cardiovascular diseases, dyslipidemia and obesity suggest that we should continue to explore the effects of fish-derived n3-PUFA on human health.
Table legends

Table 1: Characteristics of studies included in the systematic review. Country and setting of the studies are given, as well as sample size per group, exposure used, and duration of studies. All except Abete 2009 and Troseid 2009 were included in the meta-analyses.

Table 2: Quality criteria of studies included in the systematic review. The criteria chosen were: correct method of randomization, correct concealment of allocation, blinding of participants, clinicians and outcome assessors, and the application of an intention-to-treat data analysis. For each study it was stated if the criterion was met or not, or if it was not described (classified as unclear). Criteria that were not possible to meet (e.g., blinding for fish meals) were classified as non applicable.
Figure legends

Figure 1: Flow chart of studies throughout the systematic review process. Numbers of studies found, selected and included or excluded were given for each review step, with reasons for exclusion in full text studies.

Figure 2: Results of meta-analyses performed for different outcomes on the association between fish or fish oil intake and body composition. The number of datasets can be higher than the number of studies included, if some studies reported their results divided into subgroups (as for instance by intervention type or by sex). The mean differences between intervention and control groups and their 95% confidence intervals are given for each outcome. Note that the unit of measure for each outcome is different.

Figure 3: Forest-plot of meta-analysis on the association between fish or fish oil and BMI, by time of study duration. Studies are divided into two groups: less than two months of study duration vs. more than two months of study duration. Only studies of less than two months of study duration show a BMI-lowering effect of fish or fish oil.
Supporting information

Supporting information document S1: Search strategy for the database Medline. The search strategies for the databases Embase and CENTRAL were similar.

Supporting information document S2: Figure showing funnel plots of studies for the outcomes body weight (12 studies) and BMI (13 studies). There was no indication for publication bias.

Supporting information document S3: Forest plots of meta-analyses on the association between fish oil intake and body composition measures. Figure 1 shows the results for the outcome body weight, Figure 2 for the outcome BMI. Figure 3 shows the results for the outcome body fat percentage, Figure 4 for the outcome waist circumference. Figure 5 shows the results for the outcome fat mass, Figure 6 for the outcome lean body mass. For all outcomes the weighted mean difference between changes from baseline comparing intervention group and control group and 95% confidence intervals are given, as well as overall estimates. All meta-analyses were performed as fixed effects models, as no one showed evidence for heterogeneity.
### Table 1: Characteristics of studies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Country</th>
<th>Setting or population</th>
<th>Intervention group (N, % males)</th>
<th>Control group (N, % males)</th>
<th>Exposure, per day (mg): EPA / DHA</th>
<th>Duration of study (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abete 2009</td>
<td>Spain</td>
<td>General population</td>
<td>8 (100%)</td>
<td>10 (100%)</td>
<td>3 meals with fatty fish weekly</td>
<td>56</td>
</tr>
<tr>
<td>Bays 2009</td>
<td>USA</td>
<td>Unclear</td>
<td>84 (71%)</td>
<td>83 (76%)</td>
<td>1860 / 1500</td>
<td>56</td>
</tr>
<tr>
<td>Crochemore 2012</td>
<td>Brazil</td>
<td>Hospital, high blood pressure and diabetes program</td>
<td>28 (0%)</td>
<td>13 (0%)</td>
<td>A: 547.5 / 352.5 B: 328.5 / 211.5</td>
<td>30</td>
</tr>
<tr>
<td>DeFina 2011</td>
<td>USA</td>
<td>General population</td>
<td>64 (31%)</td>
<td>64 (31%)</td>
<td>2500 / 500</td>
<td>168</td>
</tr>
<tr>
<td>Ebrahimi 2009</td>
<td>Iran</td>
<td>General population</td>
<td>47 (15%)</td>
<td>43 (9%)</td>
<td>180 / 120</td>
<td>180</td>
</tr>
<tr>
<td>Emsley 2008</td>
<td>South Africa</td>
<td>Community psychiatric services and university hospital</td>
<td>39 (69%)</td>
<td>33 (70%)</td>
<td>2000 / 0</td>
<td>84</td>
</tr>
<tr>
<td>Hill 2007</td>
<td>Australia</td>
<td>Unclear</td>
<td>33 (33%)</td>
<td>32 (41%)</td>
<td>Total 6000</td>
<td>84</td>
</tr>
<tr>
<td>Itariu 2012</td>
<td>Austria</td>
<td>Bariatric surgery clinic</td>
<td>27 (15%)</td>
<td>28 (18%)</td>
<td>1840 / 1520</td>
<td>56</td>
</tr>
<tr>
<td>Kabir 2007</td>
<td>France</td>
<td>Diabetes department outpatient clinic</td>
<td>12 (0%)</td>
<td>14 (0%)</td>
<td>1080 / 720</td>
<td>60</td>
</tr>
<tr>
<td>Kunesova 2006</td>
<td>Czech Republic</td>
<td>Unclear</td>
<td>11 (0%)</td>
<td>9 (0%)</td>
<td>Total 2800</td>
<td>21</td>
</tr>
<tr>
<td>Marqués 2008</td>
<td>Spain</td>
<td>Follow up from SEAFOODPlus YOUNG Study</td>
<td>14 (100%)</td>
<td>7 (100%)</td>
<td>Total 1070</td>
<td>56</td>
</tr>
<tr>
<td>Munro 2012</td>
<td>Australia</td>
<td>General population</td>
<td>18 (17%)</td>
<td>14 (21%)</td>
<td>420 / 1620</td>
<td>98</td>
</tr>
<tr>
<td>Munro 2013</td>
<td>Australia</td>
<td>General population</td>
<td>20 (25%)</td>
<td>19 (21%)</td>
<td>420 / 1620</td>
<td>56</td>
</tr>
<tr>
<td>Paniagua 2011</td>
<td>8 European</td>
<td>LIPGENE study</td>
<td>83 (48%)</td>
<td>77 (44%)</td>
<td>Total 1240</td>
<td>84</td>
</tr>
<tr>
<td>Thorsdottir 2007</td>
<td>Iceland, Spain</td>
<td>SEAFOODPlus YOUNG Study</td>
<td>244 (43%)</td>
<td>80 (40%)</td>
<td>Total: cod: 300, salmon: 3000, capsules: 1500</td>
<td>56</td>
</tr>
<tr>
<td>Troseid 2009</td>
<td>Norway</td>
<td>Follow up from Oslo Diet and Antismoking Study</td>
<td>282 (100%)</td>
<td>281 (100%)</td>
<td>840 / 480</td>
<td>1095</td>
</tr>
<tr>
<td>Yamaoka 2007</td>
<td>Japan</td>
<td>Female college students</td>
<td>57 (0%)</td>
<td>46 (0%)</td>
<td>0 / 700</td>
<td>35</td>
</tr>
</tbody>
</table>

† = not included in meta-analyses.
References


22


Fig. 1: Flow chart of study selection.

Records identified through database search (n = 2234)
(Medline: n = 939, Embase: n = 632, Cochrane: n = 663)
Records after duplicates removed (n = 988)
Records screened by title and abstract (n = 988)
Full-text articles assessed for eligibility (n = 38)
Studies included in qualitative synthesis (n = 17)
Studies included in quantitative synthesis (meta-analyses) (n = 15)
Studies excluded from meta-analyses (n = 2)
Reason: No suitable data provided

Records excluded (n = 950)
Reason: Topic not relevant

Full-text articles excluded (n = 21)
Reasons:
Wrong study design = 3
Wrong exposure = 4
Wrong or missing outcome = 2
Wrong aim = 6
Double reporting = 6
**Fig 2:** Results of meta-analyses performed for different outcomes on the association between fish or fish oil intake and body composition.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Datasets</th>
<th>Unit</th>
<th>Mean difference (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC</td>
<td>13</td>
<td>cm</td>
<td>-0.81 (-1.34, -0.28)</td>
</tr>
<tr>
<td>Body weight</td>
<td>19</td>
<td>Kg</td>
<td>-0.59 (-0.96, -0.21)</td>
</tr>
<tr>
<td>BMI</td>
<td>21</td>
<td>Kg/m²</td>
<td>-0.24 (-0.40, -0.08)</td>
</tr>
<tr>
<td>Body fat %</td>
<td>10</td>
<td>%</td>
<td>-0.49 (-0.97, -0.01)</td>
</tr>
<tr>
<td>Fat mass</td>
<td>8</td>
<td>Kg</td>
<td>-0.36 (-0.96, 0.24)</td>
</tr>
<tr>
<td>Lean mass</td>
<td>8</td>
<td>Kg</td>
<td>-0.19 (-0.72, 0.33)</td>
</tr>
</tbody>
</table>

WC = waist circumference, BMI = body mass index
**Fig. 3:** Forest-plot on the association between fish or fish oil and BMI, by time of study duration.
**Table 1: Characteristics of studies**

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<tr>
<td>DeFina 2011 (85)</td>
<td>USA</td>
<td>General population</td>
<td>64 (31%)</td>
<td>64 (31%)</td>
<td>2500 / 500</td>
<td>168</td>
</tr>
<tr>
<td>Ebrahimi 2009 (6)</td>
<td>Iran</td>
<td>General population</td>
<td>47 (15%)</td>
<td>43 (9%)</td>
<td>180 / 120</td>
<td>180</td>
</tr>
<tr>
<td>Emsley 2008 (86)</td>
<td>South Africa</td>
<td>Community psychiatric services and university hospital</td>
<td>39 (69%)</td>
<td>33 (70%)</td>
<td>2000 / 0</td>
<td>84</td>
</tr>
<tr>
<td>Hill 2007 (87)</td>
<td>Australia</td>
<td>Unclear</td>
<td>33 (33%)</td>
<td>32 (41%)</td>
<td>Total 6000</td>
<td>84</td>
</tr>
<tr>
<td>Itariu 2012 (88)</td>
<td>Austria</td>
<td>Bariatric surgery clinic</td>
<td>27 (15%)</td>
<td>28 (18%)</td>
<td>1840 / 1520</td>
<td>56</td>
</tr>
<tr>
<td>Kabir 2007 (11)</td>
<td>France</td>
<td>Diabetes department outpatient clinic</td>
<td>12 (0%)</td>
<td>14 (0%)</td>
<td>1080 / 720</td>
<td>60</td>
</tr>
<tr>
<td>Kunesova 2006 (28)</td>
<td>Czech Republic</td>
<td>Unclear</td>
<td>11 (0%)</td>
<td>9 (0%)</td>
<td>Total 2800</td>
<td>21</td>
</tr>
<tr>
<td>Marquès 2008 (99)</td>
<td>Spain</td>
<td>Follow up from SEAFODPlus YOUNG Study</td>
<td>14 (100%)</td>
<td>7 (100%)</td>
<td>Total 1070</td>
<td>56</td>
</tr>
<tr>
<td>Munro 2012 (14)</td>
<td>Australia</td>
<td>General population</td>
<td>18 (17%)</td>
<td>14 (21%)</td>
<td>420 / 1620</td>
<td>98</td>
</tr>
<tr>
<td>Munro 2013 (12)</td>
<td>Australia</td>
<td>General population</td>
<td>20 (25%)</td>
<td>19 (21%)</td>
<td>420 / 1620</td>
<td>56</td>
</tr>
<tr>
<td>Paniagua 2011 (8)</td>
<td>8 European countries</td>
<td>LIPGENE study</td>
<td>83 (48%)</td>
<td>77 (44%)</td>
<td>Total 1240</td>
<td>84</td>
</tr>
<tr>
<td>Thorsdottir 2007 (18)</td>
<td>Iceland, Spain,</td>
<td>SEAFODPlus YOUNG Study</td>
<td>244 (43%)</td>
<td>80 (40%)</td>
<td>Total: cod: 300, salmon: 3000,</td>
<td>56</td>
</tr>
<tr>
<td>Troseid 2009 (32)†</td>
<td>Norway</td>
<td>Follow up from Oslo Diet and Antismoking Study</td>
<td>282 (100%)</td>
<td>281 (100%)</td>
<td>capsules: 1500, 840 / 480</td>
<td>1095</td>
</tr>
<tr>
<td>Yamaoka 2007 (19)</td>
<td>Japan</td>
<td>Female college students</td>
<td>57 (0%)</td>
<td>46 (0%)</td>
<td>0 / 700</td>
<td>35</td>
</tr>
</tbody>
</table>

† = not included in meta-analyses.
### Table 2: Methodological quality of studies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Sequence generation</th>
<th>Concealment of allocation</th>
<th>Blinding participants</th>
<th>Blinding investigator</th>
<th>Blinding outcome assessor</th>
<th>ITT</th>
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<tbody>
<tr>
<td>Abete 2009</td>
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<td>n. a.</td>
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<td>yes</td>
<td>yes</td>
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<td>n. a.</td>
<td>n. a.</td>
<td>unclear</td>
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</tr>
</tbody>
</table>

ITT = intention-to-treat analysis performed; n. a. = non applicable.