Dietary Cholesterol in Cold Water Prawns: Implications for Cardiovascular Disease Risk

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Coronary Heart Disease and Thrombosis

Coronary atherosclerosis

Cholesterol

Lumen

Coronary thrombosis

Thrombus
Plasma (LDL) cholesterol (mmo/l)
6-year death rate per 1000 men

Mortality Curves from Prospective Cohort Studies

- Total mortality
- CHD mortality

Raised serum LDL cholesterol: Unequivocally related to cardiovascular disease

Atherosclerotic coronary lesions shrink after cholesterol-lowering therapy
Main dietary sources of cholesterol

**Eggs**
1 egg yolk contains ~200mg cholesterol

**Shellfish**
- Crab (brown meat) 200
- Prawns (cold water) 166
- Lobster 166
- Squid 123
- Mussels 60
Blood Cholesterol

Dietary Cholesterol

Low Density Lipoprotein (LDL)

Coronary Heart Disease
Effect of dietary cholesterol on blood cholesterol depends on how much dietary cholesterol you eat to begin with and how much you add to your diet.
Differential Effects of Dietary Fatty Acids on Plasma Lipoproteins

Micha & Mozzaffarin (2010) Lipids 45, 893-905
How LDL Receptor Regulates Blood Cholesterol

Plasma LDL cholesterol → Cells

- Cell makes more LDL receptors
- LDL receptor gene expression -

Free Cholesterol → Cells

- Cell makes more LDL receptors
- LDL receptor gene expression -

Saturated Fatty Acids

Cholesterol
Metabolic Ward Studies
Changes in blood total cholesterol associated with replacing dietary SFA with PUFA, MUFA and with reducing dietary cholesterol

Replacement of 5% calories as saturated fat (for example, 17% to 12%) by polyunsaturated fat: (-0.39)

Replacement of 5% calories as saturated fat (for example, 12% to 7%) by monounsaturated fat: (-0.24)

Reduction of dietary cholesterol by 200 mg (for example, 340 mg/day to 140 mg/day): (-0.13)

Sum of above dietary changes: (-0.76)

Calculated Effects of Dietary Cholesterol versus Saturated Fat on Serum Cholesterol

Change in dietary cholesterol
100 mg/day (~half an egg yolk)

Change in saturated fat
2-3g (~1% total energy)

Change in serum cholesterol
~0.06 mmol/l (~2mg/dl)

~1-3% change in CHD risk
# Cholesterol & Saturated Fat Content of Selected Foods

<table>
<thead>
<tr>
<th>Per 100 grams</th>
<th>Energy (KJ / Kcal)</th>
<th>Fat (g)</th>
<th>Saturated Fat (g)</th>
<th>Cholesterol (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Egg (boiled)</strong></td>
<td>612 / 147</td>
<td>10.8</td>
<td>3.1</td>
<td>391</td>
</tr>
<tr>
<td><strong>Prawns (boiled)</strong></td>
<td>418 / 99</td>
<td>0.9</td>
<td>0.2</td>
<td>280</td>
</tr>
<tr>
<td><strong>Crab (boiled)</strong></td>
<td>535 / 128</td>
<td>5.5</td>
<td>0.7</td>
<td>72</td>
</tr>
<tr>
<td><strong>Mussels (boiled)</strong></td>
<td>440 / 104</td>
<td>2.7</td>
<td>0.5</td>
<td>58</td>
</tr>
<tr>
<td><strong>Burger</strong></td>
<td>1206 / 291</td>
<td>24.7</td>
<td>10.7</td>
<td>76</td>
</tr>
<tr>
<td><strong>Pork Sausage</strong></td>
<td>1282 / 309</td>
<td>25.0</td>
<td>9.2</td>
<td>60</td>
</tr>
<tr>
<td>(raw, 65-70% meat)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sausage Roll</strong></td>
<td>1596 / 383</td>
<td>27.6</td>
<td>11.2</td>
<td>N</td>
</tr>
</tbody>
</table>

(With puff pastry)

**McChance & Widdowson, 2007**

- **Δ serum cholesterol (mmol/l)**
  - Burger + Sausage: +0.40 - 0.60
  - 2 eggs or 100g prawns: +0.17 - 0.23
Dietary Cholesterol and Saturated Fat
Smashing the CHD cholesterol myth
Why the public perception of dietary cholesterol and CHD is based on scrambled thinking
Lifting the limits on egg consumption

“There is no recommended limit on how many eggs people should eat”

British Dietetic Association

“Smashing the CHD cholesterol myth”
Effects of shrimp consumption on plasma lipoproteins

Randomised cross-over study - 18 normo-lipidaemic subjects - three, 3 wk diets matched for energy and macronutrient content, but different amounts of cholesterol from 100g of shrimp and egg versus baseline

<table>
<thead>
<tr>
<th></th>
<th>Baseline Calculated</th>
<th>Baseline Analyzed</th>
<th>Shrimp Calculated</th>
<th>Shrimp Analyzed</th>
<th>Egg Calculated</th>
<th>Egg Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kJ/d)</td>
<td>10029</td>
<td>9619</td>
<td>10017</td>
<td>9673</td>
<td>9945</td>
<td>9552</td>
</tr>
<tr>
<td>Fat (% of energy)²</td>
<td>30.0</td>
<td>30.0</td>
<td>30.0</td>
<td>28.5</td>
<td>29.9</td>
<td>28.9</td>
</tr>
<tr>
<td>Protein (% of energy)²</td>
<td>15.0</td>
<td>14.1</td>
<td>15.0</td>
<td>17.8</td>
<td>15.0</td>
<td>14.4</td>
</tr>
<tr>
<td>Carbohydrates (% of energy)²</td>
<td>55.0</td>
<td>55.7</td>
<td>55.0</td>
<td>53.8</td>
<td>55.2</td>
<td>56.5</td>
</tr>
<tr>
<td>Dietary cholesterol (mg/d)</td>
<td>107</td>
<td>120</td>
<td>590</td>
<td>595</td>
<td>581</td>
<td>528</td>
</tr>
<tr>
<td>Dietary fiber (g/d)</td>
<td>14.3</td>
<td>—</td>
<td>13.4</td>
<td>—</td>
<td>14.6</td>
<td>—</td>
</tr>
</tbody>
</table>

¹ Based on 10 042-kJ consumed/d.
² Average of days 1 and 2 of menu.

<table>
<thead>
<tr>
<th></th>
<th>Shrimp - baseline % Δ</th>
<th>P</th>
<th>Egg - baseline % Δ</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td>8.5</td>
<td>0.0003¹</td>
<td>10.0</td>
<td>0.0001¹</td>
</tr>
<tr>
<td>Triacylglycerols</td>
<td>-13.0</td>
<td>0.004¹</td>
<td>7.2</td>
<td>0.28</td>
</tr>
<tr>
<td>VLDL cholesterol</td>
<td>4.3</td>
<td>0.15</td>
<td>16.6</td>
<td>0.03</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>7.1</td>
<td>0.014¹</td>
<td>10.2</td>
<td>0.0001¹</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>12.1</td>
<td>0.0001¹</td>
<td>7.6</td>
<td>0.004¹</td>
</tr>
<tr>
<td>Total cholesterol:HDL cholesterol</td>
<td>-1.9</td>
<td>0.20</td>
<td>4.0</td>
<td>0.09</td>
</tr>
</tbody>
</table>
Randomised Controlled Dietary Intervention with Cold Water Prawns

Study Rationale

Prawns represent the greatest percentage of all shellfish consumed in the UK diet, but patterns of consumption are negatively influenced by the belief that because they are a rich source of cholesterol they will raise blood cholesterol.

Study Aim

To determine the effect of cold water prawns on plasma LDL cholesterol and other biomarkers of CHD risk, relative to an appropriate control, in normal healthy men.
Subjects
21 healthy, normo-lipidaemic, weight-stable, non-smoking males (mean age 41, range 20-70yr), recruited from university staff and students

Characteristics at baseline

<table>
<thead>
<tr>
<th></th>
<th>Pre-Prawn</th>
<th>Pre-Control</th>
<th>UK (35-44yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body weight (kg)</td>
<td>82.1 (12.2)</td>
<td>81.9 (12.6)</td>
<td>-</td>
</tr>
<tr>
<td>Blood pressure (mmHg)</td>
<td>125 / 73</td>
<td>124 / 72</td>
<td>130 / 76</td>
</tr>
<tr>
<td>Plasma cholesterol (mM)</td>
<td>5.1 (1.1)</td>
<td>5.1 (0.9)</td>
<td>68% &gt;5.0</td>
</tr>
<tr>
<td>Plasma triacylglycerol (mM)</td>
<td>1.3 (0.5)</td>
<td>1.2 (0.6)</td>
<td></td>
</tr>
<tr>
<td>LDL-cholesterol (mM)</td>
<td>3.0 (0.9)</td>
<td>3.0 (0.7)</td>
<td></td>
</tr>
<tr>
<td>HDL-cholesterol (mM)</td>
<td>1.6 (0.4)</td>
<td>1.6 (0.4)</td>
<td>8% &lt;1.0</td>
</tr>
</tbody>
</table>

Values are means (SD)
Dietary Interventions

225g/day for 4 weeks
## Composition (/100g) of Prawns and Crabsticks

<table>
<thead>
<tr>
<th></th>
<th>Energy (Kcals)</th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Cholesterol (mg)</th>
<th>EPA+DHA (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold water prawn</td>
<td>100</td>
<td>21.2</td>
<td>1.73</td>
<td>165</td>
<td>547</td>
</tr>
<tr>
<td>(in shell)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shelled, &amp; cooked</td>
<td>62</td>
<td>13.9</td>
<td>0.74</td>
<td>131</td>
<td>267</td>
</tr>
<tr>
<td>Crab sticks</td>
<td>115</td>
<td>7.80</td>
<td>1.60</td>
<td>trace</td>
<td>trace</td>
</tr>
</tbody>
</table>

225g prawns deliver between 295-371mg cholesterol & 0.6-1.2g EPA+DHA per day
Study Design

**Outcomes Measures**

- Total plasma cholesterol, LDL-C, HDL-C, TAG
- Small, dense LDL
- Plasma apoproteins B and A-I
- Blood pressure
- Body weight
- Dietary intakes (WINDIET)
<table>
<thead>
<tr>
<th></th>
<th>Prawn</th>
<th>Control</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy Kj (Kcals)</strong></td>
<td>8,162 (1,940)</td>
<td>8,840 (2,099)</td>
<td>9,880-8,610</td>
</tr>
<tr>
<td><strong>Carbohydrate %E (g)</strong></td>
<td>43 (208)</td>
<td>49 (259)</td>
<td>48%E (275g)</td>
</tr>
<tr>
<td><strong>Protein %E (g)</strong></td>
<td>24 (114)</td>
<td>19 (101)</td>
<td>16.5%E (88g)</td>
</tr>
<tr>
<td><strong>Total fat %E (g)</strong></td>
<td>30 (64)</td>
<td>29 (66)</td>
<td>36%E (87g)</td>
</tr>
<tr>
<td><strong>SFA (g)</strong></td>
<td>19</td>
<td>21</td>
<td>13%E</td>
</tr>
<tr>
<td><strong>PUFA (g)</strong></td>
<td>14</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td><strong>MUFA (g)</strong></td>
<td>22</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td><strong>Cholesterol (mg)</strong></td>
<td><strong>794</strong></td>
<td>275</td>
<td>304mg/d</td>
</tr>
<tr>
<td><strong>Alcohol (%E)</strong></td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

Values are means ** p<0.001
Total Plasma Cholesterol

- **Total plasma cholesterol (mmol/l)**
- **Pre-prawn:** 5.1 ± 0.8
- **Post-prawn:** 5.1 ± 0.8
- **Pre-control:** 5.1 ± 0.8
- **Post-control:** 5.1 ± 0.8
Plasma cholesterol (mmol/l)

<table>
<thead>
<tr>
<th></th>
<th>Pre-prawn</th>
<th>Post-prawn</th>
<th>Pre-control</th>
<th>Post-control</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.02 ± 0.6</td>
<td></td>
<td></td>
<td>0.4 ± 0.2</td>
<td>* 0.6 ± 0.4</td>
</tr>
<tr>
<td>2.98 ± 0.6</td>
<td></td>
<td></td>
<td>0.6 ± 0.4</td>
<td></td>
</tr>
</tbody>
</table>

**LDL cholesterol**

*Small, dense LDL*

*p<0.05 Prawn vs Control*
Plasma HDL cholesterol (mmol/l)

- Pre-prawn: 1.57 ± 0.4
- Post-prawn: 1.55 ± 0.4
- Pre-control: 1.55 ± 0.4
- Post-control: 1.55 ± 0.4

Plasma triacylglycerol (mmol/l)

- Pre-prawn: 1.15 ± 0.43
- Post-prawn: 1.15 ± 0.43
- Pre-control: 1.23 ± 0.42
- Post-control: 1.23 ± 0.42

HDL cholesterol

Triacylglycerol
Other results

- Significant decrease in plasma apoprotein B over time with prawns ($p<0.05$)

  No significant differences, either between or within the prawn and control groups, for:

- Body weight
- Total cholesterol : HDL cholesterol ratio
- Serum apoprotein A-I
- Systolic and diastolic blood pressures
Results Summary

- Dietary interventions were well tolerated and complied with as evidenced from dietary intakes.
- Dietary intakes were well matched for energy and macronutrients, but not dietary cholesterol.
- Cold water prawns produced no effect on the concentration of total plasma and LDL cholesterol.
- There were significant decreases in plasma sdLDL and apo B between the prawn and control, and within the prawn group, respectively.
- No other significant effects.
Conclusions

In healthy individuals consuming a balanced diet, an intake of dietary cholesterol of ≤ 300mg/d is unlikely to be associated with a clinically significant increase in serum LDL cholesterol, i.e. that which would increase risk of CVD.

The addition of up to 400mg dietary cholesterol per day in the form of cold water prawns was not associated with an increase in plasma LDL cholesterol in normo-lipidaemic men consuming their habitual diet.

There is no evidence to support the restricted intake of prawns on the grounds of unfavourable effects on overall lipid profile or blood cholesterol.
Manifestations of Cardiovascular Disease

Atherosclerosis  Thrombosis  Arrhythmias

Anti-atherogenic  Anti-thrombogenic  Anti-arrhythmic
(reverse dyslipidaemia)  1-2g/d  2-3g/d  0.5–1g/d

Anti-inflammatory

Long chain n-3 PUFA
### Long Chain n-3 Polyunsaturated Fatty Acids in Shellfish (EPA + DHA mg/100g)

<table>
<thead>
<tr>
<th></th>
<th>Autumn</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CRUSTACEANS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold water prawns hand peeled</td>
<td>547</td>
<td>658</td>
</tr>
<tr>
<td>Cold water prawns (<em>processed as eaten</em>)</td>
<td>267</td>
<td>332</td>
</tr>
<tr>
<td>Warm water prawns <em>P vannamei</em></td>
<td>181</td>
<td>197</td>
</tr>
<tr>
<td>Brown shrimp <em>Crangon crangon</em></td>
<td>514</td>
<td>475</td>
</tr>
<tr>
<td>Scampi tails</td>
<td>186</td>
<td>246</td>
</tr>
<tr>
<td>Lobster</td>
<td>415</td>
<td>413</td>
</tr>
<tr>
<td>Crab <em>Cancer pagurus</em> white meat</td>
<td>174</td>
<td>307</td>
</tr>
<tr>
<td>Crab <em>Cancer pagurus</em> brown meat</td>
<td>2450</td>
<td>2474</td>
</tr>
<tr>
<td><strong>MOLLUSCS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mussels <em>Mytilus edulis</em></td>
<td>992</td>
<td>372</td>
</tr>
<tr>
<td>Pacific oysters <em>Crassostrea gigas</em></td>
<td>1739</td>
<td>1463</td>
</tr>
<tr>
<td>Cockles <em>Cerastoderma edule</em></td>
<td>426</td>
<td>258</td>
</tr>
<tr>
<td>Scallops <em>Pecten maximus</em> (roe-on)</td>
<td>182</td>
<td>597</td>
</tr>
<tr>
<td>Whelks <em>Buccinum undatum</em></td>
<td>231</td>
<td>272</td>
</tr>
<tr>
<td>Octopus meat</td>
<td>315</td>
<td>898</td>
</tr>
<tr>
<td>Squid</td>
<td>537</td>
<td>878</td>
</tr>
</tbody>
</table>

### Reference Figures for Fish

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cod</td>
<td>170-260</td>
</tr>
<tr>
<td>Herring</td>
<td>1600-2350</td>
</tr>
<tr>
<td>Mackerel</td>
<td>1300-2600</td>
</tr>
</tbody>
</table>

Thank You