Effect of specific dietary constituents on coronary heart disease risk factors

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Graduate Diploma in Nutrition and Dietetics
Masters in Biomedical Science

Submitted in fulfilment of the requirements for the
Degree of Doctorate in Philosophy

University of Tasmania

September 2006
Candidate Declaration

I certify that the thesis entitled

“Effect of specific dietary constituents on coronary heart disease risk factors”

submitted for the degree of Doctorate in Philosophy is the result of my own research, except otherwise acknowledged and that this thesis in whole or in part has not been submitted for an award, including a higher degree, to any other university or institution.

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Full Name   Kiran Deep Kaur Ahuja
Signed           ..............................
Date      October 9, 2006
I wish to express my sincere gratitude and appreciation to everyone who has been involved in the underlying work of this thesis, with special thanks to:

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I dedicate this thesis to my parents, Gurcharan Kaur and Daman Singh Ahuja.
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### Acronyms used in this thesis

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>CVD</td>
<td>Cardiovascular disease</td>
</tr>
<tr>
<td>AG</td>
<td>Augmentation</td>
</tr>
<tr>
<td>AGE</td>
<td>Advanced glycation end products</td>
</tr>
<tr>
<td>Alx</td>
<td>Augmentation index</td>
</tr>
<tr>
<td>Apo-A1</td>
<td>Apolipoprotein A1</td>
</tr>
<tr>
<td>Apo-B</td>
<td>Apolipoprotein B</td>
</tr>
<tr>
<td>AUC</td>
<td>Area under the curve</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>BMR</td>
<td>Basal metabolic rate</td>
</tr>
<tr>
<td>CETP</td>
<td>Cholesterol ester transfer protein</td>
</tr>
<tr>
<td>CHD</td>
<td>Coronary heart disease</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence interval</td>
</tr>
<tr>
<td>DBP</td>
<td>Diastolic blood pressure</td>
</tr>
<tr>
<td>eNOS</td>
<td>Endothelial nitric oxide synthase</td>
</tr>
<tr>
<td>ET-1</td>
<td>Endothelin-1</td>
</tr>
<tr>
<td>GTN</td>
<td>Glyceryl trinitrate</td>
</tr>
<tr>
<td>HCLF</td>
<td>High carbohydrate low fat</td>
</tr>
<tr>
<td>HDL</td>
<td>High density lipoprotein</td>
</tr>
<tr>
<td>HR</td>
<td>Heart rate</td>
</tr>
<tr>
<td>LDL</td>
<td>Low density lipoprotein</td>
</tr>
<tr>
<td>LO</td>
<td>Low olive oil</td>
</tr>
<tr>
<td>MD</td>
<td>Mean difference</td>
</tr>
<tr>
<td>MUFA</td>
<td>Monounsaturated fatty acid</td>
</tr>
<tr>
<td>NO</td>
<td>Nitric oxide</td>
</tr>
<tr>
<td>OO</td>
<td>Olive oil</td>
</tr>
<tr>
<td>PUFA</td>
<td>Polyunsaturated fatty acid</td>
</tr>
<tr>
<td>PWA</td>
<td>Pulse wave analysis</td>
</tr>
<tr>
<td>SBP</td>
<td>Systolic blood pressure</td>
</tr>
<tr>
<td>SEVR</td>
<td>Subendocardial viability Ratio</td>
</tr>
<tr>
<td>SFA</td>
<td>Saturated fatty acid</td>
</tr>
<tr>
<td>SNS</td>
<td>Sympathetic nervous system</td>
</tr>
<tr>
<td>TG</td>
<td>Triglyceride</td>
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<tr>
<td>VLDL</td>
<td>Very low density lipoprotein</td>
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</table>
Publications and presentations at conferences during the PhD candidature

(May 2002 to September 2006)

A. Publications and presentations directly arising from the work described in this thesis

Published articles

Chapter 2


Chapter 3

Ahuja KDK, Robertson IR, Geraghty DP and Ball MJ. The effect of 4-week chilli supplementation on metabolic and arterial function in humans. Eur J Clin Nutr advance online publication, August 23, 2006; doi:10.1038/sj.ejcn.16025172006.

Chapter 4


Chapter 5


Chapter 6


Abstract publications and Conference Presentations


Ahuja K, Ball M. Lycopene and olive oil combination: A step towards reducing CHD risk? Health & Medical Research Week. Launceston General Hospital, Launceston, 2003.


Geraghty D, Ahuja K, Fassett R, Ball M. Effect of regular chilli consumption on endothelium-dependent and -independent vasodilation. Joint meeting of Australasian

Ahuja K, Robertson I, Williams A, Geraghty D, Ball M. Effect of meals containing chilli on glucose metabolism and energy expenditure. Heart Foundation Conference and Scientific meeting. Sydney, Australia, 2006.

B. Articles and presentations related to but not directly arising from this thesis

Published articles


Ahuja KD, Ashton EL, Ball MJ. Effects of a high monounsaturated fat, tomato-rich diet on serum levels of lycopene. Eur J Clin Nutr 2003;57:832-841.

Abstract publications and conference presentations


Davies AN, Ahuja K, Ball M. Chilli diet may affect sleep quality and daytime activity. 18th Annual Scientific meeting of the Australasian Sleep Association. Gold Coast, Queensland, Australia, 2005 (abstract published in Internal Medicine Journal 2006; 36: A38).

Abstract

Diet influences the coronary heart disease (CHD) risk factors including lipids and lipoproteins, glucose, insulin, and endothelial function. This research thesis examined the effects of the three different (tomato-olive oil combination and chilli) but widely consumed dietary components, on a range of metabolic and vascular parameters of CHD risk.

The aims of this thesis were to investigate the effects of:

- a lycopene (tomato)-rich high monounsaturated fat (light olive oil) diet and a lycopene-rich high carbohydrate diet (each diet of 10 days duration) on serum lycopene, lipid profile and serum oxidation in 21 men and women aged between 22 and 70 years with a BMI of 18 – 30kg/m².

- a chilli blend (30g/day) supplemented diet and a bland (chilli free) diet (each diet of four week duration) on a range of metabolic and vascular parameters in 36 men and women aged between 22 and 70 years with a BMI of 18 – 35kg/m². The measured parameters included serum lipids and lipoproteins, lipid oxidation, glucose, insulin, basal metabolic rate (BMR), heart rate (HR), peripheral and aortic blood pressure, augmentation index (AIx; a measure of arterial stiffness) and subendocardial viability ratio (SEVR; an indicator of myocardial perfusion).

- single meals containing chilli blend (30g) with or without the background of a chilli-containing diet on a range of postprandial metabolic and vascular parameters (n = 36).

- a chilli blend supplemented diet (of three weeks duration) on endothelial-independent and -dependent vasodilation (assessed after administration of glyceryl trinitrate (GTN) and salbutamol, respectively) compared to the effects of a bland diet (n = 15).

- the active ingredient of spices (in different concentrations) including chilli (capsaicin and its analogue dihydrocapsaicin), turmeric (curcumin), piprine (black pepper)
pepper) and the colour pigment of tomatoes (lycopene) on the in vitro copper-induced 
oxidation of serum lipids.

The dietary intervention studies were conducted using a randomized crossover design on 
a weight maintenance regime. Two different groups of people volunteered to take part in 
the tomato-olive oil and the chilli studies. All participants from the four week chilli study 
also took part in the meal studies.

Ten days of a high lycopene monounsaturated fat rich and high lycopene carbohydrate 
rich diets presented similar increase in serum lycopene concentration and a similar 
reduction in serum total and LDL cholesterol.

The AIx after three weeks of regular chilli consumption was lower on the chilli diet 
compared to the bland diet, but there was no significant difference in the overall effects 
of GTN and salbutamol on endothelium-independent and -dependent vasodilation 
between the two diets. Four weeks of iso-energetic weight maintenance chilli and bland 
diets produced no significant differences in serum lipids, glucose, insulin, peripheral and 
central blood pressure, AIx, SEVR or BMR. HR was lower after four weeks of chilli-
supplemented diet in men, but not in women. Serum collected after the chilli-
supplemented diet exhibited a lower rate of copper-induced oxidation compared to the 
serum after the bland diet. Women, but not men, also showed a longer lag phase after the 
chilli-supplemented diet compared to the bland diet. This was probably due to the higher 
chilli/capsaicin and dihydrocapsaicin intake (per kg body weight) in women. In vitro 
studies with capsaicin, dihydrocapsaicin (and curcumin) also exhibited a concentration 
effect for the resistance to copper-induced serum lipid oxidation.

Results of the meal tests were surprising and exciting. The CAB meal (chilli-containing 
meal after the bland diet, eaten on day 29 of the bland diet) and the CAC meal (chilli-
containing meal after the chilli diet, eaten on day 29 of the chilli diet) showed a lower
maximum increase in postprandial serum insulin and overall postprandial serum insulin response compared to the BAB meal (bland meal after the bland diet, eaten on day 22 of the bland diet). The probable reason for this ameliorated insulin profile was a small reduction in insulin secretion and a large increase in the hepatic insulin clearance. The correlation between insulin and SEVR indicated an increase in the myocardial perfusion after the CAC meal compared to the BAB meal. All these results were more pronounced after the CAC meal and in people with BMI \( \geq 26 \text{kg/m}^2 \). Contrary to popular belief and some previously published data, we did not observe a significantly higher energy expenditure (EE) after the CAB meal or the CAC meal compared to the BAB meal. In fact, a lower EE was observed in people with increased BMI on the CAC meal compared to the BAB meal. This effect was possibly the consequence of improved postprandial insulin profile and reduced sympathetic nervous system activity after the CAC meal.

The results from these investigations may have significance in improving serum lycopene concentrations, lipid profile (tomatoes and olive oil), postprandial insulin response (chilli) and increased resistance of serum to copper induced oxidation (chilli) and hence decreasing the risk of CHD, especially in people with increased BMI for whom the risk of cardiovascular morbidity and mortality is higher than in lean individuals. Together, the results from these studies not only advance our knowledge relating to the relationship between some foods and the CHD risk factors but provide an opportunity to combine olive oil, tomatoes and chillies with other foods and spices (as often used in curries) in an attempt to further investigate foods and cuisines that will minimise the various risk factors for CHD.