Induced changes in the consumption of coffee alter *ad libitum* dietary intake and physical activity level

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Dietary trials with subjects on a freely selected diet may be affected by unwanted behavioural changes. Few studies, if any, have examined changes in coffee consumption and possible concomitant changes in diet and health-related habits. The aim of the present study was to examine whether induced changes in coffee consumption lead to changes in food habits and leisure-time physical activity. Healthy, non-smoking coffee-drinkers (*n* 214) were asked to change their coffee habits in a controlled clinical trial on the metabolic effects of coffee. The participants were asked to maintain their usual dietary habits. Self-perceived changes in diet and physical activity during the 6-week intervention period were assessed at the end. In the analyses, the participants were rearranged into groups reflecting the difference in coffee intake during the trial as compared with habitual intake. Associations with changes in food intake or physical activity were analysed by Spearman rank correlation. Changes in intake of 'chocolate, sweets' (*r* 0·179, $P<0·05$), 'cakes, sweet biscuits, pastry' (*r* 0·306, $P<0·001$), and 'jam' (*r* 0·198, $P<0·05$) showed positive associations with change in coffee intake during the trial. Negative associations were found for 'dishes with fish' (*r* −0·204, $P<0·01$) and many of the drinks as well as with physical activity (*r* −0·164, $P<0·05$). Induced changes in coffee intake seem to alter *ad libitum* intake of several foods. The recognized associations between health behaviours may have physiological explanations.

Coffee: Diet: Food preferences: Physical activity

Dietary trials with subjects on a freely selected diet frequently create interpretation problems due to the need for a rather constant intake of energy and fluid. Any induced change in the sources of these two variables is likely to be compensated for by changes in other sources. If these changes are systematic, they must be accounted for, unless the replacements are inert with regard to the outcome variables. This problem is highly relevant in studies on the metabolic effects of coffee. Several cross-sectional studies describe a more atherogenic diet among high consumers of coffee compared with coffee abstainers (Haffner *et al.* 1985; Jacobsen & Thelle 1987; Solvoll *et al.* 1989; Puccio *et al.* 1990). Other factors such as smoking and physical inactivity often accompany this picture. These findings can either be due to high coffee consumers being generally uninterested in or unaware of a healthy lifestyle, or that consumption of coffee, through an unknown mechanism, can alter preference, appetite or craving for particular food groups. Only the second explanation is likely to be relevant when assessing the results from a controlled clinical trial.

While the metabolic effects of coffee have been given quite extensive attention, we are not aware of any studies examining changes in coffee consumption and possible concomitant changes in dietary habits in a trial setting. The results from the present study emerge from a randomized clinical trial where the objective was to examine the effect of coffee on the level of homocysteine in plasma and total cholesterol in serum of free-living subjects (Christensen *et al.* 2001). This gave us the opportunity to assess whether

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induced changes in coffee consumption among regular coffee drinkers altered the participants' consumption of selected foods. The food categories were sorted in two rough groups containing foods considered to give either an atherogenic or a non-atherogenic diet when eaten in significant quantities. Based on the previous cross-sectional studies reporting associations between coffee intake and particular food groups, we expected positive associations between changes in coffee intake and atherogenic food categories, and negative associations with non-atherogenic categories. Our hypothesis was that increased or decreased consumption of coffee would lead to systematic changes in food habits during a 6-week intervention period. The initial food habits in different strata of habitual coffee consumption and the changes in leisure-time physical activity during the trial are also described.

Subjects and methods

The study was organized as a prospective, unblinded controlled trial with three different groups that were to consume either no coffee, one to three cups of coffee per d, or four or more cups of coffee per d for 6 consecutive weeks. Design and sample size were chosen based on the expected changes in homocysteine between the groups (Christensen *et al.* 2001).

The participants were recruited through advertisements in the largest newspaper in Oslo, Norway. Inclusion criteria were: age range 30–69 years, a history of daily consumption of coffee for at least 5 years, and no daily tobacco smoking for the past 6 months. Exclusion criteria were clinically recognized chronic diseases such as cardiovascular diseases, cancer, renal disorders, liver disease or diabetes mellitus, the use of anti-epileptic or cholesterol-lowering drugs, and recognized vitamin deficiency in the past. After recruitment, the participants were randomly allocated to one of the three groups for a 6-week period. The coffee-consuming groups were permitted to drink the type of coffee that they were accustomed to. Altogether, 97 % of the participants reported that they were regular consumers of caffeinated filtered coffee. Participants were asked to stick to their usual diet and lifestyle. Height and weight were recorded at the beginning and the end of the trial. The first participants entered the trial in April 1999 and the last finished late in June 1999.

At the start of the intervention period, the participants were asked to fill in a Norwegian semi-quantitative food-frequency questionnaire. This food-frequency question-naire, which includes approximately 180 questions about 149 food categories, was designed to cover the whole diet. It has previously been validated against 14 d weighed records (Nes *et al.* 1992; Andersen *et al.* 1996, 1999), very-long-chain *n*-3 fatty acids in plasma phospholipids (Andersen *et al.* 1996, 1999) and α-tocopherol in adipose tissue and serum (Andersen *et al.* 1996). These studies showed that the questionnaire could be used for assessing group intakes of energy and a wide range of nutrients. The daily intake of energy and nutrients was computed by using a food database and software system developed at the Institute of Nutrition Research, University of Oslo. The food database is mainly based on the official Norwegian food composition tables.

During the final medical examination, information was gathered on behavioural changes that might affect the outcome of the main study, including changes in diet and physical activity. The participants completed a second questionnaire regarding their self-perceived changes in intake of twelve food categories and seven categories of drinks, described as 'increased intake', 'unchanged intake' or 'decreased intake', and changes in physical activity pattern during the intervention period. They also reported compliance with the intervention and side effects.

For the present study, the participants were rearranged into four groups to reflect the direction of changes in coffee intake rather than the absolute coffee intake level. Changes in coffee consumption were recorded as the difference between the habitual intake (average number of cups per d) and the coffee consumption during the trial. All the participants allocated to the coffee-abstention group were kept together in one group. The remaining participants were divided into three groups reflecting whether they had decreased their coffee intake to a lower level during the intervention, had unchanged coffee intake (± 0.5 cup per d), or increased coffee intake. The groups were ordered on an ordinal scale from 1 to 4 (1, abstainers; 2, decreased intake; 3, unchanged intake; 4, increased intake). The self-perceived changes in intake were coded along an ordinal scale (1, decreased intake; 2, unchanged intake; 3, increased intake). At baseline, the average intake of coffee was higher among the men than the women. To avoid different proportions of men and women in the baseline strata, the material was split by gender before analysing the diet in relation to habitual coffee consump-tion. Trends in dietary composition according to strata of habitual coffee consumption were analysed by multiple linear regression. Some of the variables were not normally distributed and were therefore ln-transformed before the analyses. The final outcome did not differ when compared to the same analyses on the original variables.

Difference in habitual coffee intake and age in the coffee change groups were tested with analyses of variance. The Pearson χ^2 test was used for comparing the proportion of each gender and the changes in physical activity in the groups. The associations between changes in coffee intake and food intake were analysed with Spearman rank correlation (ordinal by ordinal). Statistical significance was considered at P values <0.05. The statistical package SPSS (SPSS for Windows, 1997; SPSS Inc., Chicago, IL, USA) was used for all the analyses.

Results

Two of the 214 healthy persons recruited did not turn up to the appointed visits and four decided to withdraw during the trial. Of the remaining 208 persons, ninety-five men and 111 women completed the food-frequency question-naire and ninety-five men and 110 women completed the questionnaire regarding self-perceived changes in food intake. Mean age was 53·7 (SD 11·3) years for the men and 50·1 (SD 11·3) years for the women.

The intakes of energy and some selected nutrients in

Table 1. Intakes of energy and selected nutrients at baseline in four quartiles of habitual coffee consumption among men*

(Mean values and standard deviations)

| | All men (n 95) | | 1 (n 28) | | 2 (n 16) | | 3 (n 30) | | 4 (n 21) | | | |
			Quartiles of coffee intake									
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P†	P‡
Coffee intake (cups per d)	5·3	2·6	2·7	0·5	4·0	0·2	6·0	0·7	9·2	1·9	–	–
Energy intake (MJ/d)	10·2	3·0	9·4	2·9	10·1	2·4	10·0	2·6	11·9	3·8	0·01	0·01
Energy distribution (% energy)												
Fat	30·6	5·5	28·6	5·1	30·0	5·3	31·6	5·6	32·3	5·3	0·01	0·01
Protein	15·8	2·0	16·3	2·5	15·4	1·7	15·7	1·9	15·5	1·9	0·24	0·25
Carbohydrate	49·9	6·1	51·2	6·1	50·0	5·8	49·0	5·5	49·5	7·2	0·23	0·21
Alcohol	3·7	4·3	3·9	4·5	4·6	5·5	3·7	4·6	2·6	2·4	0·28	0·28
Nutrient intake												
β-Carotene (μg/d per 10 MJ)	4610	3630	4940	4080	4730	4910	4420	2510	4380	3450	0·70§	0·70§
Vitamin C (mg/d per 10 MJ)	151	72	188	89	127	35	139	70	139	57	0·03§	0·03§
Fibre (g/d per 10 MJ)	26·1	6·5	27·7	7·5	25·3	6·4	25·2	6·5	26·1	5·3	0·37§	0·39§

* For details of subjects and procedures, see p. 262.
† Test for trend.
‡ Test for trend, adjusted for age.
§ Analyses were based on ln-transformed data.

Table 2. Intakes of energy and selected nutrients at baseline in four quartiles of habitual coffee consumption among women*

(Mean values and standard deviations)

| | All women (n 111) | | 1 (n 29) | | 2 (n 29) | | 3 (n 20) | | 4 (n 33) | | | |
			Quartiles of coffee intake									
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	P†	P‡
Coffee intake (cups per d)	4·5	2·4	2·1	0·5	3·3	0·4	5·1	0·4	7·2	2·1	–	–
Energy intake (MJ/d)	8·0	2·3	8·2	2·0	7·7	2·1	7·8	2·2	8·4	2·6	0·60	0·54
Energy distribution (% energy)												
Fat	30·6	4·7	30·2	5·3	31·1	3·8	30·8	5·5	30·5	4·6	0·88	0·85
Protein	15·8	2·0	15·8	2·0	15·6	1·9	16·3	2·7	15·6	1·7	0·96	0·88
Carbohydrate	51·4	4·7	51·8	5·5	51·2	3·1	50·4	6·3	51·7	4·2	0·84	0·86
Alcohol	2·2	1·9	2·2	2·0	2·1	1·5	2·4	2·6	2·2	1·9	0·92	0·96
Nutrient intake												
β-Carotene (μg/d per 10 MJ)	6050	3860	7710	4790	5160	3330	5240	3110	5870	3490	0·27§	0·22§
Vitamin C (mg/d per 10 MJ)	199	125	236	131	182	129	173	70	199	140	0·27§	0·22§
Fibre (g/d per 10 MJ)	28·3	7·1	30·4	7·3	26·6	6·0	27·1	7·1	28·7	7·7	0·51§	0·38§

* For details of subjects and procedures, see p. 262.
† Test for trend.
‡ Test for trend, adjusted for age.
§ Analyses were based on ln-transformed data.

Table 5. Distribution of self-evaluated changes in intake of 'chocolate, sweets', 'cakes, sweet biscuits, pastry', 'jam', 'dishes with fish', and 'tea' in the four participant groups*

	Abstainers (*n* 69)	Decreased (*n* 45)	Unchanged (*n* 51)	Increased (*n* 40)
Chocolate, sweets:				
Decreased intake (%)	17·6	20·5	8·2	2·5
Unchanged intake (%)	67·6	72·7	85·7	67·5
Increased intake (%)	14·7	6·8	6·1	30·0
All (%)	100·0	100·0	100·0	100·0
Cakes, sweet biscuits, pastry:				
Decreased intake (%)	16·4	8·9	2·0	5·1
Unchanged intake (%)	79·1	84·4	89·8	61·5
Increased intake (%)	4·5	6·7	8·2	33·3
All (%)	100·0	100·0	100·0	100·0
Jam:				
Decreased intake (%)	8·8	4·4	6·1	7·5
Unchanged intake (%)	88·2	91·1	91·8	67·5
Increased intake (%)	2·9	4·4	2·0	25·0
All (%)	100·0	100·0	100·0	100·0
Dishes with fish:				
Decreased intake (%)	1·4	2·2	8·2	7·5
Unchanged intake (%)	85·5	91·1	91·8	87·5
Increased intake (%)	13·0	6·7	0·0	5·0
All (%)	100·0	100·0	100·0	100·0
Tea:				
Decreased intake (%)	2·9	2·2	10·2	30·0
Unchanged intake (%)	29·0	51·1	87·8	67·5
Increased intake (%)	68·1	46·7	2·0	2·5
All (%)	100·0	100·0	100·0	100·0

* For details of subjects and procedures, see p. 262.

biscuits and pastry' showed a positive association with change in coffee intake for both genders together. When the results were analysed for men only, the associations were even stronger, while the association with 'chocolate and sweets' was insignificant for the women. In addition, 'jam' had a positive relation with change in coffee intake, but was not significant in analyses of each gender separately.

Only the category 'dishes with fish' showed a significant negative association with change in coffee intake for the sample as a whole, but 'salad, raw vegetables' was negatively associated with coffee intake changes in the separate analyses of women. The other food categories did not show any significant associations with change in coffee intake.

Changes in the intake of tea, and to a lesser extent water, juice and soft drinks were significantly and inversely related to change in coffee intake. The inverse association between the change in coffee consumption and both water and soft drinks were significant among women, but not the men. For milk, an inverse association was found only among the men.

The use of Spearman rank correlation to examine the associations between change in coffee intake and change in diet gives little insight in the overall distribution of answers. Thus, crude cross-tables for the four significant dietary associations and tea, the most important substitute of liquid, are presented in Table 5.

Table 6 describes self-reported physical activity pattern during the intervention period compared with the participants' normal schedule. There was a significant negative association between change in coffee intake and change in physical activity level during the trial. Among the coffee abstainers, 14·5 % reported that they had been more active than usual during the trial compared with none among those with increased coffee intake. In contrast, 10 % of those with increased coffee intake had been less active, compared with 2·9 % among the abstainers. We did not see any systematic changes in body weight between the groups (results not shown).

Discussion

Despite the fact that the participants in this trial were asked to stick to their habitual diet, a high proportion admitted to

Table 6. Self-reported physical activity pattern during the intervention compared with the participants' normal schedule*†

	All (*n* 205)	Abstainers (*n* 69)	Decreased (*n* 45)	Unchanged (*n* 51)	Increased (*n* 40)
Less active (%)	6·3	2·9	6·7	7·8	10·0
As normal (%)	82·0	82·6	80·0	78·4	90·0
More active (%)	11·2	14·5	13·3	13·7	0·0
All (%)	100·0	100·0	100·0	100·0	100·0

* For details of subjects and procedures, see p. 262.
† Spearman rank correlation (ordinal by ordinal): r −0·164, $P<0.05$.

having changed their diet during the intervention period. The participants did not only report compensations in fluid intake, but also changes in other food categories. These unwanted dietary changes went mainly in the directions expected from the cross-sectional studies with a more atherogenic diet among high coffee consumers. No significant associations were found in the opposite direction than expected.

As mentioned earlier, two main explanations may be offered if these associations are true: (1) a general lack of interest in a healthy lifestyle in high coffee consumers; or (2) coffee intake can alter food preferences through an unknown mechanism. In a controlled trial, the first explanation should be neutralized. The reported changes may also reflect methodologically induced bias, but we find it unlikely that allocation to a particular group would influence the response pattern. With the multiple statistical testing in the present study some spurious significant results can be expected, but since the results point in the same direction as cross-sectional findings we believe that several of these are true associations. We are therefore left with a number of systematic dietary changes that are unexplained.

As the main objective of the present trial was to study the effect of coffee on metabolic variables, the importance of maintaining a constant diet and lifestyle was stressed. Thus, the dietary changes reported here may possibly underestimate the effect of coffee on dietary habits, as participants are prone to answer according to the instructions.

It therefore appears that changes in coffee intake modify our food habits. To what extent this reflects a physiological phenomenon or cultural conventions about foods that go together with coffee cannot be answered by the present study. In favour of a physiological explanation is the tendency that smoking and physical inactivity also accompany this picture (Jacobsen & Thelle, 1987; Solvoll *et al.* 1989; Puccio *et al.* 1990).

From a methodological point of view, the present study demonstrates the importance of monitoring behavioural changes in trials, particularly in unblinded trials with interventions affecting the daily way of living. Here, changes in one factor brought about other changes that could have consequences for the interpretation of the study outcome.

To our knowledge, modified food preferences associated with changes in coffee intake have never been described before. The mechanisms behind the associations between health-related behaviours should be elucidated further. They may be chains in behaviour, with either positive or negative health effects, where one behavioural change brings about another. This is a very complex relation to study, but may have implications for strategies in nutrition promotion and preventive medicine.

Conclusions

Induced changes in coffee intake seem to alter *ad libitum* intake of several foods. The recognized associations between health behaviours, here demonstrated for coffee intake, diet and physical activity, may have physiological explanations.

Acknowledgements

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