Effect of nutritional intervention on the prevalence of metabolic syndrome and heart disease risk factors in urban Tehran (Tehran Lipid and Glucose Study)

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ABSTRACT In a case–control study a nutritional intervention consisting of an educational programme based on the Therapeutic Lifestyle Change diet (TLC) guidelines was implemented in one area of Tehran. Data were collected from subjects in the intervention area (n = 133) and controls from another area (n = 183), before and 3.8 years after the intervention. Mean energy and macronutrient intakes and prevalence of risk factors including metabolic syndrome were compared between and within cases and controls. Baseline and follow-up evaluations showed improvement in hypercholesterolemia and high LDL cholesterol levels in cases versus controls. Central obesity and low HDL cholesterol levels increased significantly in controls but not in cases. As there were no significant differences between the 2 groups in energy and macronutrient intakes, it is difficult to claim that nutritional interventions played an important role.

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Introduction

Although significant reductions have occurred in the incidence of cardiovascular disease (CVD) since the mid-1970s, this is still the primary cause of morbidity and mortality in many countries [1]. Recent studies in the Islamic Republic of Iran have shown an increasing mortality from CVD, and have found it to be a major health problem which imposes a high burden of disease on the health system [2–5]. It has been shown that hypertension, hyperlipidaemia, impaired glucose tolerance and diabetes, smoking, and stress are powerful risk factors for CVD.

Previous studies in the Tehran Lipid and Glucose study (TLGS) population showed 22% of men and 24% of women were hypertensive; 23% of the total population were hypercholesterolaemic and 4% were hypertriglyceridaemic [6]. Most of these risk factors are linked to lifestyle, in conjunction with excess environmental factors, including diet, play a significant role in the development of noncommunicable diseases [11,17]. The present data indicates a shortage of appropriate intervention programmes in the Islamic Republic of Iran [18], and hence this study was conducted to investigate the effectiveness of a nutritional intervention on the prevalence of metabolic syndrome and other CVD risk factors among adults in Tehran.

Methods

The current study was conducted within the framework of the TLGS, a prospective study of a representative sample of residents of district 13 of Tehran, performed to ascertain the prevalence of noncommunicable disease risk factors and developing a healthy lifestyle to curtail these risk factors [18].

Subjects

Residents in district 13 are covered by 3 health care centres. For the TLGS, 15 005 people ≥ 3 years were selected by a multistage cluster, random sampling method. For the case–control study reported here, nutritional interventions were implemented for the population covered by one of the health care centres. The remaining populations in the areas covered by the other 2 centres had no nutritional interventions and served as controls. The area of the intervention group was far from the areas where the control subjects lived. Interactions involving schooling, shopping and gatherings were estimated to be < 5% between the intervention and control groups.

The first dietary assessment was done during 1999 to 2002 and the second during 2002 to 2003. For the first assessment a representative sample of 1474 people aged ≥ 3 years was randomly selected from the 3 areas. After 3.9 years, biochemical, anthropometric and dietary assessments were done in all these subjects. Pregnant women and subjects who had used hypoglycaemic agents, lipid-lowering and anti-hypertensive prescription medications were excluded from the study. Subjects > 20 years old with relevant data were included in the study. Finally, 316 subjects remained and were divided into 2 groups according to area of residence (133 cases and 183 controls).

All subjects signed voluntary consent forms. The protocol for the study was approved by the research council of the Endocrine Research Centre of Shahid Beheshti University of Medical Sciences.

Nutritional intervention

The nutritional intervention consisted of an educational programme according to the Therapeutic Lifestyle Change diet (TLC) guidelines which were developed by the US National Heart, Lung, and Blood Institute for the National Cholesterol Education Program [19]. The TLC diet is a low saturated fat (< 7% of total caloric intake) and low cholesterol (< 200 mg of dietary cholesterol a day) diet that emphasizes grains, cereals, legumes, vegetables, fruits, lean meats, poultry, fish and non-fat dairy products. According to the TLC, 25%–35% of the day’s total calories should be from fat, and persons who are overweight or obese with dyslipidaemia should reduce their body weight through a combination of physical activity, total calorie reduction and behaviour therapy modifications.

This programme was introduced for all individuals aged 3+ years in health care centres, schools and public places in intervention areas. At health care centres, family members were invited in turn to the centre, and were educated with a face-to-face approach between the educators and the participants. In schools, the intervention was conducted through direct education by trained teachers, parent–teacher cooperation societies and group-based activities such as fairs and competitions. Foods provided by school buffets or canteens were changed according to nutritional guidelines. Pamphlets and posters with...
related information were mailed every 2–4 months to family members, and lectures and discussion sessions were arranged in public places.

**Data collection**

The study population was interviewed privately, face-to-face. Trained interviewers using pretested questionnaires conducted interviews and all variables were assessed at baseline and at follow-up in both groups after 3.8 years.

**Assessment of dietary intake**

Dietary intake assessment was undertaken by 2-day 24-hour recall, administered to the subjects by expert interviewers who had experience in the Nationwide Food Consumption Survey project [20]. The first day recall was performed at subject’s homes and the second day recall at a clinic visit in the dietary unit of TLGS within 1–3 days of the first visit. These 2 days aimed to be among typical eating days for subjects. Standard reference tables were used to convert household portions to grammes for computerization [21]. Following coding of diaries, the dietary recall form was linked to the Nutritionist III foods nutrient database, version 7.0 designed for Iranians (N-Squared Computing) and daily intakes of carbohydrates, proteins and fats for each individual were determined from the means of the 2 × 24-hour dietary recalls.

**Assessment of other variables**

Blood pressure was measured using a standard mercury sphygmomanometer. Participants were made to rest for 15 min before their blood pressure was measured. A qualified physician measured the blood pressure of the seated subject twice; the mean of the 2 measurements was considered as the participant’s blood pressure.

Weight was measured while the subjects were minimally clothed without shoes using digital scales and recorded to the nearest 100 g. Height was measured in a standing position, without shoes using a tape measure while the shoulders were in a normal position. Waist circumference was measured at the narrowest level [22]. Body mass index (BMI) was calculated as weight divided by height squared (kg/m²).

Additional covariate information regarding age, sex, education, marital status and job was obtained using validated questionnaires.

A blood sample was drawn into vacutainer tubes from all subjects between 07:00 and 09:00 hours after 12–14 hours overnight fasting [23]. The samples were centrifuged 30–45 min after collection. All blood lipid analyses were done at the TLGS research laboratory on the day of blood collection. The analysis of samples was performed using the Selectra 2 autoanalyser (Vital Scientific). Fasting plasma glucose was measured on the day of blood collection by the enzymatic colorimetric method using glucose oxidase. Serum total cholesterol and triglyceride concentration were measured by commercially available enzymatic reagents (Pars Azmoon) adapted to the Selectra autoanalyser. High-density lipoprotein (HDL) cholesterol was measured after precipitation of the apolipoprotein B-containing lipoproteins with phosphotungstic acid. Low-density lipoprotein (LDL) cholesterol was calculated according to the method of Friedewald [24]. It was not calculated when the serum concentration of triacylglycerol was > 400 mg/dL. All samples were analysed when internal quality control met the acceptable criteria. Inter-assay and intra-assay coefficients of variation were 2.0% and 0.5% for total cholesterol and 1.6% and 0.6% for triacylglycerol respectively.

**Definition of terms**

The following definitions were used: obesity was BMI ≥ 30 kg/m² [25]; hypercholesterolaemia was total cholesterol ≥ 240 mg/dL; high LDL cholesterol was ≥ 160 mg/dL [26]; diabetes was fasting plasma glucose concentration ≥ 126 mg/dL or 2-h postchallenge glucose concentration of ≥ 200 mg/dL [27]; and hypertension was systolic blood pressure ≥ 140 mmHg or diastolic blood pressure ≥ 90 mm Hg or current use of antihypertensive medication [28]. Diagnosis of metabolic syndrome as recommended by the Adult Treatment Panel (ATP) III criteria was based on having at least 3 of the following 5 components: (1) waist circumference > 102 cm in men and > 88 cm in women; (2) serum HDL cholesterol < 40 mg/dL in men and < 50 mg/dL in women; (3) serum triacylglycerol concentrations > 150 mg/dL; (4) blood pressure > 130/85 mmHg; and (5) fasting plasma glucose concentration > 110 mg/dL [26].

**Statistical methods**

All data were analysed using SPSS, version 9.05. Mean energy and macronutrient intakes were measured and compared within the 2 groups using the paired t-test. Analysis of covariance (ANCOVA) was used to compare the means between the 2 groups after controlling for age, sex and baseline variables. The chi-squared test was performed to compare the prevalence of risk factors and metabolic syndrome between the 2 groups after interventions. Mantel–Haenszel test was used to compare the prevalence of risk factors and metabolic syndrome between the 2 groups after controlling for age, sex and baseline variables. McNemar test was used to assess the change of risk factors status and metabolic syndrome, pre- and post-intervention.

**Results**

The mean age was 42.1 (standard deviation (SD) 11.9) years in controls (73 men and 110 women), and 40.6 (SD 10.7) years in cases (61 men and 72 women).

The mean values for macronutrient intakes of the 2 groups are shown in Table 1. The reported mean daily intakes of energy, carbohydrate and fat decreased significantly, whereas cholesterol and
protein as percentages of total energy increased significantly in both groups. Mean protein intake increased and fat as percentage of total energy decreased significantly in controls. After adjusting for age, sex and baseline variables, no significant differences regarding macronutrients and energy intake were observed between the case and control groups.

The prevalence of the risk factors and metabolic syndrome at baseline and follow-up in the 2 groups are shown in Table 2. The prevalence of low HDL cholesterol increased significantly in controls (from 39.9% to 60.4%) between baseline and follow-up measurements whereas in cases the increase was not significant (from 49.2% to 57.6%) (P < 0.01). Abdominal obesity also increased significantly in controls (from 26.2% to 38.3%) while in cases the increase was not significant (from 30.1% to 37.6%) (P < 0.01). The prevalence of high LDL cholesterol did not change in controls over the period (19.2% versus 18.9% respectively) whereas in the cases exposed to the educational intervention it decreased significantly from 21.7% to 9.5% (P < 0.05). After adjusting for age, sex and baseline variables, the same results were obtained (P < 0.05). The decrease in the rate of hypercholesterolemia was small in the controls (from 18.6% to 13.2%) but was significant in the cases (from 18.3% to 8.3%) (P < 0.01). There were no significant differences between the 2 groups regarding the prevalence of metabolic syndrome at baseline and follow-up in controls (24.6% versus 30.2% respectively) and cases (28.7% versus 29.8% respectively).

The distribution of subjects with regard to changes in risk factor status and metabolic syndrome at baseline and follow-up is shown in Table 3. In controls, 45.0% of subjects (49/109) who had normal HDL cholesterol at baseline had low HDL cholesterol at follow-up; whereas 16.4% (12/73) of subjects had low HDL cholesterol at baseline showed normal levels in the follow-up assessment. These changes were significant (P < 0.01). Also 20.7% of controls (28/135) who did not have abdominal obesity at baseline developed abdominal obesity at follow-up, whereas 12.5% (6/48) of cases who had low HDL cholesterol at baseline showed normal levels in the follow-up assessment. In the cases, 1.9% (2/106) of subjects who had normal cholesterol at baseline developed hypercholesterolaemia after the intervention, whereas 62.5% (15/24) of those with hypercholesterolaemia at baseline showed normal cholesterol at follow-up (P < 0.01). Moreover, 3.3% (3/90) of cases who had normal LDL cholesterol at baseline developed high LDL cholesterol in the follow-up measurement after the intervention; whereas 65.2% (15/23) of cases who had high LDL cholesterol at baseline, showed normal levels after the intervention (P < 0.01).

In controls 12.5% of individuals with normal triglycerides developed high hypertriglyceridaemic and 52.6% of hypertriglyceridaemic individuals returned to normal in the follow-up measurement, whereas in the cases 35.7% of hypertriglyceridaemic subjects became normal.

### Discussion

This study, conducted in an urban population of Tehran, showed that the prevalence of several risk factors for CVD improved between the baseline and the follow-up measurements 3.8 years later. The prevalence of high LDL cholesterol did not change in controls whereas in the cases exposed to the educational intervention it decreased significantly. The prevalence of low HDL cholesterol increased significantly in controls between baseline and follow-up measurements whereas in cases the increase was not significant. Abdominal obesity also increased in controls while in cases the increase was not significant. The decrease in the rate of hypercholesterolemia was small in the controls but significant in the cases.

### Table 1  Self-reported macronutrient intake at baseline and at follow-up for the control group (no intervention) and the case group (exposed to educational intervention)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Controls (n = 182) Mean (SD)</th>
<th>Follow-up Mean (SD)</th>
<th>Cases (n=133) Mean (SD)</th>
<th>Follow-up Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy (kcal/dl)</td>
<td>2327 (810)</td>
<td>2355 (673)</td>
<td>2452 (705)</td>
<td>2245 (664)</td>
</tr>
<tr>
<td>Carbohydrate (g/dl)</td>
<td>345 (117)</td>
<td>320 (99)</td>
<td>367 (110)</td>
<td>333 (106)</td>
</tr>
<tr>
<td>Protein (g/dl)</td>
<td>65 (24)</td>
<td>69 (27)</td>
<td>70 (22)</td>
<td>72 (32)</td>
</tr>
<tr>
<td>Fat (g/dl)</td>
<td>80 (40)</td>
<td>71 (32)</td>
<td>81 (33)</td>
<td>72 (29)</td>
</tr>
<tr>
<td>Carbohydrate (% of total energy)</td>
<td>59.1 (7.4)</td>
<td>58.8 (9.1)</td>
<td>59.3 (6.9)</td>
<td>59.1 (7.5)</td>
</tr>
<tr>
<td>Protein (% of total energy)</td>
<td>11.2 (2.1)</td>
<td>12.7 (3.4)</td>
<td>11.4 (1.7)</td>
<td>12.9 (4.7)</td>
</tr>
<tr>
<td>Fat (% of total energy)</td>
<td>29.8 (7.8)</td>
<td>28.1 (7.4)</td>
<td>29.2 (6.9)</td>
<td>28.3 (8.8)</td>
</tr>
<tr>
<td>Cholesterol (mg/dl)</td>
<td>130 (115)</td>
<td>219 (150)</td>
<td>164 (159)</td>
<td>199 (113)</td>
</tr>
</tbody>
</table>

*p < 0.01; **p < 0.05; *p < 0.001 comparing baseline and follow-up data using analysis of covariance test adjusted for age, sex and baseline of each variable.

SD = standard deviation.
Several studies have shown the prevalence of hypercholesterolaemia and hypertriglyceridaemia declined significantly after nutritional interventions, in both sexes and among different races [29–31]. In contrast, the National Healthy Lifestyle Programme in Singapore, implemented in 1992, was unsuccessful in reducing total blood cholesterol levels [32]. An intervention study in England that was part of a World Health Organization project was conducted on 18,210 workers in 24 factories. Subjects were followed for 5 years, and only 4% reduction in CVD risk factors was seen [33].

In the present study, despite significant decreases in energy, carbohydrate and fat intake between baseline and follow-up in both groups, the prevalence of low HDL cholesterol increased significantly only in controls. Other studies have shown that HDL cholesterol level is less affected by nutritional factors [34], and more affected by BMI, physical activity, smoking, alcohol and some hormones [35]. The significant increase in the prevalence of abdominal obesity in controls may be responsible for the change. On the other hand, the difference of the prevalence of low HDL cholesterol between the 2 groups may be due in part to differences in physical activity and other confounding factors. We did not measure physical activity data since the reliability and validity of the Lipid Research Clinic questionnaire that was used in the TLGS had not been evaluated in our country. The availability of valid data for this confounding variable could have helped to provide a better understanding of this difference of low HDL cholesterol between the 2 groups.

In this study, the prevalence of high LDL cholesterol and total cholesterol decreased significantly in the intervention group, despite significant increases in cholesterol intake and decreases in total fat in both groups. It has been shown that high cholesterol intake leads to higher LDL cholesterol levels [36], whereas some studies have found that the effect of saturated fatty acids on serum cholesterol is more important than dietary cholesterol [37]. Furthermore, it has been shown that age, obesity, physical activity, some diseases, poly- and monounsaturated fatty acids, the type of carbohydrate and some environmental factors affect serum cholesterol and triglyceride levels [38–41]. Further research assessing these factors will provide stronger evidence of this relationship.

Table 2

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Controls (n = 182)</th>
<th>Cases (n = 133)</th>
<th>P-value&lt;sup&gt;c&lt;/sup&gt; (cases vs controls)</th>
<th>P-value&lt;sup&gt;d&lt;/sup&gt; adjusted (cases vs controls)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Follow-up</td>
<td>P-value&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Baseline</td>
</tr>
<tr>
<td>Diabetes</td>
<td>5</td>
<td>2.7</td>
<td>4</td>
<td>3.1</td>
</tr>
<tr>
<td>Hypertriglyceridaemia</td>
<td>38</td>
<td>20.8</td>
<td>29</td>
<td>22.1</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>34</td>
<td>18.6</td>
<td>24</td>
<td>18.3</td>
</tr>
<tr>
<td>High LDL cholesterol</td>
<td>35</td>
<td>19.2</td>
<td>34</td>
<td>24</td>
</tr>
<tr>
<td>Low HDL cholesterol</td>
<td>73</td>
<td>39.9</td>
<td>64</td>
<td>49.2</td>
</tr>
<tr>
<td>Hypertension</td>
<td>20</td>
<td>10.9</td>
<td>20</td>
<td>15.4</td>
</tr>
<tr>
<td>Obesity</td>
<td>41</td>
<td>22.9</td>
<td>46</td>
<td>21.8</td>
</tr>
<tr>
<td>Abdominal obesity</td>
<td>48</td>
<td>26.2</td>
<td>40</td>
<td>30.1</td>
</tr>
<tr>
<td>Metabolic syndrome</td>
<td>45</td>
<td>24.6</td>
<td>37</td>
<td>28.7</td>
</tr>
</tbody>
</table>

* Using standard international criteria [24–27].
* Comparison between baseline and at follow-up using McNemar test.
* Comparison between case and control groups at follow-up using chi-squared test.
* Comparison between case and control groups at follow-up using Mantel–Haenszel, and after adjusting for baseline of each variable.
SD = standard deviation; LDL = low-density lipoprotein; HDL = high-density lipoprotein.
who were normal at baseline developed low HDL cholesterol, whereas fewer individuals with low HDL cholesterol at baseline became normal in the follow-up measurement. As mentioned before, this may be attributed to the increased prevalence of abdominal obesity in this group. More of the controls improved their hypertriglyceridaemic status from abnormal to normal than did cases. Although not significant, the changes are an interesting finding.

Despite decreased energy, carbohydrate and fat intakes in both groups, modulation of triglyceride status in controls was greater than in cases. This may be due to a significant decrease in the percentage of energy obtained from fat. As demonstrated in a recent study, decreases in the percentage of energy from fat intake could potentially decrease serum triglyceride levels [42]. Furthermore, limited saturated fat intake, modified carbohydrate intake, decreased alcohol drinking, stopping smoking and increased physical activity result in favourable lipid profiles [43,44].

Table 3 Changes in levels of risk factors and metabolic syndrome status at baseline and at follow-up for the control group (no intervention) and the case group (exposed to educational intervention)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Controls (n = 182)</th>
<th>Cases (n = 133)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deterioratedb)</td>
<td>Improvedd)</td>
</tr>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>5</td>
<td>2.8</td>
</tr>
<tr>
<td>Hypertriglyceridaemia</td>
<td>18</td>
<td>12.5</td>
</tr>
<tr>
<td>Hypercholesterolaemia</td>
<td>11</td>
<td>7.4</td>
</tr>
<tr>
<td>High LDL cholesterol</td>
<td>16</td>
<td>11.0</td>
</tr>
<tr>
<td>Low HDL cholesterol</td>
<td>49</td>
<td>45.0</td>
</tr>
<tr>
<td>Hypertension</td>
<td>10</td>
<td>6.3</td>
</tr>
<tr>
<td>Obesity</td>
<td>9</td>
<td>6.8</td>
</tr>
<tr>
<td>Abdominal obesity</td>
<td>28</td>
<td>20.7</td>
</tr>
<tr>
<td>Metabolic syndrome</td>
<td>25</td>
<td>18.5</td>
</tr>
</tbody>
</table>

aUsing standard international criteria [24–27].
bDeteriorated = number of subjects who were normal at baseline, abnormal at follow-up; % of abnormal/normal subjects. ceff, 60.0=number of subjects who were abnormal at baseline, normal at follow-up; % of normal/abnormal subjects.
cComparison between baseline and at follow-up using McNemar test.

The study was a community field trial and it was not possible educate all individuals about nutrition face-to-face. Some trials have shown that this approach is the most successful intervention programme in schools, health centres and work places [47–49]. The short duration of interventions in this study may also have been a factor, as recent studies have shown that lifestyle modifying specific dietary patterns [45].

We therefore believe that the physical activity of individuals in both controls and cases in our study may have been insufficient. As we did not measure physical activity level, it is difficult to confirm this theory.

There were some limitations to the current study. We did not find substantial differences in the measures of nutrient and energy intake between the 2 groups. This may be attributed to the 24-hour recall method used for data collection. Problems commonly associated with this method include: an inability to recall accurately the kinds and amounts of food eaten, difficulty in determining whether the day being recalled represents an individual’s typical intake and the tendency for persons to over-report low intakes and under-report high intakes of foods. Furthermore, the study was a community field trial and it was not possible educate all individuals about nutrition face-to-face. Some trials have shown that this approach is the most successful intervention programme in schools, health centres and work places [47–49]. The short duration of interventions in this study may also have been a factor, as recent studies have shown that lifestyle...
modification, especially dietary patterns, need longer-term interventions [50,51].

In summary, this study showed modulation of some CVD risk factors in cases exposed to an educational intervention compared with controls. As there was no significant difference between the 2 groups regarding energy and macronutrient intakes, it is hard to claim that nutritional interventions played an important role. Our data therefore raise the possibility that other lifestyle choices are important in the modulation of certain CVD risk factors.

**Acknowledgements**

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