Associations between apolipoprotein E genotypes and serum levels of glucose, cholesterol, and triglycerides in a cognitively normal aging Han Chinese population

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Purpose: To determine the associations between apolipoprotein E (APOE) genotypes and serum levels of glucose, total cholesterol, and triglycerides in a cognitively normal aging Han Chinese population.

Methods: There were 1,003 cognitively normal aging subjects included in this study. APOE genotypes were analyzed and biochemical parameters were tested. All the subjects were divided into three groups according to APOE genotypes: (1) E2/2 or E2/3 (APOE E2); (2) E3/3 (APOE E3); and (3) E2/4, E3/4, or E4/4 (APOE E4). Correlations of serum levels of glucose, total cholesterol, and triglycerides with APOE genotypes were assessed.

Results: E2, E3, and E4 allele frequencies were found to be 6.2%, 82.1%, and 11.7%, respectively. Serum levels of total cholesterol were higher in the APOE E4 group (P<0.05). A higher level of total cholesterol was associated with the E4 allele (adjusted odds ratio 1.689, 95% confidence interval 1.223–2.334, P<0.01). However, no association was found between APOE status and serum levels of glucose (adjusted odds ratio 0.981, 95% confidence interval 0.720–1.336, P=0.09). No correlation was found between APOE status and serum levels of triglycerides (adjusted odds ratio 1.042, 95% confidence interval 0.759–1.429, P=0.80).

Conclusion: A higher serum level of total cholesterol was significantly correlated with APOE E4 status in a cognitively normal, nondiabetic aging population. However, there was no correlation between APOE genotypes and serum levels of glucose or total triglycerides.

Keywords: Alzheimer’s disease, APOE, glucose level, cholesterol, triglycerides

Introduction
Apolipoprotein E (APOE), a major cholesterol carrier in the brain, has been proven to be associated with the pathology of Alzheimer’s disease (AD). APOE has three common alleles including E2, E3, and E4, encoding three protein isoforms. The E4 allele of APOE was consistently recognized as a risk factor for AD.1

APOE can alter cholesterol homeostasis, lipid transport, Aβ deposition, and clearance in an isoform-dependent manner.2-4 During the last few decades, studies performed in different populations have explored the associations between APOE genotypes and serum lipid metabolism; the studies have reached an agreement that the APOE E4 carrier is correlated with a higher serum of total cholesterol (TC) level as well as a low-density lipoprotein cholesterol level.5,6

In addition to its well-recognized roles mentioned above, recent studies have suggested that APOE might also be involved in glucose metabolism.7 Diabetes and perturbed glucose metabolism have been proven as risk factors for...
cognitive impairment. Dysregulation of cerebral glucose metabolism was also observed in both mild cognitive impairment and AD patients. Recently, one study reported that higher glucose levels may be a risk factor for dementia, and poor control of peripheral glucose levels resulted in worse cognitive function and accelerated the decline. Another study reported that higher serum glucose levels in cognitively normal, nondiabetic adults were associated with cerebral hypometabolism in vulnerable brain areas of AD patients and suggested that these effects might be independent of APOE E4 status. However, so far the correlations between APOE genotypes and serum glucose level have not been clearly identified.

Here, 1,003 cognitively normal, nondiabetic Han Chinese aging subjects were selected from a 2,149 aging population recruited from community epidemiologic investigations to explore the associations of APOE genotypes with the levels of serum glucose as well as TC and total triglycerides (TG). To the best of the authors’ knowledge, this is the first study on the associations between APOE genotypes with serum levels of glucose, TC, and TG in a cognitively normal Han Chinese aging population from mainland People’s Republic of China.

Methods and materials
Subjects
This study involved 1,003 cognitively normal aging subjects selected from a 2,149 aging population recruited from community epidemiologic investigations during 2011–2012. Written consents were obtained from subjects or their legally authorized caregivers. An interview about age, sex, year of education, medical history, and history of smoking and drinking was performed. Body mass index was calculated as weight divided by height squared (kg/m²). Mini-Mental State Examination and complete physical and neurologic examinations were also evaluated. As most of the subjects were illiterate, Mini-Mental State Examination score >18 was used as an inclusion criterion. All of the selected subjects denied memory or any other cognitive impairment. Additional exclusion criteria were diabetes mellitus, hepatic disease, hypothyroidism, and history of receiving drugs that affect serum glucose and lipids. Blood collections were performed according to the standard process. Briefly, the subject was positioned in a chair, placing the tourniquet 4 inches above the selected puncture site on the subject. A vein was selected and the area cleansed. The needle was then inserted through the skin into the lumen of the vein. Ethylenediaminetetraacetic acid-containing tubes were used for blood sample collection for the isolation of DNA; clot activating gel-containing serum separator tubes were used for blood sample collection for assessment of the biochemical parameters. This study was approved by the ethics committee of Huashan Hospital (Shanghai, People’s Republic of China).

Genotyping of APOE
For APOE genotype determinations, genomic DNA was extracted from peripheral blood using a Blood Genomic DNA Extraction Kit (Qiagen NV, Venlo, the Netherlands). The APOE genotypes were determined by multiplex amplification refractory mutation system polymerase chain reaction according to the method previously described.

Measurement and analysis serum levels of glucose, TC, and TG
Fasting serum glucose levels were assessed by hexokinase method on an autoanalyzer (Dimension® Xpand Plus; Siemens AG, Erlangen, Germany). Serum TC and TG levels were determined on the same autoanalyzer (Dimension Xpand Plus). According to the People’s Republic of China’s clinical laboratory criteria for lipid values, serum TC level >5.7 mmol/L, and TG level >1.8 mmol/L was defined as hypercholesterolemia and hypertriglyceridemia. For glucose, fasting venous blood glucose level >6.1 mmol/L was defined as hyperglycemia.

Statistical analysis
One-way analysis of variance was performed to assess the differences in the mean value of glucose, TC, and TG in the different groups. Categorical data such as gender, history of smoking, and history of alcohol drinking were evaluated by chi-square tests. Possible associations between APOE genotype and serum levels of glucose, TC, and TG were determined by logistic regression analyses. Serum levels of glucose, TC, and TG were used as dependent variables which were dichotomized according to the People’s Republic of China’s clinical laboratory criteria for hypercholesterolemia, hypertriglyceridemia, and hyperglycemia. Age, sex, body mass index, and history of smoking and alcohol drinking were used as covariates. All statistical analyses were performed using SPSS version 13.0 (SPSS Inc., Chicago, IL). P<0.05 was considered statistically significant.

Results
Characteristics of subjects with different APOE genotypes
The results of allele and genotype frequencies are shown in Table 1. The frequency of APOE E3 was greatest (82.1%),
and that of E2 and E4 was 6.2% and 11.7%, respectively, which is comparable with other studies performed in Asian populations. The characteristics of subjects with different APOE genotypes are shown in Table 2. Age, sex, Mini-Mental State Examination score, height, weight, body mass index, and history of smoking and drinking percentage did not differ among the different APOE status groups. Serum TC levels were found to be higher in the APOE E4 group (P=0.02). However, fasting blood glucose and TG levels showed no significant difference among the three groups.

**Table 1** Allele frequencies and prevalence of APOE genotypes in a cognitively normal aging Han Chinese population

<table>
<thead>
<tr>
<th>APOE</th>
<th>Male (n=431)</th>
<th>Female (n=572)</th>
<th>Combined (n=1,003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E2</td>
<td>46 (5.3%)</td>
<td>79 (6.9%)</td>
<td>125 (6.2%)</td>
</tr>
<tr>
<td>E3</td>
<td>710 (82.4%)</td>
<td>937 (81.9%)</td>
<td>1,647 (82.1%)</td>
</tr>
<tr>
<td>E4</td>
<td>106 (12.3%)</td>
<td>128 (11.2%)</td>
<td>234 (11.7%)</td>
</tr>
<tr>
<td>E2/E2</td>
<td>1 (0.2%)</td>
<td>8 (1.4%)</td>
<td>8 (0.9%)</td>
</tr>
<tr>
<td>E2/E3</td>
<td>28 (6.5%)</td>
<td>47 (8.2%)</td>
<td>75 (7.5%)</td>
</tr>
<tr>
<td>E2/E4</td>
<td>16 (3.7%)</td>
<td>16 (2.8%)</td>
<td>32 (3.2%)</td>
</tr>
<tr>
<td>E3/E3</td>
<td>302 (70.1%)</td>
<td>392 (68.6%)</td>
<td>695 (69.2%)</td>
</tr>
<tr>
<td>E3/E4</td>
<td>78 (18.1%)</td>
<td>106 (18.5%)</td>
<td>184 (18.3%)</td>
</tr>
<tr>
<td>E4/E4</td>
<td>6 (1.4%)</td>
<td>3 (0.5%)</td>
<td>9 (0.9%)</td>
</tr>
</tbody>
</table>

**Table 2** Characteristics of subjects with different APOE groups

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>APOE E2</th>
<th>APOE E3</th>
<th>APOE E4</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (%)</td>
<td>84 (8.4%)</td>
<td>694 (69.2%)</td>
<td>225 (22.4%)</td>
<td>NS</td>
</tr>
<tr>
<td>Age (range, years)</td>
<td>74.5±0.67 (66–92)</td>
<td>73.17±0.22 (64–94)</td>
<td>73.70±0.40 (65–90)</td>
<td>NS</td>
</tr>
<tr>
<td>Sex, male/female</td>
<td>29/55</td>
<td>302/392</td>
<td>100/125</td>
<td>NS</td>
</tr>
<tr>
<td>Height, cm</td>
<td>157.38±0.91</td>
<td>157.55±0.32</td>
<td>158.10±1.43</td>
<td>NS</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>57.49±1.29</td>
<td>58.75±0.44</td>
<td>57.68±0.76</td>
<td>NS</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>23.13±0.44</td>
<td>23.58±0.16</td>
<td>23.61±0.26</td>
<td>NS</td>
</tr>
<tr>
<td>Fasting blood glucose, mmol/L</td>
<td>5.18±0.12</td>
<td>5.27±0.04</td>
<td>5.30±0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>Serum triglycerides, mmol/L</td>
<td>1.53±0.15</td>
<td>1.52±0.03</td>
<td>1.54±0.07</td>
<td>NS</td>
</tr>
<tr>
<td>Total cholesterol, mmol/L</td>
<td>5.10±0.12</td>
<td>5.07±0.04</td>
<td>5.27±0.07</td>
<td>NS</td>
</tr>
<tr>
<td>Alcohol users (&gt;1 drink/week)</td>
<td>12 (14.3%)</td>
<td>117 (16.9%)</td>
<td>49 (21.8%)</td>
<td>NS</td>
</tr>
<tr>
<td>Cigarette smoking</td>
<td>12 (14.2%)</td>
<td>132 (19.0%)</td>
<td>50 (22.2%)</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Discussion**

In addition to the aberrant accumulation of Aβ plaques and neurofibrillary tangles, decreased cerebral glucose metabolism is also observed in vulnerable brain areas of AD patients. Abnormal metabolic change is considered as an early event in AD pathology and is supposed to be involved in other AD neuropathological changes. As a leading significant risk factor for late-onset AD, APOE has been documented to be not only linked with Aβ deposition, but also with decreased cerebral glucose metabolism in the brain. Recently, one study proposed a hypothesis that the abnormal glucose hypometabolism in the brain of an early-stage AD patient might result in lower APOE lipidation status and further lead to decreased clearance and increased deposition of Aβ. Another study using 18F-fluorodeoxyglucose positron emission tomography documented that higher serum glucose levels in cognitively normal, nondiabetic adults were associated with cerebral hypometabolism in vulnerable brain areas of AD patients. Furthermore, some researchers proposed that AD was a special form of diabetes that selectively involves the central nervous system. It is of particular interest to determine the association between AD and diabetes from the perspective of AD prevention and therapy. Both APOE and higher serum glucose levels have been considered to be implicated in AD and clearly identifying their relationships would help us to better understand the reciprocal effects of AD and diabetes. However, whether there is any correlation between APOE genotypes and serum glucose levels remains to be elucidated.

In the current study, a cross-sectional study was performed to determine the correlations between APOE genotypes and serum levels of glucose, TC, and TG in a cognitively normal, nondiabetic aging population. Great heterogeneity of APOE...
Table 3 Adjusted effects of APOE E4 allele on biochemical parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total cholesterol</td>
<td>1.689</td>
<td>1.223–2.334</td>
<td>0.001</td>
</tr>
<tr>
<td>Total triglyceride</td>
<td>1.042</td>
<td>0.759–1.429</td>
<td>0.800</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.981</td>
<td>0.720–1.336</td>
<td>0.903</td>
</tr>
</tbody>
</table>

Note: Logistic regression model was adjusted for age, body mass index, alcohol use, and smoking use.
Abbreviations: OR, odds ratio; CI, confidence interval.

Acknowledgments

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Disclosure

The authors report no conflicts of interest in this work.

References


