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Apolipoprotein E ε4 and testosterone interact in the risk of Alzheimer’s disease in men

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SUMMARY

The apolipoprotein E ε4 allele (APOEε4) is a well-established risk factor for Alzheimer’s disease (AD), but the mechanisms for this association are not well understood. In addition, other risk and protecting factors are needed to explain the causality of the disease. Sex steroid hormones, such as estradiol and testosterone, are thought to exert protective mechanisms in the brain (Lee and McEwen, 2001). Lower levels of total estradiol and total testosterone in men with AD have been found (Hogervorst et al., 2001; Rasmuson et al., 2002). The current study examined relations between APOEε4 and levels of total testosterone and total estradiol in the risk of AD in men. Copyright © 2002 John Wiley & Sons, Ltd.

KEY WORDS — Alzheimer’s disease; testosterone; apolipoprotein E ε4 allele; risk

SUBJECTS, METHODS AND RESULTS

We examined 116 male Caucasians from the Oxford Project To Investigate Memory and Ageing (OPTIMA). Fifty-one were autopsy confirmed CERAD AD cases (mean age at episode: 75.3 years, range: 58.8–89.5 years), 10 were diagnosed ‘probable AD’ by NINCDS/ADRDA criteria (69.8 years, range: 57.4–88.8 years) and 55 were without cognitive impairment and with CAMCOG scores ≥ 80 (73.6 years, range: 39.9–94.7 years). All had given their informed consent prior to the study (Clarke et al., 1998).

We analysed total testosterone using a competitive enzyme immunoassay (Bayer 1, Bayer Cooperation, Tarrytown, NY, USA) in non-fasting blood serum samples that had been stored at −70°C. Serum had been collected between 10 and 12 am. For total estradiol, duplicate serum samples were extracted with ether. Estradiol was then assessed by radioimmunoassay using a highly specific rabbit antiserum. SHBG levels were investigated using an immuno-enzymometric assay (IEMA). Subjects were genotyped by standard PCR methods for APOE and for the butyrylcholinesterase K variant.

Using a logistic regression model with age and SHBG as co-variables, low testosterone (odds ratio (OR) = 0.86, 95% confidence intervals (CI) 0.75–0.99) and the APOEε4 × testosterone interaction (OR = 1.28, 95% CI = 1.07–1.54) were significantly associated with AD, which suggested that the presence of the APOEε4 allele modified the risk of AD associated with low testosterone levels. Entering APOEε4 by itself as a risk factor for AD, gave an OR of 7.72 (95% CI = 3.63 to 16.48, p < 0.01). In a model where estradiol replaced testosterone, neither estradiol alone nor the estradiol × APOEε4 interaction was a significant predictor of AD.

Table 1 presents the results of analyses stratified by diagnosis. The two main results were: first, testosterone levels were lower in APOEε4-positive controls than in those without APOEε4; second, in men without APOEε4, testosterone levels were lower in AD than in controls. One of the lowest testosterone levels
Low testosterone is potentially a modifiable risk factor. At present, no long-term studies have investigated the possibly protective effects of testosterone against the development of AD. Short-term studies with testosterone replacement therapy in non-demented men have given mixed results (Wolf et al., 1999). A possible explanation could be that, since APOE ε4-positive controls had lower levels in the present study than those without the allele, perhaps only APOE ε4-positive men would profit from testosterone replacement therapy. Future, long-term studies should investigate the possibly protective effect of testosterone replacement therapy in APOE ε4 carriers who are at risk of AD.

ACKNOWLEDGEMENTS

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REFERENCES


(1.6 nmol/l) was in the only control who was an APOE ε4 homozygote. With estradiol, levels were lower in APOE ε4 carriers, both in AD cases and in controls.

We also examined two other alleles, apolipoprotein E ε2 (APOE ε2) and the butyrylcholinesterase K variant (BCHE-K). No significant association was found between either allele and either steroid in any analysis. Only a weak tendency was seen for APOE ε2-positive controls to have higher steroid levels than those without APOE ε2 (e.g., for testosterone: 20.2 nmol/l (n = 11) vs 16.5 nmol/l (n = 42), p = 0.1, t-test).

COMMENT

Table 1 illustrates two important results. First, APOE ε4 is associated with lower testosterone levels in men, but only significantly so in controls. Second, testosterone levels are higher in controls than in AD, but only in men without APOE ε4. These results are open to various interpretations. One is that APOE ε4, among other factors, lowers testosterone in male controls and low testosterone, whether or not due to APOE ε4 status, contributes to the onset of AD. Another interpretation is that APOE ε4 lowers testosterone in controls and that AD results in a lowering of testosterone levels for other reasons. This study cannot distinguish between these interpretations. Prospective studies are needed to resolve these issues.

Table 1. Sex steroid levels in AD and in controls, by APOE ε4 status

<table>
<thead>
<tr>
<th>Steroid</th>
<th>Subgroup (n)</th>
<th>APOE ε4 status (n)</th>
<th>Mean ± SEM</th>
<th>p (t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testosterone</td>
<td>AD (61)</td>
<td>With (44)</td>
<td>13.9 ± 5.1</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without (17)</td>
<td>15.0 ± 4.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls (53)</td>
<td>With (12)</td>
<td>11.3 ± 7.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without (41)</td>
<td>19.1 ± 5.4</td>
<td></td>
</tr>
<tr>
<td>Estradiol</td>
<td>AD (60)</td>
<td>With (43)</td>
<td>69.8 ± 28.7</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without (17)</td>
<td>94.9 ± 28.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Controls (55)</td>
<td>With (12)</td>
<td>70.6 ± 42.4</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Without (43)</td>
<td>107.8 ± 34.9</td>
<td></td>
</tr>
</tbody>
</table>

AD, Alzheimer’s disease; APOE ε4, apolipoprotein E ε4; NS, not significant.

*a Testosterone levels are in nmol/l and estradiol in pmol/l.

*b All subgroups were normally distributed; equal variances could be and were assumed in all cases.

* Testosterone, APOE ε4-negative AD cases vs APOE ε4-negative controls: p = 0.009 (t-test).


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