Original article

Long-term animal-protein consumption is associated with an increased prevalence of diabetes among the elderly: The Mediterranean islands (MEDIS) study

G.D. Pounis a, S. Tyrovolas a, M. Antonopoulou b, A. Zeimbekis c, F. Anastasiou b, V. Bountziouka a, G. Metallinos a, E. Gotsis a, E. Lioliou a, E. Polychronopoulos a, C. Lionis b, D.B. Panagiotakos a,∗

a Department of Nutrition Science – Dietetics, Harokopio University, Athens, Greece
b Clinic of Social and Family Medicine, School of Medicine, University of Crete, Heraklion, Greece
Health Center of Kalloni, General Hospital of Mitilini, Mitilini, Greece

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Abstract

Aim. – The role of animal-protein consumption on the prevalence of diabetes is not yet fully understood. For this reason, this study investigated the relationship between long-term animal-protein intake and diabetes in elderly individuals with no known cardiovascular disease.

Methods. – During 2005–2007, 1190 men and women, aged 65–100 years, from Cyprus, Mitilini, Samothraki, Cephalonia, Crete, Lemnos, Corfu and Zakynthos were enrolled into the study. Diabetes was defined as fasting blood glucose ≥ 125 mg/dL or the use of antidiabetic medication. All participants were asked about their dietary habits through a semiquantitative food-frequency questionnaire. Assessment of protein and energy intakes was performed using food-composition tables.

Results. – After adjusting for age, gender, obesity, history of hypertension, hypercholesterolaemia and dietary habits, a 5% increase in protein intake from meat and meat products was associated with a 34% (OR = 1.338, 95% CI: 1.02–1.76) greater likelihood of diabetes, while a 5% increase in total protein intake was associated with a 29% (OR = 1.288, 95% CI: 1.00–1.69) greater likelihood of diabetes. No significant associations between diabetes and protein intakes from vegetables and cereals were observed.

Conclusion. – Animal-protein consumption was associated with a higher prevalence of diabetes among the elderly, whereas protein intakes, especially from plant sources, within the recommended range appear to confer considerable protection. This suggests that reducing or controlling the burden of diabetes through dietary means in the elderly should include monitoring their daily protein intake.

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Keywords: Epidemiology; Mediterranean islands; Diabetes mellitus; Risk of diabetes; Protein consumption; Dietary habits; Elderly

Résumé

L’augmentation de la consommation à long-terme de protéines animales est associée à une augmentation du risque de diabète chez les sujets âgés : enquête des îles méditerranéennes (MEDIS).

Objectif. – Les relations entre consommation de protéines et développement du diabète sont mal connues. Cette enquête était destinée à établir les relations entre la consommation à long-terme des protéines et le diabète sucré chez des sujets âgés indemnes de maladie cardiovasculaire.

Méthodes. – L’enquête a été réalisée entre 2005 et 2007, et s’estadressée à 1190 sujets des deux sexes, âgés de 65 à 100 ans, qui habitaient Chypre, Mitilini, Samothrace, Céphalonia, La Crète, Lemnos, Corfou, et Zakynthos. Le diabète était défini par une glycémie à jeun ≥125 mg/dL, ou la prise de médicaments antidiabétiques. Tous les participants ont été interrogés sur leurs habitudes alimentaires et ont répondu à un questionnaire. L’évaluation de la consommation de protéines et des apports énergétiques a été réalisée grâce aux tables de composition des aliments.

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1. Introduction

According to the World Health Organization [1], approximately 150 million people have diabetes worldwide. Based on predictive models, this number may double by the year 2025 because of population growth, obesity, ageing, unhealthy diets and sedentary lifestyles. The prevalence of diabetes is much greater in the elderly [2–4]. Several studies have suggested that lifestyle modifications, such as a healthy diet, regular exercise and smoking cessation, can reduce the risk of diabetes and its complications [5]. In particular, dietary patterns that include a high consumption of wholegrain products, light-to-moderate alcohol intake and mostly unsaturated fats can lower the risk of diabetes [6,7]. Decreased food intake and, especially, insufficient levels of protein and micronutrients, a sedentary lifestyle and reduced energy expenditure in older adults become critical risk factors for malnutrition and diabetes [8]. Recently, a modified food-guide pyramid for older adults has been proposed [9] that recommends eating a variety of meals rich in wholegrains, vegetables and fruit, and low-fat and non-fat dairy products, including reduced lactose, while avoiding saturated and trans-fatty-acid oils, and saturated animal fats. Dietary sources of protein include meat, eggs, nuts, grains, legumes and dairy products. Protein intake is of major importance for health and wellness in the elderly, especially for maintaining adequate muscle and bone mass. The loss of both muscle and bone due to ageing has serious implications for older adults’ health. With reduced body strength, fractures are more likely to occur and, as the elderly are more likely to fall and thus, sustain serious injuries, bone and muscle loss plays an important role in their well-being [10]. Furthermore, muscle tissue has a much higher metabolic rate than fat tissue [11,12].

Yet, although protein consumption is a major component of the elderly diet, there is a lack of evidence for the implications of protein intakes on diabetes prevalence. A few epidemiological studies have suggested that high meat consumption or high total- or animal-protein intakes will increase the risk of diabetes in middle-aged individuals [13–17]. In addition, as already mentioned, the prevalence of diabetes is much higher in the older population, and is also associated with more serious clinical complications than in younger adults. Thus, the present study sought to determine the association of protein intakes from various sources (such as meat and meat products, vegetables and cereals) on diabetes in elderly men and women living in the Mediterranean islands.

2. Patients and methods

The Mediterranean Islands (MEDIS) study was a health-and-nutrition survey designed to evaluate the bioclinical, behavioural (lifestyle) and dietary characteristics of elderly individuals living in the Mediterranean islands. A randomized, population-based, multistage sampling method [including three age groups (65–75 years, 75–85 years and 85+ years) and two gender levels] was used to select men and women living in the Cyprus Republic, and the Greek islands of Mitilini, Samothraki, Cephalonia, Crete, Corfu, Lemnos and Zakynthos. Those residing in assisted-living centres and those with a clinical history of cardiovascular disease (CVD) or cancer were not included in the survey. The target sample size was 300 from Cyprus and 150 from each of the other islands. Of the individuals initially selected, 553 men (aged 76 ± 7 years) and 637 women (aged 74 ± 7 years) (n = 1190) agreed to participate (Cyprus, n = 300; Mitilini, n = 142; Samothraki, n = 103; Cephalonia, n = 115; Crete, n = 131; Corfu, n = 149; Lemnos, n = 150; and Zakynthos, n = 103). Of these, 460 (39%) were living in rural parts of the islands. The participation rate ranged from 75% to 89% across these islands. Health scientists (including physicians, dietitians and nurses) with experience in field investigations collected the required information using a quantitative questionnaire and standardized procedures.

The retrieved data were confidential, and the study followed the ethical guidelines recommended by the World Medical Association (52nd WMA General Assembly, Edinburgh, Scotland, October 2000). In addition, the institutional review board approved the design, procedures and aims of the study. Before the interviews and before giving their consent, all participants were informed of the aims and procedures of the study.

Type 2 diabetes was determined by fasting plasma glucose tests and analyzed in accordance with the American Diabetes Association diagnostic criteria (fasting blood glucose levels ≥ 125 mg/dL or the use of antidiabetic medication). Participants who had blood pressure levels ≥ 140/90 mmHg or used antihypertensive medications were classified as hypertensive. Fasting blood lipids and triglyceride levels were also recorded, and hypercholesterolaemia was defined as total serum cholesterol
levels ≥ 200 mg/dL or the use of lipid-lowering agents. The retrieved information also included basic demographic characteristics, such as age, gender, annual income and lifestyle factors, as well as various bioclinical characteristics.

Dietary habits were assessed through a semiquantitative validated and reproducible food-frequency questionnaire [18]. The frequency of consumption of various food groups and beverages (meat and meat products, fish and seafood, milk and other dairy, fruit, vegetables, green vegetables and salads, legumes, cereals, coffee and tea, and soft drinks) on a daily, weekly or monthly basis was assessed. Also, intakes of various alcoholic beverages (such as wine and beer) were measured in terms of wineglasses adjusted for ethanol intake (one 100-mL glass of wine was considered to be 12% ethanol). Assessment of protein intakes through the consumption of various food groups was performed using the exchange lists for meal planning devised by the American Diabetes Association and the American Dietetic Association [19].

For the analyses, protein intakes from vegetables and cereals (including green vegetables, salads and unrefined cereals) and from red meat and meat products were distinguished. To evaluate the overall diet, the MedDietScore was used [20]. In particular, the consumption of items similar to the suggested pattern (such as fruit, vegetables and cereals, which are to be eaten every day or as more than four servings per week) was scored from 0 to 5 when participants reported no consumption to daily consumption, respectively. On the other hand, the consumption of foods departing from this dietary pattern, such as meat and meat products, were scored from 0 to 5 when participants reported almost daily consumption to rare or no consumption, respectively. A potato consumption score of 5 was given for the recommended intake of 3–4 servings per week, a score of 4 for 1–2 servings per week and scores of 3–0 for rare, frequent, very frequent and daily consumption, respectively. For alcohol intakes, a score of 5 was assigned for <3 wineglasses per day, a score of 0 for >7 wineglasses per day, and scores of 1–4 for 3, 4–5, 6 and 7 wineglasses per day, respectively. Higher total values of these scores indicated better adherence to the Mediterranean diet [20].

2.1. Statistical analysis

Continuous variables are presented as means ± SD and categorical variables as frequencies. Prevalence was defined as the gender-specific ratio of the number of people with diabetes to the total number of people in the group. Comparisons of continuous variables between groups (independent samples) were performed using the t test (for normal distributions) or Mann–Whitney U test (for skewed distributions). Associations between categorical variables were tested using Pearson’s chi-square test. Multiple logistic-regression analyses, adjusted for age, gender, and history of hypertension and hypercholesterolaemia, evaluated the effect of protein intake on the likelihood of diabetes. To determine whether there was an interactive effect of the diabetic diet and protein intake on diabetes, the analysis was stratified into those who followed a specific glucose-control diet or not. Results are presented as odds ratios (OR) with the corresponding 95% confidence intervals (CI). The Hosmer–Lemeshow statistic was used to test the models’ goodness of fit. All tested hypotheses were two-sided, and P values < 0.05 were considered statistically significant. SPSS version 14 software was used for all calculations (SPSS Inc., Chicago, IL, USA).

3. Results

In the present study, the prevalence of diabetes was 21% in men (n = 115) and 23% in women (n = 145) (P = 0.42). Fasting blood glucose was 151 ± 50 mg/dL in the diabetics and 96 ± 12 mg/dL in the non-diabetics. In addition, 65% of the diabetics were following a special glucose-control diet and 76% were receiving pharmaceutical treatment; 10% of the diabetics were taking insulin. No significant association was observed between compliance with antidiabetic medication and age (P = 0.50) or gender (P = 0.39). Table 1 shows the various sociodemographic and lifestyle characteristics of the study participants. No differences were observed between groups in terms of age, male gender, educational status and smoking habits (P > 0.05). However, elderly diabetics showed significantly lower rates of physical activity (P < 0.001).

Table 2 presents the consumption of various food groups and protein intakes. The total protein intake, as a percentage of total energy consumption, had a tendency (P < 0.10) to differ between diabetic and non-diabetic participants (15.4 ± 2.9 and 15.0 ± 2.9, respectively; P = 0.09). In addition, protein intake from red meat and meat products was higher in the diabetic vs non-diabetic elderly participants (total energy intake: 4.8 ± 2.8% vs 4.4 ± 2.6%, respectively; P = 0.01), whereas no significant difference between these two groups was observed for protein intakes from vegetables and cereals. However, the prevalence of diabetes was 22.3% in men with protein intakes < 15% of their total energy intake and 21.9% in men with protein intakes > 15% of total energy intake (P = 0.91), while the prevalence of diabetes was 19.5% in women with protein intakes < 15% of total energy intake and 25.7% in those with protein intakes > 15% of total energy intake (P = 0.08). Nevertheless, when blood glucose levels were taken into account, no significant associations were seen between total protein intakes and glucose levels in both men and women (P = 0.45 and P = 0.83, respectively).

Table 3 shows the results of three additive logistic-regression models evaluating the association of protein intakes (total, from red and white meat and meat products, and from vegetables and cereals) with the likelihood of having diabetes after adjusting for age and gender (model 1), model 1 and the presence of obesity, hypertension and hypercholesterolaemia (model 2), and model 2 and dietary habits (model 3). The fully adjusted data analysis revealed that a 5% increase in total protein intake as a percentage of total energy consumption (approximately 20 g of protein with 1500–1600 kcal) was associated with a 28.8% greater likelihood of diabetes (OR for 5% increase: 1.065 = 1.34, 95% CI: 1.00–1.69). Also, a 5% increase in animal-protein intake was associated with a 34% greater likelihood of diabetes (OR for 5% increase: 1.062 = 1.34, 95% CI: 1.02–1.76), whereas the effect of protein consumption from vegetables and cereals on
Table 1
Sociodemographic and lifestyle characteristics of the study participants by diabetes status.

<table>
<thead>
<tr>
<th></th>
<th>Non-diabetic</th>
<th>Diabetic</th>
<th>Total</th>
<th>P&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>930</td>
<td>260</td>
<td>1190</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>74 ± 7.1</td>
<td>74 ± 6.7</td>
<td>74 ± 7.1</td>
<td>0.81</td>
</tr>
<tr>
<td>Male gender (%)</td>
<td>47</td>
<td>44</td>
<td>46</td>
<td>0.42</td>
</tr>
<tr>
<td>Educational status (years of school)</td>
<td>5.92 ± 3.3</td>
<td>5.57 ± 2.8</td>
<td>5.85 ± 3.2</td>
<td>0.13</td>
</tr>
<tr>
<td>Current smoker (%)</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Physical activity (%)</td>
<td>38</td>
<td>26</td>
<td>36</td>
<td>0.94</td>
</tr>
<tr>
<td>MedDietScore (0–55)</td>
<td>33.6 ± 4.1</td>
<td>33.5 ± 3.7</td>
<td>33.5 ± 4.0</td>
<td>0.81</td>
</tr>
</tbody>
</table>

<sup>a</sup> Diabetic vs non-diabetic participants.

Table 2
Food groups (servings/week) and protein intakes, by diabetes status, of the MEDIS study’s elderly population living in the Mediterranean islands.

<table>
<thead>
<tr>
<th></th>
<th>Non-diabetic</th>
<th>Diabetic</th>
<th>P&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red and white meat/meat products</td>
<td>2.05 ± 1.37</td>
<td>2.22 ± 1.37</td>
<td>0.05</td>
</tr>
<tr>
<td>Fish</td>
<td>1.53 ± 1.25</td>
<td>1.43 ± 1.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Unrefined cereals</td>
<td>54.0 ± 27.5</td>
<td>54.5 ± 27.0</td>
<td>0.26</td>
</tr>
<tr>
<td>Legumes</td>
<td>2.20 ± 1.69</td>
<td>2.18 ± 1.52</td>
<td>0.57</td>
</tr>
<tr>
<td>Fruit</td>
<td>31.6 ± 14.5</td>
<td>35.1 ± 12.4</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Vegetables</td>
<td>60.1 ± 34.0</td>
<td>59.6 ± 32.6</td>
<td>0.86</td>
</tr>
<tr>
<td>Potatoes</td>
<td>4.00 ± 2.77</td>
<td>3.82 ± 2.76</td>
<td>0.33</td>
</tr>
<tr>
<td>Sweets</td>
<td>1.85 ± 2.44</td>
<td>1.15 ± 1.85</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Use of olive oil in cooking (%)</td>
<td>97.3%</td>
<td>99.2%</td>
<td>0.06</td>
</tr>
<tr>
<td>1–2 wineglasses of alcohol/day (%)</td>
<td>45.0%</td>
<td>45.1%</td>
<td>0.41</td>
</tr>
<tr>
<td>Protein intakes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total g/day</td>
<td>41.9 ± 14.3</td>
<td>42.9 ± 15.6</td>
<td>0.70</td>
</tr>
<tr>
<td>Total g/kg body weight/day</td>
<td>0.58 ± 0.20</td>
<td>0.55 ± 0.20</td>
<td>0.13</td>
</tr>
<tr>
<td>Total (% total energy)</td>
<td>15.0 ± 2.9</td>
<td>15.4 ± 2.9</td>
<td>0.08</td>
</tr>
<tr>
<td>Red-meat/meat-product protein intake (% total energy)</td>
<td>4.4 ± 2.6</td>
<td>4.8 ± 2.8</td>
<td>0.01</td>
</tr>
<tr>
<td>Vegetable/cereal protein intake (% total energy)</td>
<td>7.2 ± 2.1</td>
<td>7.2 ± 2.0</td>
<td>0.87</td>
</tr>
</tbody>
</table>

<sup>a</sup> Diabetic vs non-diabetic participants.

the likelihood of having diabetes was not significant (Table 3). In addition, after grouping total protein intakes into quartiles (< 13%, 13–15%, 15–17% and > 17%) of total energy consumption, multiple log-regression analyses revealed that only the highest protein intake of > 17% of total energy consumption appeared to significantly increase diabetes prevalence (OR: 1.59, 95% CI: 1.00–2.53; < 0.05) while, in the other quartiles, the effect was not significant (P > 0.05). Furthermore, after animal-protein intake was also grouped into quartiles (< 2.79%, 2.79–3.68%, 3.69–6.4% and > 6.4%) of total energy intake and after adjusting for the above-mentioned confounders, those in the higher quartiles of consumption (> 6.4% of total energy intake or about 30 g/day of animal protein) had an increased likelihood of having diabetes compared with those in the lower quartiles (OR: 1.78, 95% CI: 1.15–2.76; P = 0.01), while the other quartiles of protein intake had no association with diabetes prevalence (P > 0.05). To determine a possible non-linear effect of total protein intake on glucose levels, their association was further evaluated using multiple linear models. Specifically, the effect of the square of total protein intake on glucose levels, after controlling for total protein intake, was tested and proved to be not significant (b ± SE = –0.001 ± 0.123; P = 0.996). Thus, the effect of the square of total protein intake on glucose levels, after controlling for total protein intake, was tested and proved to be not significant (b ± SE = –0.001 ± 0.123; P = 0.996). Thus, the effect of the square of total protein intake on glucose levels, after controlling for total protein intake, was tested and proved to be not significant (b ± SE = –0.001 ± 0.123; P = 0.996). Thus,

Table 3
Results from multiple log-regression analyses evaluating the main effects of protein intake, red-meat protein intake and vegetable/cereal-protein intake on diabetes risk.

<table>
<thead>
<tr>
<th></th>
<th>OR, 95% CI, P&lt;sup&gt;a&lt;/sup&gt;</th>
<th>OR, 95% CI, P&lt;sup&gt;b&lt;/sup&gt;</th>
<th>OR, 95% CI, P&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total protein (per % energy)</td>
<td>1.043, 0.99–1.10, 0.09</td>
<td>1.047, 1.00–1.10, 0.07</td>
<td>1.052, 1.00–1.11, 0.06</td>
</tr>
<tr>
<td>Model 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Animal protein (per % energy)</td>
<td>1.062, 1.01–1.12, 0.02</td>
<td>1.055, 1.00–1.12, 0.05</td>
<td>1.060, 1.00–1.12, 0.04</td>
</tr>
<tr>
<td>Model 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetable/cereal protein (per % energy)</td>
<td>1.005, 0.94–1.08, 0.88</td>
<td>1.007, 0.94–1.08, 0.84</td>
<td>1.007, 0.94–1.08, 0.86</td>
</tr>
</tbody>
</table>

<sup>a</sup> Adjusted for age and gender.

<sup>b</sup> Adjusted for age, gender, obesity, history of hypertension and hypercholesterolaemia.

<sup>c</sup> Adjusted for age, gender, obesity, history of hypertension, hypercholesterolaemia and MedDietScore.
the hypothesis of a J-shaped association was not confirmed by the present data.

A further analysis was performed to evaluate the presence of a moderating effect of a diabetic diet on the tested relationship between protein intake and diabetes. The interaction between a specific diet and protein intake with diabetes was not significant in any of the three models (Table 3; all \( P > 0.05 \)). Nevertheless, a stratified analysis was performed, and the association between protein consumption from animals and diabetes remained significant (OR per 5%: \( 1.090^3 = 1.53, 95\% \) CI: 1.015–2.38; \( P = 0.04 \)) in those who were not following a special diabetic diet, even after adjusting for age, gender, obesity, history of hypertension, hypercholesterolaemia and dietary habits. In contrast, no significant association between vegetable/cereal-protein consumption and diabetes was found in this subgroup (data not shown here).

4. Discussion

The present study revealed a positive association between animal-protein intake and the likelihood of diabetes in the elderly. In particular, diabetic elderly people appear to consume larger quantities of total and red-meat protein compared with non-diabetics, with no difference observed for protein intakes from vegetables and cereals. A high protein intake from red meat and meat products was also associated with higher diabetes prevalence. These findings are the first to be reported in the literature for older adults and merit special attention from a general public-health perspective.

The Western dietary pattern is characterized by high intakes of red meat [21,22], saturated fats and cholesterol, all of which have been associated with a higher risk of diabetes [23]. However, several studies suggest that the positive association between red-meat consumption and the risk of diabetes is independent of dietary fats. Yiqing Song et al. [13], in a prospective study of red-meat consumption and type 2 diabetes in 37,309 middle-aged and elderly women, revealed that meat intakes of ≥ 5 times/week vs ≤ 1 time/month were associated with a 23% increase in relative risk for diabetes. That study also stressed that high animal-protein intakes were associated with a 44% increase in diabetes risk compared with low animal-protein consumption. Similarly, van Dam et al. [14], in a prospective study of 42,504 middle-aged and elderly individuals from the Health Professionals Follow-Up Study, suggested that the increase in diabetes risk was around 46%. Fung et al. [16], after analyzing the prospective data from 69,554 women aged 38–63 years, reported that the relative risk for diabetes for every 1-serving increase in meat intake was 1.26. Sluijs et al. [17], after a 10-year follow-up of 38,094 participants from the European Prospective Investigation into Cancer and Nutrition (EPIC)-NL study, suggested that higher total and animal-protein intakes are associated with, respectively, 2.15 and 2.18 times greater likelihood of diabetes compared with a low consumption. Finally, a large prospective cohort study of 91,246 American women, aged 26–46 years, revealed that the consumption of meat ≥ 5 times/week vs 1 time/week was associated with a 91% greater risk of diabetes [15].

Our present findings are somewhat in accordance with these epidemiological studies, and support the hypothesis of an independent effect of meat consumption on the prevalence of diabetes. In particular, it may be that increased protein intakes, especially from red meat and meat products, increase the likelihood of diabetes in the elderly. This association was independent of adherence to a diabetic diet or not, highlighting the importance of the finding. However, no significant relationship was observed between vegetable/cereal-protein intakes and the prevalence of diabetes. This lack of association may be attributed to the low energy density, low glycaemic load, and high fibre and micronutrient content of such foods, which appear to protect against the development of diabetes [24].

Our findings also suggest that a total protein intake of up to 17% of total energy consumption is most likely safe in the elderly, whereas higher intakes increase the likelihood of diabetes, and such a level of consumption is recommended to avoid the usual co-morbidities of ageing [25–27].

One of the major findings of the present study was that a high consumption of animal protein (> 6.4% of total energy intake or around 30 g/day of protein) was associated with higher diabetes prevalence. Recent studies have suggested that protein intakes of 0.8–1.0 g/kg of body weight (or 15–18% of total energy consumption for a 70-kg person with a typical diet of 1500 kcal) is appropriate for the elderly [25–27]. In fact, protein intakes that are 10–15% of the total energy intake are the recommended intake for adult populations [28]. This suggests that, on the basis of the present findings as well, physicians, dietitians and other healthcare scientists need to promote protein intakes especially from plant sources within the above-mentioned moderate range to both prevent diabetes and promote well-being in older adults.

A possible pathophysiological explanation for the role of protein intake on glycaemic-control indices and, consequently, diabetes prevalence is that high protein intakes, especially from red meat, contain certain types of preservatives, additives and other chemicals related to meat preservation, packaging and processing. The compounds that are most associated with the pathogenesis of diabetes are nitrates and nitrates, which are added in meat processing, as well as a variety of heterocyclic amines and polycyclic aromatic hydrocarbons formed in red meat, especially when cooked to ‘well done’ [29]. These compounds can be converted to N-nitrosamines [29], which are toxic to pancreatic beta cells [30]. In fact, foods containing high levels of nitrates and nitrosamines have been associated with type 1 diabetes [31–33]. Moreover, the frequent consumption of red-meat protein is associated with high iron stores, and cross-sectional [34] and cohort studies [35] have suggested a positive association of iron with blood glucose concentrations and the risk of diabetes. This has been supported by findings from animal studies suggesting that iron depletion enhances glucose disposal [36,37]. Thus, it may be hypothesized that these are the main reasons why protein intakes, especially from meat sources, can affect the prevalence of diabetes. However, a biological mechanism that supports the effect of protein intake per se on diabetes risk cannot be excluded.

This is the first investigation into the role of protein intake on the prevalence of diabetes in non-institutionalized elderly
people. However, the Mediterranean region, and Greece in particular, have several geographical particularities, one of which is its islands. People living in the Aegean and Ionian Seas, and on Crete, have cultural traditions that are somewhat different from those of people living on the mainland. In the past, these traditions have never been explored, except in the Seven Countries Study and a few local surveys in Crete. This makes the present study unique in its field. Yet, as this was a cross-sectional study, it has the inherent limitations of such a design. This means that no causal relationships can be conclusively determined, and the dietary information was retrieved only once and, thus, may be prone to recall bias and seasonal variation. Also, inverse causality is always possible, as patients with diabetes may have adopted different, healthier dietary habits after being diagnosed with the disease. However, the dietary habits reported by our participants were life-long and, therefore, may have been established before the development of diabetes.

5. Conclusion

The present study evaluated the dietary habits of a large sample of elderly men and women living in the Mediterranean islands. Data analyses revealed that high protein consumption was associated with an increased prevalence of diabetes, and the latter was more evident with animal- than plant-protein consumption. Thus, the present findings may serve as a basis for future research into whether or not reducing animal-protein intakes while increasing plant-protein intakes (within the recommended range) can help to better control the burden of diabetes in the elderly.

6. Conflicts of interest

No conflicts of interest.

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