*Article*

# Dietary diversity and nutritional adequacy among an older Spanish population with metabolic syndrome in the PREDIMED-Plus Study: A cross-sectional analysis.

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**Abstract:** Dietary guidelines emphasizes the importance of a varied diet to provide an adequate nutrient intake. However, the aging is often associated with consumption of monotonous diets that can be nutritionally inadequate, increasing the risk for the development or progression of diet-related chronic diseases such as the metabolic syndrome (MetS). To assess the relationship between dietary diversity (DD) and nutrient adequacy and to identify associated demographic variables related with DD. We analysed cross-sectional baseline data from the PREDIMED-Plus study: 6587 Spanish adults, aged 55–75 years, with overweight/obesity and MetS. Using a 143-item validated semi-quantitative food frequency questionnaire (FFQ), we calculated an energy-adjusted score of DD (DDS). Nutrient inadequacy was defined as an intake below 2/3 of the recommended dietary intake at least of ≥4 of 17 nutrients. Logistic regression models were used to evaluate the relationship between nutritional inadequate intakes and DDS. In the higher DDS quartile there were more women and less current smokers. Compared with subjects in the highest DDS quartile, those in the lowest DDS quartile had a higher risk of inadequate nutrient intake OR=28.56 (95% C.I. 20.80-39.21). When we estimated diversity for each one of the food groups, participants in the first quartile of diversity had a higher risk of nutrient deficiency: for vegetables, OR= 14.03 (IC 95% 10.55-18.65), fruits OR=11.62 (IC 95% 6.81-19.81), dairy products OR= 6.54 (IC 95% 4.64-9.22) and protein foods OR=6.60 (IC 95% 1.96-22.24). As DDS decreases, the risk of inadequate nutrients intake rises. Given the impact of nutrient intake adequacy on the prevention of non-communicable diseases, health policies should focus on the promotion of a healthy varied diet, specifically promoting the intake of vegetables and fruit among population groups with lower DDS such as men, smokers or widow people.

**Keywords:** Dietary diversity; nutrient adequacy; metabolic syndrome; aging; PREDIMED-Plus study.

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## 1. Introduction

Metabolic Syndrome (MetS), a clustering of risk factors (central obesity, insulin resistance, dyslipidaemia and hypertension) [1], is a well-known condition in the causal pathway of cardiovascular disease (CVD). The MetS has also been associated with a higher risk of other chronic diseases, such as cancer [2] and neurodegenerative ones [3]. In recent years, the prevalence of MetS has increased worldwide to the point that presently it is considered as a major public health problem [4]. This trend has also been observed in Spain, where the current prevalence of MetS is approximately 22.7% and increases with age [5]. Typically subjects with MetS have a higher use of health care services, incrementing costs [6].

MetS is a multifactorial disease that may be associated with some modifiable risk behaviours, such as unhealthy lifestyles and dietary patterns [7]. Among these factors, dietary intake plays a critical role in the prevention and treatment of the MetS. Thus, dietary patterns that include healthy varied food groups and which provide adequate nutrient intake have been shown to be beneficial in the progression of the MetS [8]. In this sense, the Mediterranean dietary pattern (MedDiet] has been related not only to a delay in the progression and a lower mortality of MetS [9], but also to an adequate nutritional intake [10]. This can be explained by the great variety of food products that characterize the MedDiet. These foods, such as fruit and vegetables, nuts, legumes, fish and whole grain cereals, have a relatively low caloric value but a high nutrient content, increasing the probability to meet nutritional requirements [11].

Spanish dietary guidelines have emphasized the importance of a varied, balanced and moderated diet to reduce the risk of diet-related chronic diseases [12]. However, the role of a varied diet on chronic disease development is still uncertain. Some studies have suggested that dietary diversity (DD) contributes to high energy consumption and has a positive association with a poor quality diet, increasing the risk of MetS in aged subjects [13-16]; other researchers have reported that DD is a key component of high-quality diets, being associated with nutrient adequacy [17] and reducing the rates of CVD [18] and MetS [19] in the overall population.

Aged populations with chronic diseases are considered vulnerable groups, as they are at greater nutritional risk due to a higher prevalence of inadequate nutrient intakes [20]. This could be a consequence of the consumption of monotonous and nutritionally inadequate diets, influenced by several factors, including loneliness, low socioeconomic status and functional quality [21].

There is evidence that nutritional inadequacy is prevalent in the aged Spanish population [22] which could accelerate the progression of chronic diseases such as MetS, in probable relation to a monotonous diet. In this study we examined DD among PREDIMED-Plus participants, and aged population with MetS, with the aim of assessing the relationship between DD and nutrient adequacy and to identify associated demographic variables related with DD.

## 2. Materials and Methods

### Design of the Study

A cross-sectional analysis on baseline data of the PREDIMED-Plus study was conducted. The PREDIMED-Plus study is an ongoing multicenter, randomized and parallel-group primary cardiovascular prevention trial. The PREDIMED-Plus study aims to assess the potential advantages of the synergy of a high-quality energy reduced MedDiet plus a weight-loss intervention and behavioural support on the incidence of CVD, in comparison to a standard MedDiet advice (control group). The participant recruitment methods and data collection process have been described previously [23]. The Institutional Review Boards of all participating centers approved the study protocol. The clinical trial was registered in 2014 at the International Standard Randomized Controlled Trial (www.isrctn.com/ISRCTN89898870). All participants provided written informed consent.

### Study Population

The study participants were men and women aged 55-75 and 60-75 years, respectively, with overweight or obesity (body mass index (BMI) ≥27 and ≤40 kg/m$^2$), who at baseline met at least three

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components of the MetS: triglyceride level ≥150 mg/dL, blood glucose ≥100 mg/dL or use of oral antidiabetic drugs, systolic blood pressure ≥130 mm Hg and/or diastolic blood pressure ≥85 mmHg or use of antihypertensive drugs, and HDL-cholesterol level <40 mg/dL for men and <50 mg/dL for women according to the harmonized criteria of the International Diabetes Federation and the American Heart Association and National Heart, Lung and Blood Institute [24]. Prior cardiovascular disease or other active systemic, neurological or endocrine diseases or active cancer were exclusion criteria.

A total of 6874 subjects were recruited and randomized in 23 centres of the PREDIMED-Plus clinical trial from October 2013 to December 2016 from different universities, hospitals and research institutes across Spain. Out of them, 287 participants were excluded for the present study **(Figure 1)**: 47 participants because they did not complete the Food Frequency Questionnaire (FFQ) survey, and 240 participants because they reported values for total energy intake outside predefined limits (<3347kJ <800kcal/day or >17573kJ >4000kcal/day for men); (<2510kJ <500kcal/day or >14644kJ >3500kcal)/day for women) [25]. A final sample of 6587 participants was analysed.

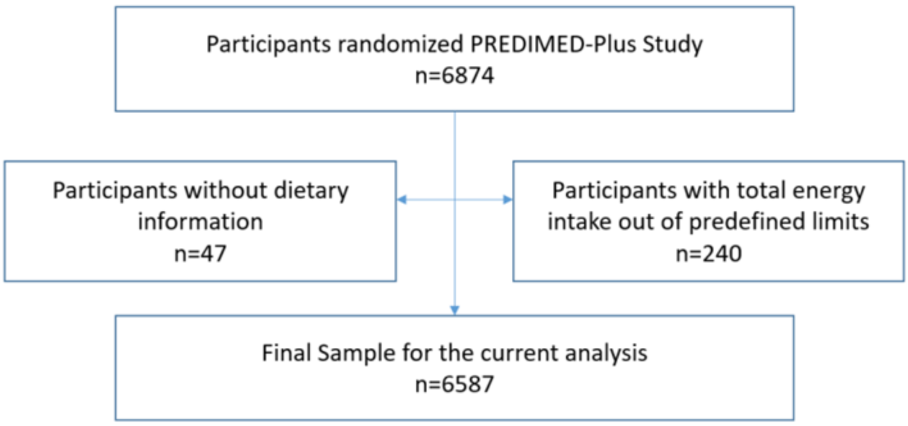


**Figure 1.** Flow-chart of participants

**Dietary Intake Assessment**

Trained dieticians collected data on dietary intake at baseline in a face-to-face interview. Dietary intake was assessed using a 143 item semi-quantitative FFQ previously and repeatedly validated in Spain [26]. The FFQ provided a list of foods commonly used by the Spanish population and inquired about the consumption of these foods during the previous year. It included 9 response options (never or almost never, 1-3 times a month, once a week, 2-4 times a week, 5-6 times a week, once a day, 2-3 times a week day, 4-6 times a day and more than 6 times a day). The indicated frequencies of consumption were converted to intakes per day and multiplied by the weight of the standard serving size in order to estimate the intake in grams per day. Nutrient information was derived from Spanish food composition tables [27,28].

**Dietary diversity score construction**

The dietary diversity score (DDS) was calculated by the method originally developed by Kant et al. [29] and recently used by Farhangi et al. [30]. We included 5 food groups: vegetables, fruits, cereals, dairy products and protein food groups (legumes, meat, fish, eggs and nuts), based on the food groups recommended by the Spanish guidelines' pyramid [12]. The vegetable group was divided into four subgroups, including: green vegetables, tomatoes, yellow vegetables and mushrooms. Cereal group included potatoes and refined or whole-grain cereals (bread, pasta, rice and breakfast cereals). The fruit group included all fresh fruit products divided in three categories: citrus fruits, tropical fruits and other seasonal fruits. The dairy group included all kinds of milk, yogurt and cheese. Protein food groups

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included legumes (peas, beans, lentils and chickpeas), white meats (poultry and rabbit), fish (oily fish, white fish and other shellfish/seafood), eggs and nuts. Non-recommended food groups (that should be consumed as little as possible) [31], including sugar food groups (pastries, pies, biscuits, chocolate, fruit in sugar syrup and fruit juices) and food groups with high contents in salt or saturated fat (butter, margarine, unhealthy vegetable fats, red meat, processed meats, sauces, pre-cooked dishes, condiments and snacks) were not included in the analysis as they are less healthy products and their variety is not desirable.

To be counted as a consumer for any of the food group categories reported previously, a subject should consume at least half of the recommended serving during one day (that is, if the Spanish nutritional recommendation advises a usual protein intake of 3 servings per week, for each protein item, participants should consume at least 1.5/7 servings/day). Within each food group, we summed up the number of items consumed. Each of the 5 predefined food categories received a maximum diversity score of 2 points, so the sum was rescaled to a 0-to-2 score, multiplying by 2 and dividing by the maximum score in that food group. Total DDS is the sum of the scores of the five main groups, theoretically ranging between 0 and 10 points. The score was adjusted by total energy intake, due to the general concern that high food variety might be a consequence of overconsumption of energy [14]. Finally, DDS was categorised in quartiles (Q) and the cutoff points were 3.8, 4.6 and 5.4. The variety of each food group was classified into 4 categories (C) (C1=0 points), (C2=>0-≤0.5 points), (C3=>0.5-<1 points) and (C4≥1 point).

Subjects were asked about MedDiet adherence by a 17-item screening questionnaire used to both evaluate compliance with the intervention and guide the motivation interviews during the study follow-up. This screener is a modification of a previously validated 14-item MeDiet adherence questionnaire [32]. Compliance with each of the 17 items relating to characteristic food habits was scored with 1 point, and 0 point otherwise, so that the total score range was 0-17, with 0 meaning no adherence and 17 meaning maximum adherence. Adherence to MedDiet, was categorized in tertiles as lower level (1st tertile, ≤7 points], medium (2nd tertile, 8-10 points] or higher level of adherence (3rd tertile, ≥11 points].

**Nutrient Adequate Intake**

The dietary intake of 17 selected nutrients including vitamins A, $B_1$, $B_6$, $B_9$, $B_{12}$, C, D, E, minerals such as calcium, phosphorus, magnesium, iron, iodine, potassium, selenium, and zinc, and dietary fiber, was compared with age and sex-specific recommended intakes for these nutrients according to the established criteria by the Dietary Reference Intake (DRI] for the North-American population [33]. DRI is the general term for a set of reference values used to plan and assess nutrient intakes for healthy people. These values vary by age and sex. Intake levels above DRI imply a low likelihood of inadequate intake. To decrease potential measurement errors derived from the use of the FFQ, we calculated the proportion of individuals with intakes below two thirds (2/3) of the DRIs [34]. Furthermore, we estimated the proportion of inadequate intake according to European Food Safety Agency (EFSA) average requirements (ARs), taking as reference adequate intake (AI) when ARs were not available [35]. Results were based on dietary intake data only, excluding supplements.

**Assessment of non-dietary variables**

At the baseline visit, trained PREDIMED-Plus staff collected information about lifestyle variables, educational achievement and socioeconomic status. The variables included were sex, age (55-70 years, and >70 years), educational level (primary, secondary and tertiary level, which includes university studies), civil status (married, widowed, divorced/single or other), and whether they lived alone or not. Other lifestyle variables such as smoking habit (non-smoker, current smoker or never smoker), alcohol intake and physical activity (less active, moderately active and active) where taken into account. We collected physical activity information by using the validated Spanish version of the Minnesota questionnaire [36,37]. Anthropometric variables (weight, height and waist circumference) were determined by trained staff in accordance with the PREDIMED-Plus operations protocol. Weight and height were measured with calibrated scales and a wall-mounted stadiometer, respectively. BMI was

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calculated as the weight in kilograms divided by the height in meters squared. Waist circumference (WC) was measured midway between the lowest rib and the iliac crest using an anthropometric tape.

**Statistical Analysis**

Data were analyzed using Stata (12.0, StataCorp LP, Tx. USA). We used the PREDIMED-Plus baseline database generated in August 2017. For the statistical analysis, participants were classified according to DDS quartiles. Baseline characteristics of participants were described as mean ± standard deviations (SD) for continuous variables or number and percentages for categorical variables. Comparison of quantitative variables across DDS quartiles was performed using ANOVA. Pearson $\chi^2$ test was used to compare the distribution of qualitative variables among DDS quartiles. A linear regression model was fitted to estimate the association of sociodemographic and lifestyle variables (sex, age, educational level, civil status, living alone, physical activity, smoking and drinking status) with DDS. Logistic regression models were used to evaluate the relationship between nutritional inadequate intakes (≥4 nutrients) as dependent variable and total DDS and food variety groups as main independent variables. All analyses were adjusted for potential confounders based on prior knowledge: sex, age, energy intake, BMI, WC, level of education, smoking status, physical activity, MedDiet adherence, marital status and living alone. We used a significance level of 0.05 for all analyses.

## 3. Results

### *3.1. Baseline characteristics of PREDIMED-Plus participants by quartiles of DDS*

Table 1 shows the comparison of demographic, anthropometric and lifestyle variables according to quartiles of DDS. We found significant differences for age, sex, smoking habits, marital status, educational level and WC (p<0.001), but not for physical activity or BMI. Participants in the top DDS quartile (Q4) were older (65.8 ± 4.7) and more likely to be women (63.6%), never smokers (54.3%) and married (77.8%) (p<0.05) in comparison with the lower DDS quartiles. Moreover, participants in the top DDS quartile had a lower WC (106.3±9.6) and lower educational level. The association between these demographic and lifestyle variables with DDS as continuous variable is presented in (Table S1). We observed that DDS was significantly higher among women (mean difference=0.26, C.I. 95%: 0.18,0.33), non-smokers (mean differences= 0.18, C.I. 95%: 0.09,0.27) and participants with higher adherence to the MedDiet (mean difference=0.65, C.I. 95%: 0.58,0.73), whereas alcohol intake (mean difference=-0.01, C.I. 95%: -0.01,-0.01) and being widowed (mean difference=-0.15, C.I. 95%:-0.26,-0.05) were inversely associated with higher DDS.

**Table 1.** Baseline characteristics of PREDIMED-Plus participants by quartiles of DDS (total population=6587)

| | **Q1** (n=1647) | **Q2** (n=1647) | **Q3** (n=1647) | **Q4** (n=1646) | **P value** |
|---|---|---|---|---|---|
| **Age (y), n (%)** | | | | | |
| 55-70 y | 1442 (87.6) | 1416 (86.0) | 1403 (85.2) | 1356 (82.4) | <0.001 |
| > 70 y | 205 (12.5) | 231 (14.0) | 244 (14.8) | 290 (17.6) | |
| Mean ±SD | 64.1 ± 5.1 | 64.8 ± 4.9 | 65.3 ± 4.8 | 65.8 ± 4.7 | <0.001 |
| **Sex, n (%)** | | | | | |
| Male | 1116 (67.8) | 916 (55.6) | 770 (46.8) | 600 (36.5) | <0.001 |

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| | | | | | |
|---|---|---|---|---|---|
| Female | 531 (32.2) | 731 (44.4) | 877 (53.3) | 1046 (63.6) | |
| **Smoking habits, n (%)** | | | | | |
| Current Smoker | 297 (18.0) | 195 (11.8) | 171 (10.4) | 152 (9.2) | <0.001 |
| Former Smoker | 793 (48.2) | 747 (45.4) | 722 (43.8) | 593 (36.0) | |
| Never Smoker | 548 (33.3) | 699 (42.4) | 749 (45.5) | 893 (54.3) | |
| Without information | 9 (0.6) | 6 (0.4) | 5 (0.3) | 8 (0.5) | |
| **Physical Activity, n (%)** | | | | | |
| Less active | 1014 (61.7) | 985 (59.9) | 983 (59.9) | 940 (57.4) | 0.29 |
| Moderately active | 294 (17.9) | 304 (18.5) | 319 (19.4) | 326 (19.9) | |
| Active | 335 (20.4) | 355 (21.6) | 340 (20.7) | 373 (22.8) | |
| **Educational level, n (%)** | | | | | |
| Tertiary level | 421 (25.6) | 360 (21.9) | 340 (20.6) | 320 (19.5) | <0.001 |
| Secondary level | 534 (32.4) | 480 (29.2) | 449 (27.3) | 435 (26.4) | |
| Primary level | 679 (41.3) | 796 (48.4) | 842 (51.1) | 873 (53.1) | |
| Without information | 13 (0.7) | 11 (0.6) | 16 (1.0) | 18 (1.0) | |
| **Civil status, n (%)** | | | | | |
| Married | 1258 (76.7) | 1254 (76.4) | 1243 (75.7) | 1278 (77.8) | 0.030 |
| Widowed | 151 (9.2) | 162 (9.9) | 182 (11.1) | 186 (11.3) | |
| Divorced/Separated | 145 (8.8) | 123 (7.5) | 130 (7.9) | 117 (7.1) | |
| Others[a] | 93 (5.2) | 108 (6.2) | 92 (5.3) | 65 (3.8) | |
| **Living alone, n (%)** | 193 (11.8) | 189 (11.5) | 220 (13.4) | 212 (12.9) | 0.29 |
| **BMI (kg/m$^2$), Mean ±SD** | 32.6 ± 3.4 | 32.5 ± 3.4 | 32.5 ± 3.5 | 32.5 ± 3.5 | 0.82 |
| **WC (cm), Mean ±SD** | 109.3 ± 9.5 | 108.1 ± 9.5 | 107.0 ± 9.7 | 106.3 ± 9.6 | <0.001 |

Values are presented as means ± SD for continuous variables and n (%) for categorical variables. Pearson's chi-square test was performed for categorical variables and ANOVA test for continuous variables.

[a] includes religious and single status

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*3.2. Adherence to MedDiet and dietary intake of PREDIMED-Plus participants by quartiles of DDS adjusted by energy*

Comparing across DDS quartiles, individuals in Q4 had significantly higher MedDiet adherence, higher intake of dietary fiber, carbohydrates, proteins and polyunsaturated fat, but lower saturated fat intake (table 2). Vitamin and mineral intake increased progressively across DDS quartiles ($p<0.001$). On the other hand, participants in the bottom DDS quartile (Q1) reported higher alcohol intake. Total energy intake followed a U-shaped line, higher in Q1 and Q4 than in Q2-Q3.

**Table 2.** Adherence to MedDiet, mean energy, alcohol and nutrient intakes of PREDIMED-Plus participants by quartiles of DDS adjusted by energy

| | Q1 (n=1647) | Q2 (n=1647) | Q3 (n=1647) | Q4 (n=1646) | P value |
|---|---|---|---|---|---|
| **MedDiet Adherence, n (%)** | | | | | |
| Low adherence | 857 (52.0) | 638 (38.7) | 507 (30.8) | 372 (22.6) | <0.001 |
| Medium adherence | 602 (36.7) | 686 (41.7) | 717 (43.5) | 684 (41.6) | |
| High adherence | 188 (11.4) | 323 (19.6) | 423 (25.7) | 590 (35.8) | |
| Mean, ±SD | 7.4±2.5 | 8.3±2.6 | 8.8±2.5 | 9.5±2.6 | <0.001 |
| **Nutrient intake, Mean ±SD** | | | | | |
| Total energy (Kcal/d) | 2382.3±612.8 | 2345.0±557.9 | 2340.7±527.0 | 2397.1±502.6 | 0.006 |
| Total fat intake (%) | 39.9±7.1 | 39.9±6.6 | 39.5±6.3 | 38.9±5.9 | <0.001 |
| Monounsaturated fat (%) | 20.7±4.9 | 20.8±4.7 | 20.5±4.6 | 20.1±4.3 | 0.002 |
| Polyunsaturated fat (%) | 6.2±1.9 | 6.3±1.9 | 6.4±1.8 | 6.6±1.8 | <0.001 |
| Saturated fat (%) | 10.1±2.2 | 10.1±2.1 | 9.9±1.9 | 9.7±1.8 | <0.001 |
| Carbohydrate intake (%) | 40.1±7.5 | 40.2±7.0 | 40.7±6.5 | 41.3±6.1 | <0.001 |
| Protein intake (%) | 15.4±2.6 | 16.6±2.7 | 17.2±2.8 | 17.9±2.6 | <0.001 |
| Fiber intake (g/d) | 21.4±7.8 | 24.8±7.7 | 27.1±7.8 | 31.3±8.8 | <0.001 |
| Vitamin A (µg/d) | 909.3±624.6 | 1075.1±648.9 | 1133.2±587.7 | 1302.9±650.3 | <0.001 |
| Vitamin B1 (mg/d) | 1.5±0.4 | 1.6±0.4 | 1.7±0.4 | 1.8±0.4 | <0.001 |
| Vitamin B6 (mg/d) | 2.0±0.5 | 2.2±0.5 | 2.4±0.5 | 2.7±0.6 | <0.001 |
| Vitamin B9 (µg/d) | 290.7±82.3 | 335.6±88.9 | 363.6±90.9 | 416.1±102.0 | <0.001 |
| Vitamin B12 (µg/d) | 9.0±4.5 | 9.7±4.5 | 10.1±4.3 | 10.9±4.5 | <0.001 |
| Vitamin C (mg/d) | 147.5±66.4 | 189.0±74.3 | 216.5±78.3 | 255.7±83.2 | <0.001 |
| Vitamin D (µg/d) | 5.3±3.2 | 5.9±3.3 | 6.4±3.4 | 7.1±3.6 | <0.001 |
| Vitamin E (mg/d) | 9.6±4.1 | 10.4±3.9 | 10.7±3.7 | 11.7±3.8 | <0.001 |
| Calcium (mg/d) | 876.6±325.3 | 987.2±325.1 | 1071.8±320.3 | 1201.5±326.2 | <0.001 |
| Phosphorus (mg/d) | 1556.4±389.7 | 1699.4±388.3 | 1796.7±389.7 | 1985.6±397.1 | <0.001 |
| Magnesium (mg/d) | 371.0±99.3 | 403.7±98.4 | 428.2±98.8 | 479.4±108.5 | <0.001 |
| Iron (mg/d) | 15.2±3.9 | 16.0±3.8 | 16.6±3.7 | 18.1±3.9 | <0.001 |
| Iodo (µg/d) | 242.9±163.6 | 274.7±153.1 | 297.0±155.3 | 327.2±151.1 | <0.001 |

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| | | | | | |
|---|---|---|---|---|---|
| Potassium (mg/d) | 3767.9±858.1 | 4262.1±880.0 | 4619.6±929.3 | 5256.5±1053.4 | <0.001 |
| Selenium (µg/d) | 113.6±36.8 | 115.9±32.9 | 116.4±31.3 | 122.5±30.9 | <0.001 |
| Zinc (mg/d) | 12.5±3.5 | 13.0±3.2 | 13.2±3.1 | 14.1±3.1 | <0.001 |
| Alcohol intake, Mean ±SD | 16.5±19.4 | 11.7±15.0 | 9.1±12.4 | 6.8±9.8 | <0.001 |

Values are presented as means ± SD for continuous variables and n (%) for categorical variables. Pearson's chi-square test was performed for categorical variables and ANOVA test for continuous variables.

### *3.3. Evaluation of inadequate nutrient intake according to recommended intakes by DDS quartiles*

Table 3 shows the proportion of participants with an intake below 2/3 of DRIs by DDS quartiles and stratified by sex and group of age. The prevalence of inadequate intake of all nutrients decreased across DDS quartiles in all age and sex strata, except for vitamin D in older individuals. We excluded Vitamins B1, B12, C, phosphorus, iron, potassium, selenium and zinc due to the high number of categories with zero cases, as nearly all the prevalent cases of deficient intake were at Q1 of DDS (Table S2.). These results were similar if the EFSA recommendations were used instead (Table S3.).

**Table 3.** Percentage of participants of PREDIMED-Plus study with nutrient intake below 2/3 of DRIs according to DDS

| Nutrient | Group | DRI[a] | Q1 (n=1647) | Q2 (n=1647) | Q3 (n=1647) | Q4 (n=1646) | P value[1] |
|---|---|---|---|---|---|---|---|
| Dietary fiber | Male 55-70 | 30g /d | 49.6 | 25.9 | 12.0 | 4.7 | <0.001 |
| | Male >70 | 30g /d | 38.8 | 32.1 | 12.9 | 5.5 | <0.001 |
| | Female 60-70 | 21 g/d | 13.4 | 4.6 | 1.2 | 0.4 | <0.001 |
| | Female >70 | 21 g/d | 18.0 | 5.7 | 0.7 | 0 | <0.001 |
| P value[2] | | | <0.001 | <0.001 | <0.001 | <0.001 | |
| Vitamin A | Male 55-70 | 900 µg/d | 33.8 | 15.7 | 12.0 | 3.5 | <0.001 |
| | Male >70 | 900 µg/d | 31.9 | 20.2 | 9.9 | 7.7 | <0.001 |
| | Female 60-70 | 700 µg/d | 14.9 | 8.4 | 3.4 | 0.7 | <0.001 |
| | Female >70 | 700 µg/d | 22.5 | 12.3 | 6.3 | 0 | <0.001 |
| P value[2] | | | <0.001 | <0.001 | <0.001 | <0.001 | |
| Vitamin $B_9$ | Male 55-70 | 400 µg/d | 40.6 | 15.7 | 8.8 | 3.0 | <0.001 |
| | Male >70 | 400 µg/d | 33.6 | 25.7 | 6.9 | 5.5 | <0.001 |
| | Female 60-70 | 400 µg/d | 39.4 | 24.8 | 13.5 | 3.1 | <0.001 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Female >70 | 400 µg/d | 46.1 | 27.9 | 12.6 | 5.0 | <0.001 |
| **P value[2]** | | | 0.31 | <0.001 | 0.020 | 0.33 | |
| **Vitamin D** | Male 60-70 | 15 µg/d | 88.5 | 84.0 | 80.1 | 72.5 | <0.001 |
| | Male >70 | 20 µg/d | 98.3 | 99.1 | 97.0 | 95.6 | 0.401 |
| | Female 60-70 | 15 µg/d | 89.1 | 84.2 | 82.3 | 76.2 | <0.001 |
| | Female >70 | 20 µg/d | 96.6 | 98.4 | 98.6 | 97.0 | 0.66 |
| **P value[2]** | | | 0.001 | <0.001 | <0.001 | <0.001 | |
| **Vitamin E** | Male 55-70 | 15 mg/d | 61.7 | 46.6 | 42.5 | 29.3 | <0.001 |
| | Male >70 | 15 mg/d | 62.1 | 56.0 | 43.6 | 30.8 | <0.001 |
| | Female 60-70 | 15 mg/d | 67.2 | 57.8 | 53.1 | 35.3 | <0.001 |
| | Female >70 | 15 mg/d | 79.8 | 69.7 | 59.4 | 50.3 | <0.001 |
| **P value[2]** | | | 0.003 | <0.001 | <0.001 | <0.001 | |
| **Calcium** | Male 55-70 | 1000 mg/d | 24.4 | 9.4 | 4.8 | 0.1 | <0.001 |
| | Male >70 | 1200 mg/d | 48.3 | 26.6 | 18.8 | 9.9 | <0.001 |
| | Female 60-70 | 1200 mg/d | 49.1 | 35.6 | 20.7 | 7.1 | <0.001 |
| | Female >70 | 1200 mg/d | 41.6 | 36.1 | 18.9 | 10.6 | <0.001 |
| **P value[2]** | | | <0.001 | <0.001 | <0.001 | <0.001 | |
| **Magnesium** | Male 55-70 | 420 mg/d | 14.6 | 4.1 | 1.8 | 0.4 | <0.001 |
| | Male >70 | 420 mg/d | 15.5 | 6.4 | 2.0 | 1.1 | <0.001 |
| | Female 60-70 | 320 mg/d | 3.2 | 1.2 | 0.3 | 0 | <0.001 |
| | Female >70 | 320 mg/d | 3.4 | 0.8 | 0 | 0 | 0.011 |
| **P value[2]** | | | <0.001 | 0.001 | 0.012 | 0.06 | |
| **Iodine** | Male 55-70 | 150 µg/d | 17.7 | 9.4 | 7.6 | 3.3 | <0.001 |
| | Male >70 | 150 µg/d | 24.1 | 11.0 | 9.9 | 3.3 | <0.001 |
| | Female 60-70 | 150 µg/d | 22.6 | 14.5 | 8.3 | 4.5 | <0.001 |
| | Female >70 | 150 µg/d | 13.5 | 9.8 | 6.3 | 3.0 | 0.007 |
| **P value[2]** | | | 0.037 | 0.029 | 0.73 | 0.63 | |

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DRI[a]: Dietary Reference Intake. Pearson´s Chi-Square test was used to estimate differences among prevalence of inadequate nutrient intakes according to quartiles of DDS for each age and sex strata (*p value*[1]) and also to estimate differences among prevalence of inadequate nutrient intakes according to age and sex, for each DDS quartile (*p value*[2]).

### *3.4. Distribution of participants by number of nutrients below adequate intake according DDS by age and sex*

Table 4 shows the prevalence of 4 or more inadequacies in nutrient intake according to DDS quartiles, stratified by sex and age. Independently of age and sex, we observed that participants at the top of DDS (Q4) showed a lower number of nutrient inadequacies (p<0.001). Also the prevalence of 4 or more inadequacies in nutrient intake decreased across DDS quartiles (p<0.001) regardless of age or sex. When we used the EFSA dietary recommendations, we obtained similar results (Table S4.).

**Table 4.** Distribution of participants by number of nutrients below adequate intake according DDS by age and sex

| | | | | | |
|---|---|---|---|---|---|
| **≤70 years** | | | | | |
| | **MEN** | | | | |
| | **Q1 (n=787)** | **Q2 (n=763)** | **Q3 (n=973)** | **Q4 (n=489)** | **P value** |
| **Number of inadequacies, mean ±SD** | 3.0±1.1 | 2.3±1.1 | 2.0±0.1 | 1.7±0.7 | <0.001[1] |
| **Participants with ≥4 nutrients below 2/3 DRI, n (%)** | 468 (46.8) | 156 (19.3) | 78 (11.7) | 12 (2.4) | <0.001[2] |
| | **WOMEN** | | | | |
| | **Q1 (n=630)** | **Q2 (n=610)** | **Q3 (n=884)** | **Q4 (n=529)** | **P value** |
| **Number of inadequacies, mean (SD)** | 2.9±1.0 | 2.5±1.1 | 2.1±1.0 | 1.7±0.8 | <0.001[1] |
| **Participants with ≥4 nutrients below 2/3 DRI, n (%)** | 169 (38.2) | 145 (23.8) | 81 (11.0) | 23 (2.7) | <0.001[2] |
| **>70 years** | | | | | |
| | **MEN** | | | | |
| | **Q1 (n=124)** | **Q2 (n=136)** | **Q3 (n=111)** | **Q1 (n=48)** | **P value** |
| **Number of inadequacies, mean (SD)** | 2.9±1.1 | 2.6±1.2 | 2.0±1.0 | 1.6±0.9 | <0.001[1] |
| **Participants with ≥4 nutrients below 2/3 DRI, n (%)** | 51 (44.0) | 37 (33.9) | 11 (10.9) | 5 (5.5) | <0.001[2] |
| | **WOMEN** | | | | |
| | **Q1 (n=138)** | **Q2 (n=137)** | **Q1 (n=177)** | **Q1 (n=103)** | **P value** |
| **Number of inadequacies, mean (SD)** | 3.0±1.1 | 2.5±1.1 | 2.0±0.9 | 1.7±0.8 | <0.001[1] |
| **Participants with ≥4 nutrients below 2/3 DRI, n (%)** | 38 (42.7) | 30 (24.6) | 14 (9.8) | 6 (3.0) | <0.001[2] |

[1]P value: Pearson´s Chi-Square test was used to estimate differences among prevalence of inadequate nutrient intake according to quartiles of DDS for sex strata. [2]P value: ANOVA test was performed to estimate differences among mean of inadequate nutrient intakes according to sex, for each DDS quartile**.**

### *3.5. Multivariable logistic regression model for inadequate intake of 4 or more out 8 micronutrients according to food group's diversity intake and total DDS quartiles*

The risk of inadequate intake of 4 or more nutrients increased in the lower DDS quartiles, whatever model we chose to adjust by (table 5). The adjusted OR of inadequate intake was 28.56 (C.I. 95%: 20.80-39.21) for Q1 compared to Q4. We analyzed the prevalence of inadequate intake according

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to the category of DD for each one of the included food groups and found the same trend for all of them except for the cereal food group. The groups showing the strongest association were vegetables and fruit. These results are comparable if the EFSA criteria are used to define inadequate intake (Table S5.).

**Table 5.** Multivariable logistic regression models for inadequate intake of 4 or more out 8 micronutrients according to food group's diversity intake and total DDS quartiles in the PREDIMED-Plus study participants

| | C1 (n=550) | C2 (n=1315) | C3 (n=2482) | C4 (n=2240) |
|---|---|---|---|---|
| **Vegetable group** | | | | |
| Model 1 | 17.99 (14.17-22.83) | 7.34 (6.00-9.01) | 3.10 (2.54-3.77) | 1 (Ref.) |
| Model 2 | 19.82 (15.19-25.85) | 7.28 (5.85-9.10) | 2.74 (2.22-3.38) | 1 (Ref.) |
| Model 3 | 14.03 (10.55-18.65) | 6.21 (4.92-7.83) | 2.52 (2.02-3.14) | 1 (Ref.) |
| | **C1 (n=845)** | **C2 (n=4497)** | **C3 (n=779)** | **C4 (n=466)** |
| **Fruit group** | | | | |
| Model 1 | 25.30 (15.50-41.31) | 5.41 (3.36-8.72) | 2.73 (1.61-4.62) | 1 (Ref.) |
| Model 2 | 19.75 (11.87-32.86) | 3.76 (2.30-6.15) | 2.23 (1.29-3.84) | 1 (Ref.) |
| Model 3 | 11.62 (6.81-19.81) | 2.71 (1.62-4.53) | 2.02 (1.15-3.57) | 1 (Ref.) |
| | **C1 (n=350)** | **C2 (n=4767)** | **C3 (n=1390)** | **C4 (n=80)** |
| **Cereal group** | | | | |
| Model 1 | 8.83 (3.74-20.83) | 3.32 (1.44-7.65) | 1.62 (0.69-3.77) | 1 (Ref.) |
| Model 2 | 1.33 (0.54-3.31) | 1.13 (0.47-2.71) | 0.90 (0.37-2.19) | 1 (Ref.) |
| Model 3 | 0.83 (0.32-2.19) | 0.84 (0.33-2.14) | 0.71 (0.28-1.82) | 1 (Ref.) |
| | **C1 (n=26)** | **C2 (n=1254)** | **C3 (n=2770)** | **C4 (n=2537)** |
| **Proteins group** | | | | |
| Model 1 | 31.76 (12.63-79.84) | 5.24 (4.39-6.25) | 2.74 (2.33-3.21) | 1 (Ref.) |

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| | | | | |
|---|---|---|---|---|
| Model 2 | 12.33 (4.10-37.19) | 3.00 (2.48-3.62) | 2.00 (1.69-2.37) | 1 (Ref.) |
| Model 3 | 6.60 (1.96-22.24) | 2.02 (1.64-2.48) | 1.63 (1.36-1.96) | 1 (Ref.) |
| | **C1** (n=686) | **C2** (n=2447) | **C3** (n=2600) | **C4** (n=854) |
| **Dairy group** | | | | |
| Model 1 | 13.57 (10.00-18.42) | 4.58 (3.45-6.01) | 1.88 (1.40-2.51) | 1 (Ref.) |
| Model 2 | 9.51 (6.88-13.14) | 3.35 (2.50-4.49) | 1.52 (1.12-2.06) | 1 (Ref.) |
| Model 3 | 6.54 (4.64-9.22) | 2.40 (1.76-3.27) | 1.24 (0.90-1.71) | 1 (Ref.) |
| | **Q1** (n=1647) | **Q2** (n=1647) | **Q3** (n=1647) | **Q4** (n=1646) |
| **Total DDS** | | | | |
| Model 2 | 27.42 (20.13-37.34) | 10.00 (7.30-13.72) | 4.37 (3.14-6.09) | 1 (Ref.) |
| Model 3 | 28.56 (20.80-39.21) | 9.97 (7.25-13.70) | 4.33 (3.11-6.04) | 1 (Ref.) |

Model 1: Unadjusted. Model 2: Adjusted for energy intake. Model 3: Adjusted for energy intake, sex, age, smoking habits, physical activity, educational level, MedDiet adherence, BMI, alcohol intake, living alone and civil status.

## 4. Discussion

The present study, conducted among older individuals with MetS, showed that the greater the DDS, the lower the risk of inadequate nutrient intake. Special attention should be paid to the groups with lower DDS: males, widowed and divorced individuals, smokers and alcohol drinkers.

It is well known that demographic characteristics influence diet quality. The influence of age and sex on DDS could be attributable to multiple factors, including psychological and mental health issues, poorer nutritional knowledge, lack of cooking skills, and increased loneliness [21,38]. Our results are in line with other studies regarding the impact of sex on the variety of food choices: women consume more varied diets than men [39]. Regarding age, Despite other authors have pointed out that dietary variety declined with age [40], we have not found the same trend, probably because the percentage of participants with >70 years old was small in our sample. Living alone has also been traditionally considered as a risk factor for poor dietary habits, mainly due to lower diversity of food intake [41,42]. We found lower DDS for widowed and divorced people, but not for people living alone.

In addition, some studies have highlighted the fact that lower levels of education and economic status predict lower dietary variety [43,44]. Principally, economic factors could explain low consumption of foods such as fish, fruits, and vegetables, which require more frequent purchase and consumption and can also be more expensive. Our results are not consistent on this point. The discrepancy might be attributed to the fact that these studies have been carried out in non-European countries with heterogeneous socioeconomic levels. In our study, most participants had primary or secondary educational level and similar economic capacity (they were mostly retired], the cultural and economic differences among them being small.

In the literature, smoking status and alcohol intake were the most important lifestyles variables related to food choices among older adults. In our study, non-smokers and drinkers of low quantities

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of alcohol showed higher DDS. Several studies have reported that smoking and drinking status are directly associated with less variety of food choices and poor nutrient intakes, concurring with results [45,46]. However these findings have not been supported by a study carried out in middle-aged adults in Japan, probably because of socio-cultural differences and small sample size [47].

Dietary guidelines worldwide have promulgated the benefits of a variety of dietary intake, mainly because it is easier to provide the necessary amount of nutrients with a highly diverse diet. This could be especially important for obesity and chronic disease management [48,49]. In this regard, monotonous diets usually imply unhealthy eating habits, as well as the worsening of the progression of certain diseases, for example CVD [50]. In spite of this, some observational studies have related the diversity of food intake to higher rates of obesity and poor nutritional adequacy in adults [13,16]. However, In the case-control study of *Karimbeiki et al* [16], cases were chosen from participants attending an obesity treatment group and dietary intake referred to the previous year, hence it is difficult to know if it was cause or consequence. The study of *Jayawardena et al* [13] is not comparable with ours because, on the one hand, they estimate a DDS from a 24-hour food record and not from a FFQ, and on the other hand their results are not adjusted by total energy intake.

A recent non-systematic review concluded that "the scientific evidence to date does not support benefits of greater dietary diversity for optimal diet quality or healthy weight" [51] pointing out a need for standardized, reliable measures defining what diet diversity is. In the current study, high DDS level (Q4) was directly associated with adequate nutrient intake (≥4 nutrients out of 8) even after adjustment for confounders such as sociodemographic and lifestyle variables. This association corroborates findings reported by other authors [17,52,53], emphasizing the need to increase diet variety, specifically in elderly populations, in order to achieve adequate nutrient intakes in these vulnerable groups. A variety of recommended foods, such as vegetables, fruit, cereals and dairy products, decreases the risk of inadequate nutrient intake, mainly because these foods group are rich in vitamins and minerals and other healthy nutrients such as dietary fiber [54].

Based on results obtained from adjusted binary logistic regression analyses, the higher DDS of the majority of the food groups analyzed was inversely associated with the risk of inadequate intake of nutrients (≥4 nutrients), except for cereals. Probably because the cereal group included not only whole grains, but also potatoes and refined grains. These findings are consistent with previous studies reporting a low probability of inadequate nutrient intakes in consumers of a high variety of foods groups, including vegetables and fruit [55], dairy products and protein-rich foods [52,56,57]. The notion is that for people who eat less variety of the healthy food groups, the intake of several nutrients might be endangered. For instance, although vegetables provide a considerable amount of dietary fiber and water, green vegetables provide vitamins $B_9$, while yellow ones are rich in vitamin A and carotenes. Another example of variety within the same group is the protein, which includes eggs, white meat, legumes, fish and nuts. This group is an excellent source of high quality protein, minerals and vitamins. In particular, white meat is high in B-vitamins, while oily fish is rich in polyunsaturated fat and eggs provide vitamins D and E and minerals such as zinc, iron and iodine [28,31] .

Our study has some limitations. First, the study sample is not representative of the general population. Due to the trial inclusion and exclusion criteria, only older adults with MetS were included. Second, we did not have data about income status; however, we registered the education level and employment status, which are both reasonable "proxy" indicators of socioeconomic status. Third, the cross-sectional design of the study does not allow inferring causality. Irrespective of the direction of the associations, the variables included in the analysis have a high potential to improve the nutrient intake in older populations and allow the detection of groups of individuals more prone to nutrient deficiencies (those with lower DDS). Fourth, we used a FFQ to measure dietary intakes. Despite that the FFQ used has been validated in an adult Spanish population and has a good reproducibility and validity [26], it might not be the ideal tool to measure micronutrient intake [58]. For this reason, we considered that there was an inadequacy only when the intake did not reach 2/3 of the DRIs, correcting the possible bias introduced by the FFQ and assuming in any case that the inadequate micronutrient intake should be higher than the estimated figures. Fifth, it is important to consider the fact that, besides pharmacological treatments, chronic diseases entail changes in dietary

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habits and nutrient metabolism, which have not been assessed. Last, we have estimated a DDS following the methodology of Kant et al. [29]. However, we excluded non-recommended product such as sweets, snacks, juices and sweet beverages and processed foods because these products are high-energy density foods, rich in sodium, sugar and saturated fat, but low-nutrient density foods, thus we considered that the intake of these food groups could not increase dietary diversity [59]. Also, a culinary fat group was not taken into account because Spanish individuals consume olive oil almost exclusively [60].

Some strengths of our study are its large sample size (n=6587) and the considerable amount of baseline information collected in a large on-going primary prevention trial, using a standardized protocol that reduces information bias regarding reported food intakes, sociodemographic characteristics and lifestyles. The individual analysis of each food groups' diversity can help to determine which aspects may maximize diet quality. The follow-up of this cohort will allow to identify the relationship between dietary diversity and clinical, metabolic, and cardiovascular outcomes.

## 5. Conclusions

According to our findings, older Spanish adults with MetS had a high risk of inadequate nutrient intake. As DDS decreases, risk of inadequate nutrients intake increased. The impact of nutrient intake adequacy on the prevention of chronic non-communicable diseases, mainly among population groups with lower DDS such as men, older or widow people is very likely to play a crucial role from a public health perspective. Health policies should focus on the promotion of a healthy varied diet, specifically promoting the intake of a variety of vegetables and fruits among population groups with lower DDS such as men, smokers or widow people.

**Supplementary Materials:** The following are available online at www.mdpi.com/xxx/s1 Table S1: Linear regression model to evaluate demographic and lifestyle variables associated with DDS (DDS measure as continuous variable), Table S2: Percentage of participants in the PREDIMED-Plus study with nutrient intake below 2/3 of DRIs according to DDS, Table S3: Participants of PREDIMED-Plus study with nutrient intake below AR/AI proposed by EFSA according to DDS, Table S4: Distribution of participants by number of nutrients below adequate intake according to EFSA criteria by DDS stratified by sex, Table S5: Multivariable logistic regression models for inadequate intake of 4 or more out 8 micronutrients according to EFSA AR/AI by food group's diversity intake and total DDS quartiles in the PREDIMED-Plus study participants.

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