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The influence of vegetarian and omnivorous diet quality on metabolic profiles and cardiovascular risk

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Cardiovascular diseases are the leading global cause of mortality and a major contributor to disability. As inadequate nutrition accounts for approximately 50% of cardiovascular deaths, understanding the impact of different dietary patterns is crucial. This study aimed to compare cardiovascular risk factors and 10-year cardiovascular risk in adults following a vegetarian (VG) or omnivorous (OM) diet. Cardiovascular risk was calculated using SCORE2, body composition was assessed through dual-energy X-ray absorptiometry, biochemical parameters were determined from capillary blood, and diet quality was evaluated using the 14-item Mediterranean Diet (MD) adherence questionnaire for OM, and the healthful plant-based diet index for VG. A cross-sectional design was performed with 110 participants (55 OM and 55 VG). No significant differences between groups were found in the 10-year cardiovascular risk. However, for biochemical parameters, OM showed higher levels of total cholesterol ($p < 0.001$), LDL cholesterol ($p = 0.001$), and non-HDL cholesterol ($p = 0.004$). Conversely, for body composition, VG men showed lower Appendicular Lean Mass Index (ALMI) values ($p = 0.005$). Upon analyzing diet quality, high adherence to the MD in the OM group (OR 0.861; $p = 0.013$) and high diet quality in the VG group (OR 0.590; $p = 0.001$) were protective factors against high cardiovascular risk. When reanalyzing data only for individuals with high-quality diets, OM individuals showed lower values of fat mass ($p = 0.003$) and Visceral Adipose Tissue ($p = 0.023$). Meanwhile, VG individuals showed significantly lower total cholesterol levels ($p = 0.013$). A high-quality VG diet demonstrated better results concerning lipid profile, while an OM diet with high adherence to the MD showed greater potential regarding body composition. Additionally, the key factor for optimal cardiovascular health does not seem to be related to a specific dietary pattern but rather to the quality of the diet adopted.

Keywords Vegetarian diet, Omnivorous diet, Cardiovascular risk, Body composition, Diet quality

Cardiovascular diseases (CVD) are the leading global cause of mortality and one of the primary factors for years lived with disability[1]. The prevalence of CVD cases has nearly doubled in recent years, increasing from 271 million in 1990 to 523 million in 2019[1]. The number of deaths due to CVD has also risen, reaching 18.6 million in 2019[1]. In Portugal, CVD remains the leading cause of death, accounting for 18% of all mortality in 2020, with stroke as the top contributor[2]. Despite a gradual reduction in mortality rates in recent decades, the burden of CVD continues to pose a significant public health challenge[3,4]. Therefore, preventing CVD is a key factor in promoting the population's better quality of life[5,6].

High consumption of plant-based products, such as fruits, vegetables, and whole grains, has been widely associated with decreased CVD incidence and mortality[7–9]. On the other hand, consumption of animal products, especially red and processed meats, has been associated with higher mortality rates due to the saturated fat content in these foods[5,10].

Concerns about health and sustainability have increased demand for plant-based diets, with the Vegetarian (VG) diet and Mediterranean diet (MD) among the most sought-after[11]. Studies on the subject have increased,

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and evidence has shown that individuals who follow a VG diet have a reduced risk of ischemic heart disease (29%) and a slight trend towards a reduced risk of circulatory diseases (16%) and cerebrovascular diseases (12%) compared to individuals who follow an Omnivorous (OM) diet[12,13]. Intervention studies with the MD have found a 30% reduction in the probability of stroke, but did not find an improvement in the reduction of CVD mortality[14]. However, when results were analyzed for higher vegetable and lower meat consumption, a significant reduction in CVD mortality rates was observed[15].

These findings highlight the need to deepen our understanding of how different dietary patterns affect cardiovascular health, especially given the growing interest in plant-based diets[11]. Despite the existing literature, there remains a lack of consensus regarding the comparative cardiovascular impact of vegetarian (VG) and OM diets in real-world populations[16], particularly when applying validated risk scores.

In recent years, interventions in the prevention of CVD have greatly benefited from calculating CVD risk in a given population, that is, the risk of suffering fatal or nonfatal events in a foreseeable time[17]. The objective is to increase the effectiveness of health policies in risk groups, considering the full range of these population characteristics to reduce risk and improve their quality of life[17]. Several scores have been used, such as the ASCVD score[18] in the United States, the QRISK3[19] in the United Kingdom, and the SCORE2 in Europe[20].

Given the importance of diet in cardiovascular prevention and the growing interest in plant-based eating patterns, this study explores the relationship between dietary patterns, specifically VG and OM (MD in particular), and cardiovascular health. The main goal is to identify differences regarding the 10-year cardiovascular risk score validated for the European population (SCORE2). Additionally, the study explores the impact of the quality of these dietary patterns on various CVD determinants.

Methodologies

Study design, selection criteria, and ethical considerations

The present study consisted of a cross-sectional design conducted as part of the project "*Met_BCCV*: Metabolism, Body Composition and Cardiovascular Health." For this study, individuals aged 40 to 65 years were eligible, and they did not meet any of the following exclusion criteria: use of illicit drugs; following the VG or OM dietary pattern for less than one year; use of medication that may cause edema or dehydration; presence of a pacemaker or metal implants; being pregnant, breastfeeding, or within seven days of the premenstrual phase; inability to sign the informed consent form (*e.g.* illiteracy); previously diagnosed chronic non-communicable diseases and/or infectious diseases.

Participant recruitment occurred in two phases: in the first phase, all participants meeting the general project criteria were recruited through internal communication channels (personal and institutional social networks and Lusófona Group partners). In the second phase, recruitment focused on vegetarians, leveraging partnerships with institutions and communities associated with the vegetarian lifestyle.

Initially, 337 participants were included in the *Met_BCCV* project (205 OM and 132 VG). In the first phase, 103 participants were excluded due to the absence of biochemical data. In the second phase, an additional 124 participants were excluded for being under 40 years old. As a result, 110 participants were included in this study, as described in Supplementary Fig. 1.

All participants provided informed written consent to participate in the study before data collection. The procedures adhered to the principles of good clinical practice adopted for studies involving human subjects outlined in the Helsinki Declaration[21] and Nuremberg Code[22]. The study was approved by the Ethics Committee of the School of Health Sciences and Technologies from *Universidade Lusófona* (EC.ECTS/P05.21).

Interviews and dietary patterns

Each assessment began with an interview, divided into three parts. The first part consisted of questions related to participants' sociodemographic characteristics (gender, age, area of residence, education level, monthly net household income, family medical history, and smoking habits). In the second part, the International Physical Activity Questionnaire - Short Form was applied to obtain and classify data regarding each participant's level of physical activity[23]. Finally, the third part included questions regarding participants' dietary intake and nutrition using the Portuguese Food Frequency Questionnaire (FFQ)[24,25], comprising 86 items.

After integration into the study and based on the responses from the FFQ to confirm the dietary group assigned, participants were divided into two groups, VG or OM. The VG group included individuals who did not consume any type of meat or fish or their derivatives, except a few animal products (dairy, eggs, and honey). Conversely, the OM group included individuals who consumed meat, meat products, and/or fish. In the second phase of the dietary analysis, the dietary pattern groups were subdivided according to their adherence to the MD (analysis performed exclusively for OM individuals) or diet quality score (analysis performed exclusively for VG individuals). The 14-Item Mediterranean Diet Adherence Screener (MEDAS) questionnaire[26] was used to classify adherence to the MD, considering participants to have high adherence to the MD when their score was ≥ 10 points. To assess the quality of the VG diet, the healthful Plant-based Diet Index (hPDI)[27] was applied, using the dietary intake data derived from the FFQ to calculate the daily consumption (in g/day) of 18 predefined food groups included in the index. The total index score was obtained by summing the scores assigned to each group, with a score equal to or higher than 52 points indicative of good diet quality.

Body composition

The Dual-Energy X-ray Absorptiometry (DXA Lunar Prodigy Advance - General Electric Healthcare®; Chicago, Illinois, USA) was used to measure fat mass, fat-free mass, lean mass, bone mass, bone mineral density, Visceral Adipose Tissue (VAT), and Subcutaneous Adipose Tissue (SAT). It is important to note that the assessment of VAT and SAT by DXA was limited to the abdominal region. Data regarding body mass using an electronic scale with a precision of 0.1 kg (0.1–200 kg). The participants' height was also collected based on their citizen identification cards. Waist circumference was measured with a metallic tape measure at the midaxillary line, at the midpoint between the lower edge of the last palpable rib and the upper edge of the iliac crest, at the end of several unforced expirations, with the participant's feet apart and weight evenly distributed. All assessments were conducted under the same conditions, with volunteers fasting for at least 12 hours and refraining from physical exercise for (at least) 24 hours before the assessment.

Subsequently, with the collected data, body mass index (BMI) was calculated using the formula [BMI = body mass (kg) / height (m^2)][28], Appendicular Lean Mass Index (ALMI) was calculated using the formula [ALMI = (lean mass of the legs (kg) + lean mass of the arms (kg)) / height (m^2)][29] and the VAT/ SAT Ratio was calculated using the formula [VAT/SAT Ratio = VAT (cm^2)/SAT (cm^2)][30]. To identify individuals with excess body fat, cut-off points for diagnosing obesity developed in NHANES 1999–2014 were used, considering excess body fat when values were greater than 30% in men and over 40% in women[31]. On the other hand, for the classification of ALMI deficit, cut-off points from EWGSOP2 were applied[32], considering a deficit when values were lower than 5.5 kg/m^2 in women and lower than 7.0 kg/m^2 in men. It is noteworthy that although these cut-off points were developed for an elderly population, they are recommended in the GLIM criteria for application in the adult population[33]. Finally, waist circumference (WC) was classified according to WHO criteria, with increased WC defined as values ≥ 94 cm in men and ≥ 80 cm in women and substantially increased WC as values ≥ 102 cm in men and ≥ 88 cm in women[34].

Basic clinical chemistry, hemodynamics, and cardiovascular risk assessment

Participants' basic biochemical profile was obtained from capillary blood collected in the fingertip using the portable LINX DUO device (A. Menarini Diagnostics, Firenze, Italy). The main quantifiable variables were fasting glucose, glycated hemoglobin (HbA1c), total cholesterol (TC), low-density lipoprotein cholesterol (LDL cholesterol), high-density lipoprotein cholesterol (HDL cholesterol), very low-density lipoprotein cholesterol (VLDL cholesterol), TC/HDL ratio, non-HDL cholesterol, and triglycerides (TG).

A digital sphygmomanometer (Beurer Healthcare Product Co, Shanghai, China) was used to measure basic hemodynamic indicators, including systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate. The mean arterial pressure (MAP) was calculated using the formula [MAP = DBP + 0.412 × (SBP – DBP)][35]. The 10-year risk of cardiovascular events (fatal and non-fatal) was calculated using SCORE2[36].

For HbA1c and fasting glucose, the American Diabetes Association's cut-off points were used to classify values above the recommendations[37]: HbA1c ≥ 5.7% and fasting glucose ≥ 100 mg/dL. According to the European Society of Cardiology (ESC) recommendations, the remaining parameters were considered above the recommended levels when TG levels were ≥ 150 mg/dL[38], TC was ≥ 155 mg/dL[38], LDL cholesterol was ≥ 100 mg/dL[36], SBP was ≥ 129 mmHg[36], and DBP was ≥ 84 mmHg[36]. HDL cholesterol levels were considered below the recommendations when values were < 50 mg/dL for women and < 40 mg/dL for men[39].

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS v.27.0 SPSS Inc., Chicago, IL USA). The normality of the variables was tested, with parametric tests used for normally distributed samples and non-parametric tests for non-normally distributed samples. The Kolmogorov–Smirnov normality test was used when $n > 50$, and the Shapiro–Wilk normality test when $n \leq 50$. Data were expressed as mean and standard deviation (SD), median (interquartile range, IQR), and percentages (absolute values, n), depending on the variable type. To assess the influence of confounding factors on the variables, multiple linear regression was used, with two models (I and II) of confounding factors created. Model 1 included age, sex, BMI, total energy intake per kg of body mass, physical activity level, smoking habits, educational qualifications, and dietary pattern as confounding factors. In Model 2, fat mass and VAT data were added to the factors included in Model 1. The models obtained met the Gauss-Markov conditions (residuals with zero mean, constant variance, and normal distribution). To better understand the effect of dietary intake on cardiovascular risk, binary logistic regression was used to obtain odds ratio values, creating a dichotomous variable with the cardiovascular risk score (low risk vs. moderate/high risk). All statistical tests were two-tailed, with a significance level set at $p < 0.05$.

Results

The total population of the present study was comprised of 110 participants (55 OM and 55 VG), mostly female (68.20%), with a mean age of 49.17 ± 6.91 years, a BMI of 24.28 ± 3.99 kg/m^2, and a waist circumference of 89.74 ± 9.26 cm for men, and 78.74 ± 12.41 cm for women. The majority of participants did not report smoking habits (76.40%), practiced moderate physical exercise (45.50%), had a monthly net income between 1000–3000€, and had a high-level education degree (70.00%). Regarding dietary adherence, all OM participants (100%) had followed this diet since birth (more than 10 years), whereas the majority of VG participants (63.60%) had adopted the diet within the past 1–5 years. There were no statistically significant differences regarding sociodemographic characteristics between the dietary patterns, as shown in Table 1.

In Table 2, the macronutrient intake for each sex according to their dietary pattern is described. The OM population showed a higher energy intake (OM: 2128.42 [765.80] Kcal versus VG: 1854.76 [679.49] Kcal; U = 968.000; $p = 0.001$) compared to the VG population. The OM group also had a higher protein intake (OM: 1.45 [0.66] g/kg of body mass versus VG: 0.81 [0.45] g/kg of body mass; U = 449.000; $p < 0.001$), total fat intake (OM: 43.02 ± 8.61% versus VG: 36.28 ± 8.51%; t = 4.132; $p < 0.001$), and dietary cholesterol intake (OM: 344.88 [125.15] mg versus VG: 31.39 [94.23] mg; U = 71.000; $p < 0.001$). On the other hand, the VG population had a higher carbohydrate intake (VG: 55.69 ± 8.08% versus OM: 40.08 ± 9.69%; t = -9.174; $p < 0.001$) and dietary fiber intake (VG: 40.66 [17.16]g versus OM: 29.26 [16.33] g; U = 2275.000; $p < 0.001$).

In Table 3, related to the 10-year risk of cardiovascular events (fatal and non-fatal), there were no statistically significant differences ($p = 0.573$) between the different dietary patterns analyzed. However, regarding

		Total population (*n* = 110)	Omnivorous (*n* = 55)	Vegetarians (*n* = 55)	*p*-value
Sex, % (*n*)					
Men		31.80 (35)	32.70 (18)	30.90 (17)	0.838[b]
Woman		68.20 (75)	67.30 (37)	69.10 (38)	
Age, years		49.17 (6.91)*	49.00 (10.00)	46.00 (11.00)	0.136[a]
Height, m		1.66 (0.09)*	1.64 (0.14)	1.63 (0.13)	0.822[a]
Weight, kg		67.48 (13.79)*	67.50 (20.40)	63.20 (21.50)	0.180[a]
BMI, kg/m^2		24.28 (3.99)*	24.30 (4.48)	22.80 (5.00)	0.114[a]
Waist Circumference, cm	Men	89.74 (9.26)*	86.65 (6.35)	91.00 (11.15)	0.163[a]
	Woman	78.64 (12.41)*	78.00 (23.90)	72.00 (12.05)	0.120[a]
Academic qualifications, % (n)					
High school		30.00 (33)	29.10 (16)	30.90 (17)	0.927[b]
Bachelor's degree		40.00 (44)	41.80 (23)	38.20 (21)	
Master's and Doctorate degree		30.00 (33)	29.10 (16)	30.90 (17)	
Time following the dietary pattern, % (n)					
Between 1 to 5 years		31.80 (35)	0.00 (0)	63.60 (35)	**< 0.001**
Between 5 to 10 years		18.20 (20)	0.00 (0)	36.40 (20)	
More than 10 years		50.00 (55)	100.00 (55)	0.00 (0)	
Smoking habits, % (n)					
Non-smoker		76.40 (84)	74.50 (41)	78.20 (43)	0.435[b]
Former smoker		12.70 (14)	10.90 (6)	14.50 (8)	
Smoker		10.90 (12)	14.50 (8)	7.30 (4)	
Physical activity level, % (n)					
Low		36.40 (40)	38.20 (21)	34.50 (19)	0.861[b]
Moderate		45.50 (50)	45.50 (25)	45.50 (25)	
High		18.20 (20)	16.40 (9)	18.20 (20)	
Family monthly income, % (n)					
< 1000 €		12.70 (14)	10.90 (6)	14.50 (8)	0.652[b]
1000–3000 €		56.40 (62)	54.50 (30)	58.20 (32)	
> 3000 €		30.90 (34)	34.50 (19)	27.30 (15)	

Table 1. Sociodemographic characteristics of the population according to dietary pattern. Data expressed as percentage (n) or median (IQR) for categorical or continuous variables, respectively. *Data expressed as mean (SD). p-values for group comparisons were tested using the [a]Mann–Whitney U test or [b]Chi-square test, as appropriate. BMI, Body Mass Index.

biochemical parameters, the OM population showed significantly higher levels of TC (OM: 199.00 [52.00] mg/dL versus VG: 172.00 [26.00] mg/dL; U = 893.000; $p < 0.001$), LDL cholesterol (OM: 117.87 ± 34.26 mg/dL versus VG: 99.85 ± 22.54 mg/dL; t = 3.259; $p = 0.001$), and non-HDL cholesterol (OM: 138.00 [56.00] mg/dL versus VG: 116.00 [35.00] mg/dL; U = 1036.000; $p = 0.004$). These differences remained statistically significant after adjusting for confounding factors (TC: adjusted $p < 0.001$, adjusted R2 = 0.140; LDL cholesterol: adjusted $p = 0.003$, adjusted R2 = 0.202; non-HDL cholesterol: adjusted $p = 0.007$, adjusted R2 = 0.153). No other statistically significant differences were found. For a more detailed analysis of biochemical and hemodynamics parameters, cut-off points were applied to fasting glucose, HbA1c, TC, HDL cholesterol, LDL cholesterol, TG, SBP, and DBP data to classify individuals with values higher or lower than recommended. In Fig. 1, it was observed that there were no significant differences between dietary patterns. However, the vast majority of OM men showed LDL cholesterol values above the recommended level (OM: 83.30% versus VG: 52.90%; χ^2 = 3.747; $p = 0.053$).

In Table 4, the body composition of each sex was analyzed according to their dietary pattern. It was found that VG men showed significantly lower ALMI values (VG: 7.43 ± 0.80 kg/m^2 versus OM: 8.30 ± 0.90 kg/m^2; t = 3.02; $p = 0.005$), and this difference remained statistically significant after adjusting for confounding factors (adjusted $p = 0.026$; adjusted R^2 = 0.370). No other statistically significant differences in body composition were found between the dietary patterns. For a more detailed analysis of body composition, cut-offs were also applied to fat mass, ALMI, and WC data to classify individuals with values outside the recommended ranges, as shown in Fig. 2. In both sexes, no statistically significant differences were observed. However, it was noted a slightly higher percentage of OM women showed above-recommended values of fat mass (OM: 35.10% versus VG: 15.80%; χ^2 = 3.709; $p = 0.085$) and WC (WC ↑ - OM: 21.60% versus VG: 5.30% and WC ↑↑ - OM: 27.00% versus VG: 21.10%; χ^2 = 3.709; $p = 0.085$). It was also observed that a slightly higher percentage of VG men showed above-recommended values for fat mass (VG: 35.30% versus OM: 11.10%; χ^2 = 2.900; $p = 0.085$).

After analyzing diet quality, we found that high adherence to the MD in OM (OR = 0.861; $p = 0.013$) and high diet quality in VG (OR = 0.590; $p = 0.001$) were shown to be protective factors against a high SCORE2 for 10-year cardiovascular event risk by 41% and 13.9%, respectively, as illustrated in Fig. 3. Additionally, the consumption

	Total Population (*n* = 110)			Men (*n* = 35)			Women (*n* = 75)		
	Omnivorous (*n* = 55)	Vegetarians (*n* = 55)	*p*-value	Omnivorous (*n* = 18)	Vegetarians (*n* = 17)	*p*-value	Omnivorous (*n* = 37)	Vegetarians (*n* = 38)	*p*-value
Energy, kcal	2128.42 (765.80)	1854.76 (679.49)	**0.001**[b]	2128.53 (592.50)	1781.40 (556.42)	**0.014**[b]	2125.10 (929.34)	1859.18 (670.95)	**0.016**[b]
Protein, % TEV	18.51 (4.12)	11.49 (1.95)	**< 0.001**[b]	18.53 (4.93)	11.18 (2.66)	**< 0.001**[b]	18.41 (2.84)	11.66 (1.64)	**< 0.001**[a]
Protein, g/kg of body mass	1.45 (0.66)	0.81 (0.45)	**< 0.001**[b]	1.32 (0.74)	0.64 (0.32)	**< 0.001**[b]	1.46 (0.60)	0.85 (0.47)	**< 0.001**[b]
Carbohydrates	40.08 (9.69)	55.69 (8.08)	**< 0.001**[a]	42.03 (13.02)	54.55 (8.74)	**0.002**[a]	39.13 (7.61)	56.20 (7.83)	**< 0.001**[a]
Complex CHO, % TEV	12.89 (4.20)	19.66 (4.78)	**< 0.001**[a]	13.67 (4.32)	20.48 (4.21)	**< 0.001**[a]	12.51 (4.15)	19.30 (5.02)	**< 0.001**[a]
Simple CHO (sugars), % TEV	16.14 (5.44)	21.42 (9.45)	**< 0.001**[b]	15.07 (6.85)	18.48 (8.87)	0.184[b]	16.62 (3.36)	22.28 (5.73)	**< 0.001**[a]
Dietary fiber	29.26 (16.33)	40.66 (17.16)	**< 0.001**[b]	32.21 (20.61)	41.26 (15.02)	0.072[b]	27.81 (13.59)	40.34 (18.75)	**< 0.001**[b]
Insoluble, g	19.23 (9.82)	27.09 (12.18)	**< 0.001**[b]	21.84 (13.76)	28.10 (9.12)	0.072[b]	17.89 (9.81)	26.96 (12.64)	**< 0.001**[b]
Soluble, g	7.45 (4.38)	10.82 (4.09)	**< 0.001**[b]	7.85 (5.95)	11.02 (3.02)	0.057[b]	7.45 (4.08)	10.60 (5.47)	**< 0.001**[b]
Total fat	43.02 (8.61)	36.28 (8.51)	**< 0.001**[a]	41.59 (10.43)	37.36 (10.03)	0.230[a]	43.72 (7.64)	35.79 (7.83)	**< 0.001**[a]
SFA, % TEV	10.06 (1.99)	6.22 (8.08)	**< 0.001**[b]	9.27 (2.43)	6.22 (2.01)	**< 0.001**[a]	10.29 (2.18)	6.22 (2.28)	**< 0.001**[b]
MUFA, % TEV	22.36 (6.28)	20.37 (5.92)	0.089[a]	21.73 (7.17)	21.14 (6.79)	0.803[a]	22.67 (5.87)	20.02 (5.55)	**0.049**[a]
PUFA, % TEV	7.33 (1.53)	7.08 (1.84)	0.434[a]	7.31 (1.69)	7.54 (1.91)	0.705[a]	7.34 (1.47)	6.87 (1.80)	0.219[a]
Omega 3, g	1.48 (0.78)	0.86 (0.52)	**< 0.001**[b]	1.55 (0.80)	0.86 (0.65)	**0.009**[b]	1.48 (0.86)	0.88 (0.52)	**< 0.001**[b]
Omega 6, g	14.49 (5.99)	13.06 (3.96)	0.146[a]	16.47 (6.85)	14.61 (5.07)	0.372[a]	13.52 (5.36)	12.37 (3.19)	0.262[a]
TFA, % TEV	0.35 (0.17)	0.10 (0.10)	**< 0.001**[b]	0.31 (0.18)	0.10 (0.08)	**< 0.001**[b]	0.36 (0.17)	0.11 (0.14)	**< 0.001**[b]
Dietary cholesterol, mg	344.88 (125.15)	31.39 (94.23)	**< 0.001**[b]	331.55 (176.26)	18.09 (30.14)	**< 0.001**[b]	349.25 (120.41)	42.29 (105.55)	**< 0.001**[b]

Table 2. Macronutrient intake, by sex, according to dietary pattern. Data expressed as mean (SD) or median (IQR), as appropriate. p-values for group comparisons were tested using [a]Student's t-test or [b]Mann–Whitney U, as appropriate. CHO, Carbohydrates; MUFA, Monounsaturated fatty acids; PUFA, Polyunsaturated fatty acids; SFA, Saturated fatty acids; TFA, Trans fatty acids; TEV, Total energy value.

		Total population (*n* = 110)	Omnivorous (*n* = 55)	Vegetarians (*n* = 55)	*p*-value	Adjusted *p*-value*
Cardiovascular risk						
10-year risk, %		2.88 (3.04)	3.16 (3.49)	2.60 (2.50)	0.334[a]	0.573
Low level, % (n)		71.80 (79)	72.70 (40)	70.90 (39)	0.901[c]	0.307
Moderate level, % (n)		21.80 (24)	20.00 (11)	23.60 (13)		
High level, % (n)		6.40 (7)	7.30 (4)	5.50 (3)		
Biochemical parameters						
Fasting glucose, mg/dL		93.00 (12.00)	94.00 (14.00)	92.00 (14.00)	0.190[b]	0.641
HbA1c, %		5.56 (0.38)	5.50 (0.33)	5.62 (0.41)	0.091[a]	0.058
Total cholesterol, mg/dL		182.00 (43.00)	199.00 (52.00)	172.00 (26.00)	**< 0.001**[b]	**< 0.001**
HDL cholesterol, mg/dL	Men	51.09 (11.06)	50.56 (12.59)	51.65 (9.53)	0.775[a]	0.381
	Woman	63.24 (14.88)	64.14 (15.26)	63.45 (13.66)	0.534[a]	0.190
LDL cholesterol, mg/dL		108.86 (30.25)	117.87 (34.26)	99.85 (22.54)	**0.001**[a]	**0.003**
VLDL cholesterol, mg/dL		19.00 (12.00)	18.00 (14.00)	20.00 (11.00)	0.717[b]	0.723
Total cholesterol / HDL, mg/dL		3.27 (1.12)	3.28 (1.33)	3.26 (1.02)	0.444[b]	0.708
Non-HDL cholesterol, mg/dL		123.00 (45.00)	138.00 (56.00)	116.00 (35.00)	**0.004**[b]	**0.007**
Triglycerides, mg/dL		99.00 (73.00)	109.00 (78.00)	99.00 (58.00)	0.517[b]	0.837
Vital signs						
Systolic blood pressure, mmHg		114.50 (18.00)	113.00 (16.00)	115.00 (19.00)	0.595[b]	0.228
Diastolic blood pressure, mmHg		75.50 (16.00)	76.00 (18.00)	75.00 (16.00	0.907[b]	0.956
Mean arterial pressure, mmHg		91.60 (15.56)	90.42 (14.00)	92.13 (16.94)	0.786[b]	0.366
Heart rate, bpm		65.00 (13.00)	65.00 (10.00)	67.00 (13.00)	0.153[b]	0.134

Table 3. Cardiovascular risk, biochemical parameters, and vital signs according to dietary pattern. Data expressed as mean (SD), percentage (n), or median (IQR), as appropriate. p-values for group comparisons were tested using [a]Student's t-test, [b]Mann–Whitney U test, or the [c]Qui-Square with Monte Carlo Simulation test, as appropriate. *For adjusted p-values, model 1 was used. HbA1c, Glycated hemoglobin; HDL, High-density lipoprotein; LDL, Low-density lipoprotein; VLDL, Very low-density lipoprotein.

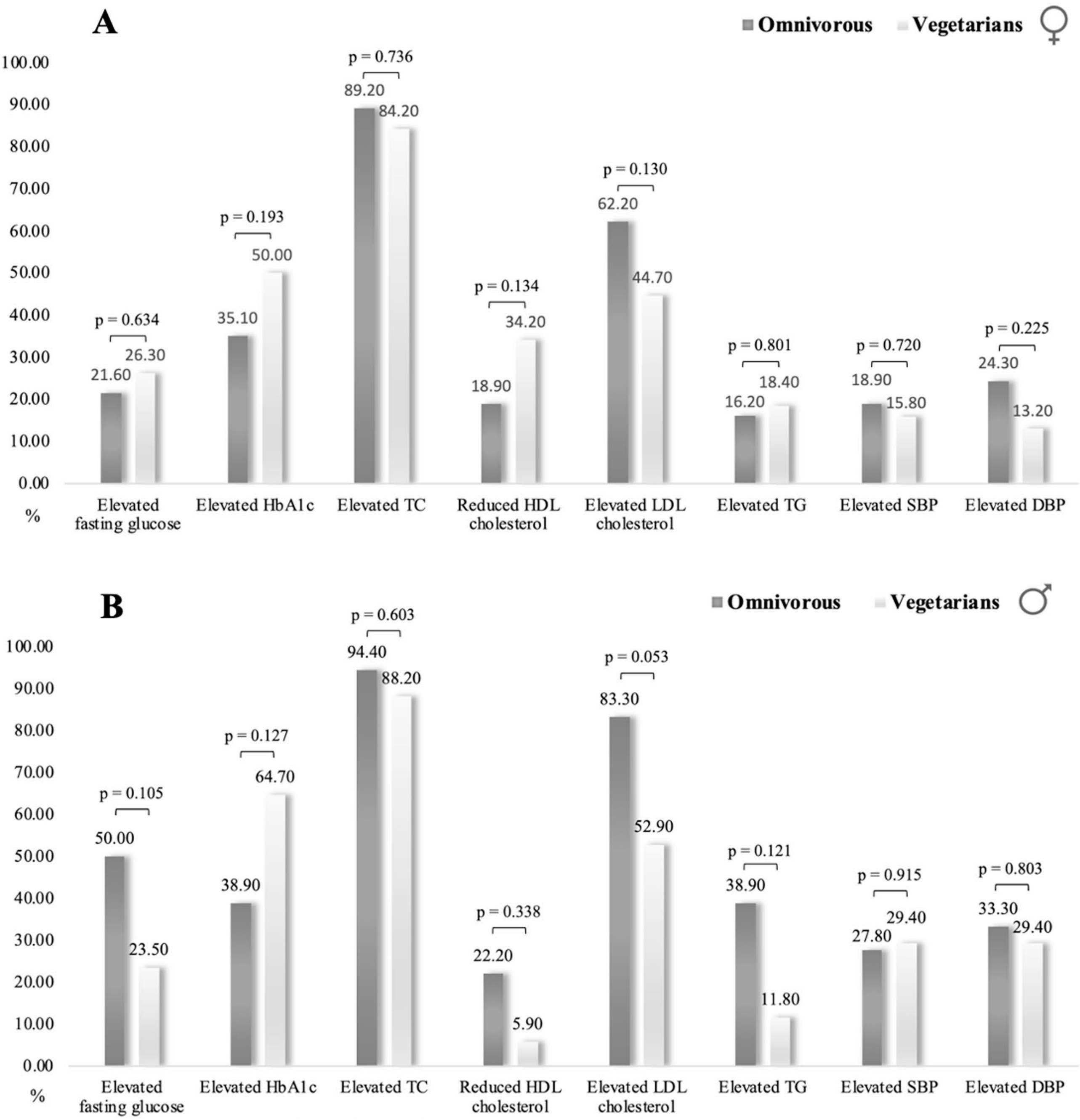

Fig. 1. Analysis of biochemical parameters and vital signs that are above or below recommended levels, in both sexes (**A**: females and **B**: males), according to dietary patterns. DBP, Diastolic blood pressure; HbA1c, Glycated hemoglobin; HDL, High-density lipoprotein; LDL, Low-density lipoprotein; SBP, Systolic blood pressure; TC, Total cholesterol; TG, Triglycerides.

of vegetables (OR = 0.990; $p < 0.001$) and fruit (OR = 0.997; $p = 0.014$) was also shown to be protective factors against a high SCORE2 for 10-year cardiovascular event risk, reducing the risk by 1.00% and 0.30%, respectively.

Conversely, it was observed that the consumption of sweets (OR = 1.016; $p = 0.027$), soft drinks (OR = 1.026; $p < 0.001$), and fast food (OR = 1.021; $p = 0.022$) were risk factors for a high SCORE2 for 10-year cardiovascular event risk, increasing the risk by 1.60%, 2.60%, and 2.10%, respectively. Globally, VG and MD dietary patterns were also considered as protector factors, contributing positively to the cardiovascular risk reduction in 13,90% (OR = 0.590; $p = 0.001$) and 41,00% (OR = 0.590; $p = 0.001$), respectively (data not shown).

To better understand the impact of good adherence to the MD in OM and high diet quality in VG, we re-evaluated body composition, biochemical parameters, and cardiovascular risk between these two groups, as described in Table 5. OM individuals with MD adherence scores ≥ 10 points showed lower fat mass (OM: 25.79 ± 6.51% versus VG: 32.12 ± 6.92%; t = 3.115; $p = 0.003$) and VAT (OM: 338.76 ± 227.72 cm^3 versus VG:

	Total population ($n=110$)				Men ($n=35$)				Woman ($n=75$)			
	Omnivorous ($n=55$)	Vegetarians ($n=55$)	*p*-value	Adjusted *p*-value*	Omnivorous ($n=18$)	Vegetarians ($n=17$)	*p*-value	Adjusted *p*-value*	Omnivorous ($n=37$)	Vegetarians ($n=38$)	*p*-value	Adjusted *p*-value*
Fat mass, %	32.27 (9.22)	31.84 (6.58)	0.781[a]	0.428	25.30 (5.48)	28.69 (5.09)	0.067[a]	0.845	35.65 (8.79)	33.24 (6.75)	0.188[a]	0.586
VAT, cm^3	644.00 (828.00)	610.00 (637.00)	0.475[b]	0.816	978.28 (604.63)	1058.53 (553.96)	0.685[a]	0.587	461.00 (684.00)	429.00 (483.00)	0.270[b]	0.735
SAT, cm^3	1369.93 (817.07)	1256.11 (682.93)	0.430[a]	0.509	1160.00 (635.00)	1482.00 (1157.00)	0.126[b]	0.090	1293.00 (3547)	952.50 (810.00)	0.111[b]	0.074
VAT/SAT ratio, cm^3	0.44 (0.38)	0.46 (0.47)	0.713[b]	0.233	0.64 (0.85)	0.72 (0.39)	0.732[b]	0.493	0.39 (0.23)	0.37 (0.30)	0.735[b]	0.607
FFM, %	67.73 (9.22)	68.16 (8.72)	0.782[a]	0.376	74.71 (5.49)	71.32 (5.09)	0.068[a]	0.370	64.34 (8.79)	66.74 (6.76)	0.188[a]	0.499
Bone mass, %	3.59 (0.59)	3.59 (0.51)	1.000[a]	0.166	3.84 (0.41)	3.75 (0.46)	0.506[a]	0.491	3.46 (0.64)	3.51 (0.53)	0.690[a]	0.254
Lean mass, %	64.15 (8.72)	64.57 (6.23)	0.770[a]	0.408	70.86 (5.26)	67.57 (4.82)	0.063[a]	0.340	60.88 (8.23)	63.23 (6.38)	0.171[a]	0.430
BMD, g/cm^2	1.18 (0.13)	1.13 (0.12)	0.089[a]	0.096	1.28 (0.13)	1.21 (0.11)	0.102[a]	0.290	1.13 (0.20)	1.11 (0.11)	0.306[a]	0.208
ALMI, kg/m^2	6.72 (1.91)	6.63 (1.54)	0.110[b]	0.155	8.30 (0.90)	7.43 (0.80)	**0.005**[aa]	**0.026**	6.22 (0.86)	5.99 (1.10)	0.324[b]	0.464

Table 4. Body composition in each sex, according to their dietary pattern. Data were expressed as mean (SD) or median (IQR), as appropriate. p-values for group comparisons were tested using the [a]student's t-test or [b]Mann–Whitney U test, as appropriate. *For adjusted p-values, model 2 was used. ALMI, Appendicular Lean Mass Index; BMD, Bone Mineral Density; FFM, Fat-Free Mass; SAT, Subcutaneous Adipose Tissue; VAT, Visceral Adipose Tissue.

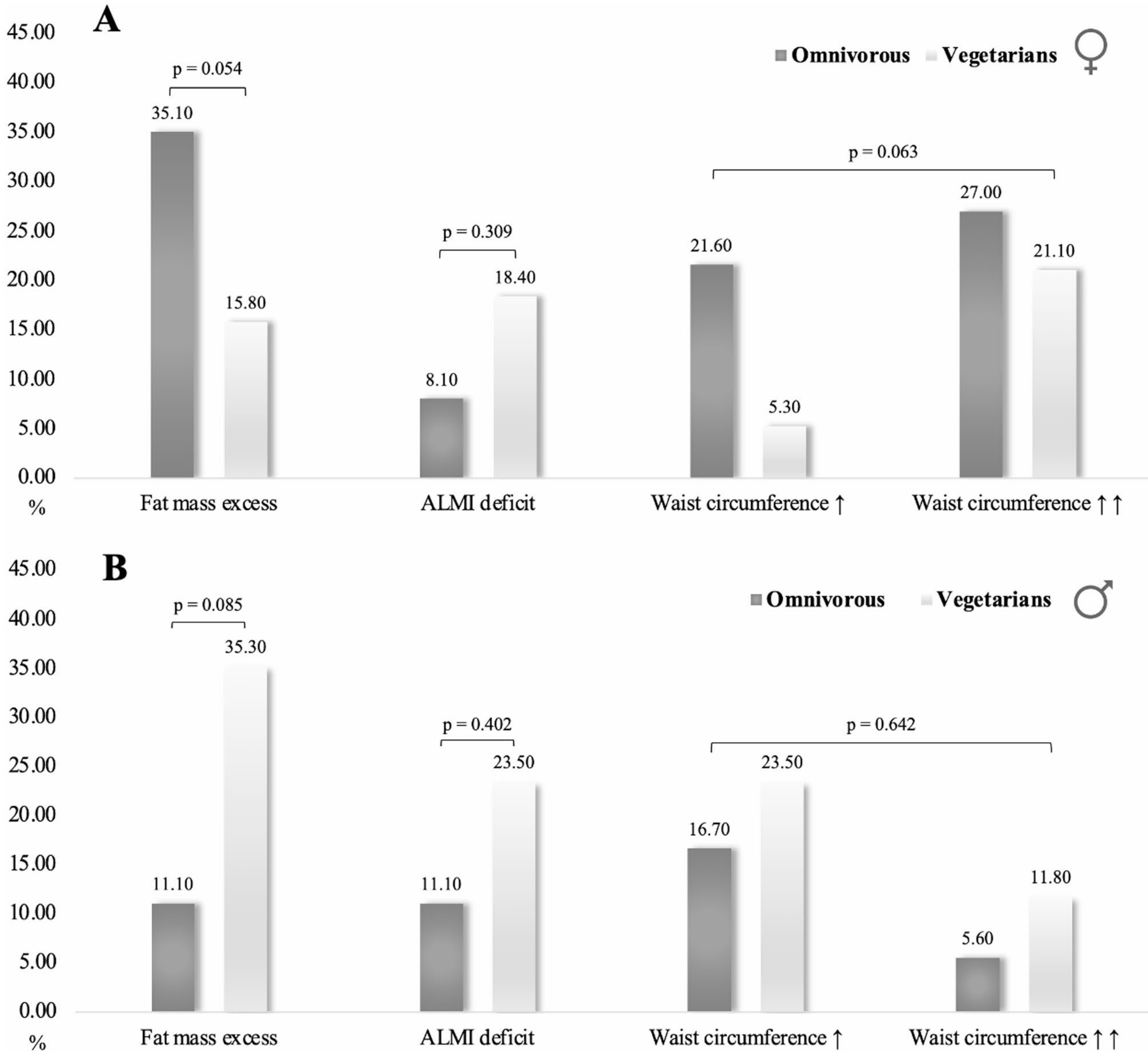

Fig. 2. Analysis of body composition that are above or below recommended levels, in both sexes (**A**: females and **B**: males), according to dietary patterns. ALMI, Appendicular Lean Mass Index. ↑ - Increased; ↑↑ - Substantially increased.

609.04 ± 477.22 cm^3; t = 2.360; $p = 0.023$). VG individuals with a hPDI score ≥ 52 showed lower TC (OM: 198.05 ± 42.17 mg/dL versus VG: 173.48 ± 16.80 mg/dL; t = -2.581; $p = 0.013$). These results remained statistically significant after adjusting for confounding factors (adjusted $p < 0.050$). Regarding the 10-year cardiovascular event risk, no differences were observed between the groups ($p = 0.617$). However, it seems that both dietary patterns negatively contributed to cardiovascular risk.

Discussion

The main objective of the present study was to compare cardiovascular risk between adult individuals who followed a VG dietary pattern or an OM dietary pattern. After analyzing the 10-year risk of cardiovascular events (fatal and non-fatal), it was found that there were no statistically significant differences ($p = 0.334$) between the dietary patterns. In our study, both groups exhibited a very low average cardiovascular risk (OM: 3.16 ± 3.49% versus VG: 2.60 ± 2.50%; $p = 0.334$). Divergent results were observed in other studies, where VG individuals showed significantly lower cardiovascular risk compared to OM individuals[40–43]. A meta-analysis of prospective cohort studies evaluating CVD mortality between VG and OM also reported a significantly lower relative risk of ischemic heart disease in VG individuals[13].

The reasons for the differences between our results and the existing scientific literature are not clear. However, it was possible to verify that there were no statistically significant differences in the sociodemographic characteristics of the two groups, with the majority of participants being non-smokers (76.40%; $p = 0.435$). It

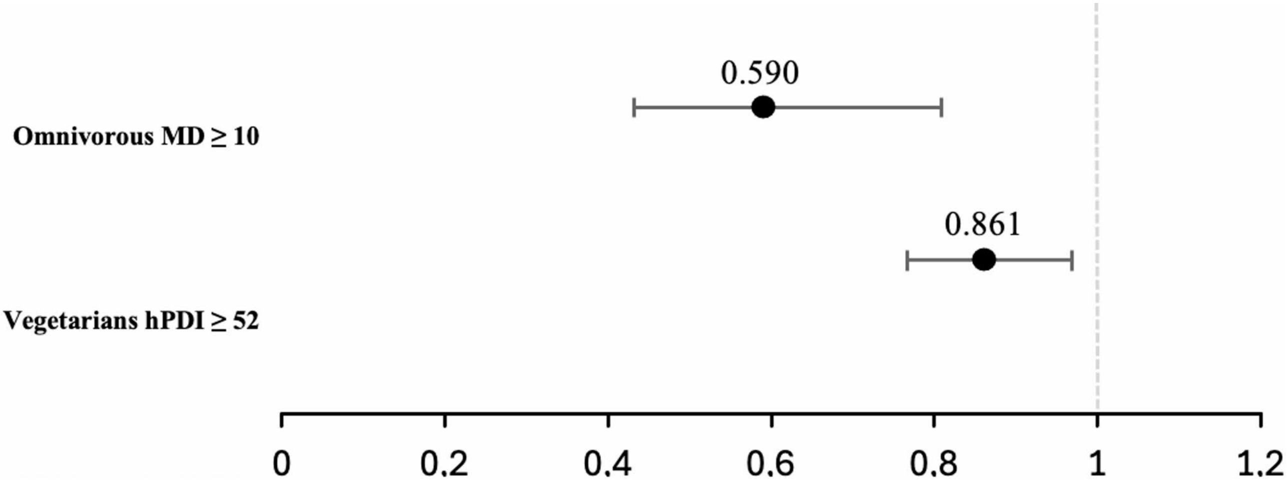

Fig. 3. Assessment of cardiovascular risk based on diet quality. Results of the binary logistic regression. hPDI, healthful plant-based diet index; MD, Mediterranean diet.

	Omnivorous MD ≥ 10 (*n* = 21)	Vegetarians hPDI ≥ 52 (*n* = 23)	*p*-value	Adjusted *p*-value*
Body composition				
Fat mass, %	25.79 (6.51)	32.12 (6.92)	**0.003**[a]	< **0.001**
VAT, cm^3	338.76 (227.72)	609.04 (477.22)	**0.023**[a]	**0.009**
VAT / SAT ratio, cm^3	0.53 (0.66)	0.51 (0.27)	0.889[b]	0.724
ALMI, kg/m^2	6.76 (1.11)	6.37 (0.85)	0.178[b]	0.153
Biochemical parameters				
HbA1c, %	5.48 (0.38)	5.58 (0.37)	0.371[a]	0.485
Total cholesterol, mg/dL	198.05 (42.17)	173.48 (16.80)	**0.013**[a]	**0.009**
LDL cholesterol, mg/dL	110.65 (34.79)	94.52 (19.50)	0.062[a]	0.336
Non-HDL cholesterol, mg/dL	133.43 (41.28)	115.39 (18.03)	0.063[a]	0.316
Cardiovascular risk				
10-year risk, %	1.40 (0.80)	1.50 (0.90)	0.617[b]	0.787

Table 5. Body composition, biochemical parameters, and cardiovascular risk according to high adherence to the Mediterranean diet and high quality of vegetarian diet. Data expressed as mean (SD) or median (IQR), as appropriate. p-values for group comparisons were tested using [a] Student's t-test or the [b] Mann–Whitney U test, as appropriate. *For adjusted p-values, model 1 or model 2 were used, as appropriate. ALMI, Appendicular lean mass index; HbA1c, Glycated hemoglobin; HDL, High-density lipoprotein; hPDI, healthful plant-based diet index; LDL, Low-density lipoprotein; MD, Mediterranean diet; SAT, Subcutaneous adipose tissue; VAT, Visceral adipose tissue.

is known that smoking, followed by hypertension, is the main risk factor for cardiovascular diseases and years lived with disability[36] and has a substantial impact on SCORE2 results. This helps to better understand the low risk found in our population. It should also be noted that the methodology used in the present study is slightly different from the others cited, and the widespread use of the Framingham Risk Score in most studies makes it difficult to reliably compare our results to other publications. Our use of SCORE2 was deliberate, as it has been properly validated for the European population and is the first score to individually assess the level of cardiovascular risk in each European country[36,44]. We know that individuals without cardiovascular disease can suffer from subclinical atherosclerosis, thus presenting an increased risk for atherosclerotic cardiovascular events[44]. Cardiovascular risk scores thus allow us to monitor these types of individuals and intervene quickly, thus preventing the occurrence of more serious events[44].

Regarding the biochemical parameters, it was found that VG individuals had lower levels of TC ($p < 0.001$), LDL cholesterol ($p = 0.001$), and non-HDL cholesterol ($p = 0.004$). These values remained statistically significant ($p < 0.05$) after adjusting for confounding factors.

A meta-analysis of randomized clinical trials published in 2023 supports the findings in our study, as VG individuals showed a reduction of approximately 7% and 10% in TC and LDL cholesterol levels, respectively[45]. This suggests that a VG diet may have a beneficial effect on lipid profile and could be a viable alternative for individuals with hypercholesterolemia.

The most plausible arguments for the difference found between VG and OM regarding TC and LDL cholesterol seem to be the higher dietary intake of saturated fatty acids, trans fatty acids, and dietary cholesterol by OM individuals, as well as a lower intake of dietary fiber since all these nutrients (except fiber) have a well-known potential to increase cholesterol levels[38]. Studies with a Mendelian randomization design have demonstrated that prolonged exposure to lower levels of LDL cholesterol is associated with a lower risk of cardiovascular events compared to shorter exposure[46,47]. These results corroborate the dyslipidemia guidelines of the ESC, published in 2019, which contradicted the “LDL cholesterol hypothesis” based on evidence establishing a causal relationship between LDL cholesterol and atherosclerotic CVD by emphasizing irrefutable[38].

In this study, in addition to a direct analysis of the raw values of biochemical parameters, a secondary analysis was conducted to verify whether the individuals under study had values above or below the recommended values. It was found that there was no significant difference between the different dietary patterns in both sexes ($p > 0.05$). Although the raw values of TC and LDL cholesterol were significantly different between the dietary patterns practiced, both lost statistical significance when inadequacy was evaluated.

Considering the previously described importance of LDL cholesterol in cardiovascular health, it is also important to note that the cut-off point used to assess TC is quite stringent, as its objective is to classify a lipid profile of excellence, as defined by the ESC[38]. This becomes evident when we observe that despite our sample consisting of healthy individuals, the majority showed higher TC and LDL cholesterol values.

Regarding body composition, it was found that VG men showed significantly lower ALMI values (VG: 7.43 ± 0.80 kg/m^2 versus OM: 8.30 ± 0.90 kg/m^2, $p = 0.005$). This difference remained statistically significant ($p = 0.026$) after adjusting for confounding factors, demonstrating that dietary pattern predicts ALMI values independently of age, BMI, energy intake per kg of body mass, level of physical activity, smoking habits, household income, and education level.

Similar results were found in a pilot study by Vanacore et al.., where individuals following a strict VG diet showed significantly lower values of lean mass and muscle mass[48]. It is believed that these results may be associated with low leucine consumption, an essential branched-chain amino acid responsible for muscle protein synthesis[49]. Leucine levels tend to be lower in individuals following a VG diet due to their low or no consumption of high-biological value proteins[48,49]. In the present study, it was observed that VG men had a significantly lower protein intake, both as a percentage of total energy intake (VG: 11.18 [2.66] % versus OM: 18.53 [4.93] %, $p < 0.001$) and as grams per kilogram of body mass (VG: 0.64 [0.32] g/kg versus OM: 1.32 [0.74] g/kg, $p < 0.001$), with this low protein intake being one of the justifications for the results found. This justification was confirmed, as a post hoc analysis revealed that when protein intake was added to the confounding factors, the dietary pattern was no longer predictive of ALMI value ($p = 0.099$, data not shown).

However, some studies have contradicted the previously mentioned results, showing that VG individuals exhibit similar values to OM individuals regarding lean mass[50], vastus lateralis muscle thickness[51], and muscle mass[52].

As for the biochemical parameters, cut-offs were also applied to body composition to determine if each individual's values were above or below the recommended values. It was found that there was no significant difference between the different dietary patterns in both sexes ($p > 0.050$). It was also observed that although males exhibited lower raw ALMI values in the VG group, the ALMI deficit was not significantly different between the two dietary patterns ($p = 0.402$), though the percentage of individuals with a deficit was slightly higher (OM: 11.10% versus VG: 23.50%).

We note, however, that Kim et al.. demonstrated that reduced ALMI values were associated with an increased risk of CVD[53], emphasizing the need to better understand the impact of these findings on the cardiovascular health of VG individuals.

To better understand the impact of dietary patterns on cardiovascular health, we analyzed whether diet quality would impact cardiovascular risk. It was found that both a high-quality VG diet (OR = 0.861; $p = 0.013$) and a high-quality OM diet (OR = 0.059; $p = 0.001$) are protective factors for a high-risk SCORE2.

VG diets have been associated with protective effects on cardiovascular health[12,54–58], especially concerning ischemic heart disease[12,54–57]. However, there is currently a lack of consensus regarding the definition of vegetarianism, with some studies defining it as the avoidance of all animal-derived protein sources except eggs and dairy[12,54–56], while others adopt a less strict definition, allowing occasional consumption of fish and/or meat[57,58]. Therefore, it is essential to reach a consensus on the correct definition of a VG diet for better reproducibility and comparison of findings across studies.

In the present study, after observing that the quality of both diets was a protective factor for cardiovascular risk, we examined the differences in body composition, biochemical parameters, and cardiovascular risk between individuals with high adherence to the MD and individuals with high quality of the VG diet.

Regarding body composition, fat mass (OM: 25.79 ± 6.51% versus VD: 32.12 ± 6.92%; $p = 0.003$) and VAT (OM: 338.76 ± 227.72 cm^3 versus VD: 609.04 ± 477.22 cm^3; $p = 0.023$) were significantly different between the two high-quality dietary patterns. Regarding biochemical parameters, only TC was significantly different between the two high-quality dietary patterns (OM: 198.05 ± 42.17 mg/dL versus VD: 173.48 ± 16.80 mg/dL; $p = 0.013$). These results remained statistically significant ($p < 0.05$) after adjustment for confounding factors.

When comparing the effects of the VG diet with the MD diet, studies have shown somewhat contradictory results[14,59–62]. Some studies suggest that a strict VG diet with low lipid content may lead to improvements in body weight, lipid profile, and insulin sensitivity[11,16,59,60,63,64]. However, these studies did not aim to give participants isocaloric diets. Thus, a significantly lower energy intake was observed in the VG diet group, leading to weight loss that cannot be dissociated from the recorded metabolic outcomes, including lipid profile and insulin sensitivity[59].

On the other hand, indicating greater benefits for the MD compared to a VG diet, some studies report the superiority of the MD in terms of apolipoproteins levels[62], increased HDL cholesterol activity in promoting serum cholesterol efflux and preventing cardiovascular system integrity[65,66]. Alvarez et al. also demonstrated that high adherence to quality dietary patterns led to lower prevalences of obesity, hypertension, and dyslipidemia, with special emphasis on the MD[61]. However, in the multivariate analysis, only obesity remained significant[61]. Such data reinforce the results of our study, as individuals with high adherence to the MD showed better outcomes regarding fat mass and VAT. These results are particularly important, especially in light of current knowledge indicating that visceral and ectopic fat are robustly associated with the development of various cardiovascular risk factors such as hypertension, dyslipidemia, insulin resistance, and atherosclerosis[67].

The present study has several strengths. Firstly, it utilizes a validated and recent cardiovascular risk score for the European population, specifically tailored to the overall risk presented by the Portuguese population[36]. Secondly, it employs a method for assessing body composition that demonstrates good precision in a non-clinical population[68]. Lastly, the study conducted a sub-analysis comparing the two dietary patterns while considering diet quality, and it benefited from a wide range of collected data, allowing for adjustment for confounding factors in the inferential analysis.

Limitations identified in this study include (i) sample size and study design; (ii) assessment of biochemical parameters through capillary blood, which prevented the exploration of other biochemical factors such as Omega-3, which has been explored as a factor with some impact on cardiovascular; and (ii) lack of assessment of muscle function, which could have provided more information about the results in relation to muscle mass. Further studies with larger samples and an interventional, randomized design comparing isocaloric and high-quality diets, are needed for a better understanding of the potential benefits of each diet on cardiovascular health.

Conclusion

The present study highlights the significant role of diet quality in modulating cardiovascular risk among individuals following VG and OM dietary patterns. While no substantial differences were found in the 10-year cardiovascular risk scores (SCORE2) between the VG and OM groups, our findings underscore the protective effect of high-quality diets in reducing cardiovascular risk. Specifically, high adherence to the MD in OM individuals and a high-quality plant-based diet in VG individuals was associated with lower cardiovascular risk scores, suggesting that diet quality is a key factor in cardiovascular health.

Moreover, VG individuals exhibited lower levels of total cholesterol (TC), LDL cholesterol, and non-HDL cholesterol, supporting its beneficial effect on lipid profile. Body composition analysis revealed that VG men had significantly lower ALMI levels compared to OM men, which may be attributed to differences in protein intake.

In conclusion, while both VG and OM diets can offer cardiovascular health benefits, it's the quality of the diet that seems to play a crucial role in reducing cardiovascular risk.

Data availability

All data supporting the findings of this study are available in the paper. Further inquiries can be directed to the corresponding author.

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T.F.: data curation, formal analysis, investigation, software, roles/writing - original draft; S.L.: data curation, investigation; M.C.: investigation, methodology, supervision, validation, visualization, writing-review and editing; E.C.: formal analysis, software, writing-review and editing; R.M.: investigation, methodology, resources, validation, visualization, writing-review and editing; L.M.R.: funding acquisition, project administration, resources, visualization, writing-review and editing; C.F.-P.: funding acquisition, project administration, methodology, resources, supervision, validation, visualization, writing-review and editing.

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Declarations

Consent for publication
All authors have read and agreed to the published version of the manuscript.

Competing interests
The authors declare no competing interests.

Ethical approval
The study was conducted following the Declaration of Helsinki and its later amendments or comparable ethical standards, with the approval of the Ethics Committee of the School of Sciences and Health Technologies from *Universidade Lusófona* (EC.ECTS/P05.21). All participants gave their informed consent before their inclusion in the study.

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