nutrients

MDPI

Article

Sex Differences in Dietary Protein Sources, Preferences, and Body Composition: A Cross-Sectional Substitution Analysis

Mauro Lombardo

Department for the Promotion of Human Science and Quality of Life, San Raffaele Open University, Via di Val Cannuta 247, 00166 Rome, Italy; mauro.lombardo@uniroma5.it

Abstract

Background/Objectives: Dietary proteins are widely promoted for weight management and fat-free mass maintenance, yet the morphological correlates of specific protein food matrices and weekly protein diversity remain unclear. **Methods:** In this cross-sectional study of 1694 Italian adults (972 women, 722 men; 41.5 ± 13.5 years), we evaluated body mass index (BMI), fat mass index (FMI), fat-free mass index (FFMI), body fat percentage (FM%), and abdominal circumference (AC) via anthropometry and bioelectrical impedance. Seven protein sources were quantified from 7-day food records, and habitual meat preferences via questionnaire. **Results:** Across weekly protein diversity tiers (≤3, 4–5, and ≥6 sources/week), adjusted ANCOVA models showed no body composition differences in women ($p \geq 0.6181$) or men ($p \geq 0.4747$). In multivariable regressions, each weekly serving of fresh meat or dairy was associated with higher FMI and AC ($p \leq 0.0181$), whereas soy intake and plant protein share showed suggestive inverse associations with adiposity. In statistical iso-frequency substitution models, modeled replacement of fresh meat with soy, eggs, fish, or legumes was associated with lower FMI and AC alongside smaller FFMI differences, whereas processed meat preference was associated with larger AC (+3.27 cm, $p = 0.0035$) and FMI (+0.97 kg/m^2, $p = 0.0021$). **Conclusions:** Qualitative protein matrix substitution, rather than numerical source variety, is associated with favorable body composition.

Keywords: dietary protein; fat mass index; fat-free mass index; abdominal obesity; protein diversity; plant protein; substitution analysis; two-compartment body composition

1. Introduction

Body composition—specifically the relative distribution of adipose tissue versus fat-free mass (which encompasses skeletal muscle, visceral organs, bone mineral, and body water)—is a far more accurate predictor of insulin resistance, cardiometabolic morbidity, and premature mortality than the body mass index (BMI) alone [1,2]. Because BMI does not distinguish between fat mass and fat-free mass, nor does it provide information on the regional distribution of fat, compartmental indices normalized for height—such as the Fat Mass Index (FMI) and the Fat-Free Mass Index (FFMI), alongside waist circumference—offer essential clinical insight for defining the phenotype of excess adiposity and "normal-weight obesity" [3,4].

Dietary proteins modulate satiety, diet-induced thermogenesis, and muscle protein synthesis; consequently, protein intake is a primary target in body weight management [5,6]. However, decades of nutritional epidemiology research demonstrate that the metabolic effects of protein-rich foods cannot be reduced solely to their nitrogen content or amino

Check for updates

Academic Editors: Javier Gómez-Ambrosi and Victoria Catalán

Received: 14 November 2026
Revised: 24 November 2026
Accepted: 25 November 2026
Published: 29 November 2026

Copyright: © 2026 by the author. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

acid profile [7,8]. Protein sources of animal origin—including fresh red and white meats, processed meats, fish, eggs, and dairy—and those of plant origin—such as legumes and soy—exist within distinct food matrices. These matrices differ significantly in their composition regarding saturated fatty acids, heme iron, sodium, nitrites, dietary fiber, isoflavones, and fats added during culinary preparation [9,10]. Consequently, the prolonged reliance on various protein sources can influence energy balance and the distribution of body tissues in opposing directions [11,12].

In the field of clinical nutrition, two practical issues remain poorly understood. First, although nutritional guidelines traditionally recommend consuming a wide variety of foods, the American Heart Association has cautioned that increasing the number of different foods—without considering their nutritional quality—can inadvertently lead to greater exposure to energy-dense foods, thereby promoting weight gain [13]. It has yet to be determined whether consuming a greater variety of protein sources over the course of a week can improve compartmental body composition in adults. Second, dietary choices are constrained by a relatively fixed weekly meal structure: adding a serving of fish, legumes, or soy typically necessitates the replacement of another protein-rich dish. Substitution models (known as "leave-one-out" substitution models), developed within the field of nutritional epidemiology, allow researchers to statistically simulate the cross-sectional morphological differences associated with replacing one specific protein source with another while keeping the overall serving frequency of intake constant [14,15]. It is also essential to account for biological sex, given the marked sexual dimorphism in the baseline distribution of fat mass versus fat-free mass, as well as culturally influenced differences in preferences for animal- versus plant-based proteins [16,17]. In this study, we evaluated the weekly intake frequencies of seven major protein sources, the overall diversity of protein sources on a weekly basis, statistically modeled iso-frequency substitutions, and habitual meat preferences in relation to FMI, FFMI, total body fat mass percentage (FM%), AC, and BMI in a large cohort of Italian adults, examining associations both for the entire population and stratified by sex.

2. Materials and Methods

2.1. Study Design and Participants

This cross-sectional study was conducted at a clinical nutrition and obesity center in Rome, Italy, affiliated with San Raffaele Open University. From an initial clinical registry of 1815 consecutive patients (1043 females, 772 males) evaluated during baseline medical consultations, we excluded 85 individuals younger than 18 years and 2 records lacking age information, yielding 1728 eligible adults (994 females, 734 males). We then excluded 33 adults (21 females, 12 males) with incomplete anthropometric or bioelectrical impedance measurements (fat mass, fat-free mass, or abdominal circumference) and 1 female adult who had complete anthropometric data but missing 7-day food record entries for eggs, legumes, and soy, resulting in a final complete-case analytical sample of 1694 adults (972 females and 722 males; Figure 1). All participants completed an online dietary and lifestyle questionnaire in Italian prior to their initial clinical visit and provided written informed consent. The study adhered to the Declaration of Helsinki, received approval from the Lazio Area 5 Territorial Ethics Committee (approval code: N.57/SR/23; approval date: 7 November 2023), and was registered on ClinicalTrials.gov (ID: NCT06654674).

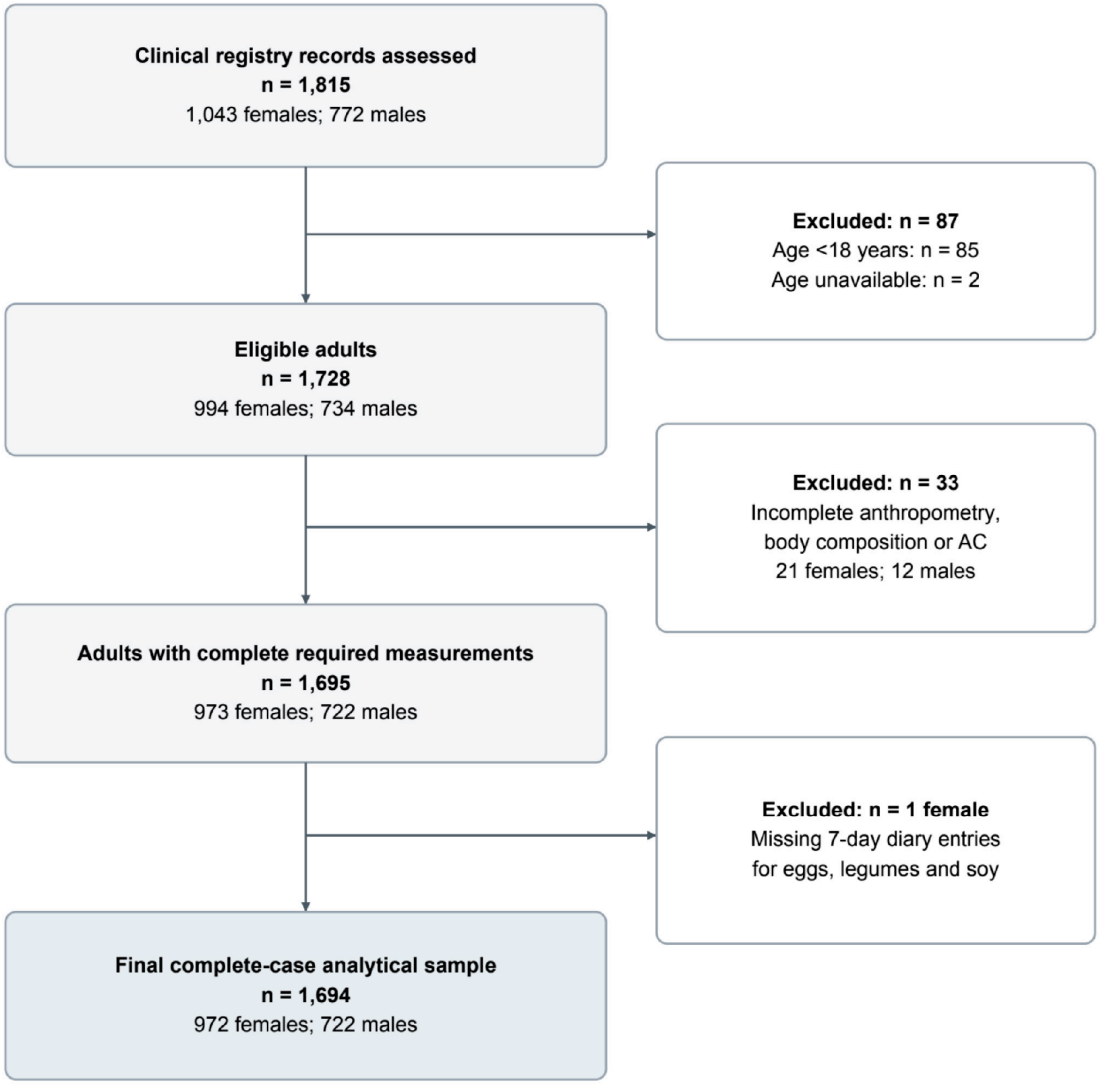


Figure 1. Participant selection and screening flow diagram from the initial clinical registry (N = 1815) to the final complete-case adult analytical sample (N = 1694). Abbreviations: BIA, bioelectrical impedance analysis.

2.2. Dietary Assessment: Structured Food Preference Questionnaire and 7-Day Food Records

Habitual dietary attitudes and actual weekly protein consumption were assessed through a two-stage protocol combining our self-developed food preference questionnaire with clinician-reviewed 7-day food records, following methodologies established across our prior cohort studies [18]. The self-developed instrument is a structured, self-administered electronic questionnaire completed by patients prior to their initial clinical consultation to capture habitual food acceptance and long-term dietary orientation across core food groups. Bilingual questionnaire responses were harmonized into three ordered preference levels: "Yes" ("Yes" or "SI", scored 1.0), "Reluctantly" ("Reluctantly" or "Se proprio devo...", scored 0.5), and "No/Unfamiliar" ("No", "NO", "Don't know", or "Non so cosa sia", scored 0.0). The instrument captured preferences for dairy items (cow's milk, low-fat white yogurt, fresh cheeses), plant-based alternatives (plant drinks, tofu), eggs, fish, legumes, processed meats (such as cured ham/prosciutto), cooked and raw vegetables, fruits, whole grains, and nuts. In an expanded version of the questionnaire completed by 1021 adults, fresh meat preference was further separated into white meat (poultry) and red meat. Habitual daily water intake (L/day), daily consumption of sugary beverages or added sugars (servings/day), and weekly frequency of alcoholic beverage intake (times/week) were also recorded. Although

the self-developed questionnaire has not undergone formal test–retest reliability testing or external psychometric validation, it has been consistently deployed across multiple published clinical cohorts [18] and demonstrated strong internal behavioral concordance against independently collected 7-day food records across all paired protein categories (all Kruskal–Wallis $p < 0.0001$; Supplementary Table S1).

During the baseline clinical evaluation, a qualified nutritionist reviewed each participant's structured 7-day food record to quantify actual weekly consumption frequencies (servings/week) across seven dietary protein categories—fresh meat, processed meat, fish, eggs, dairy products, legumes, and soy products—standardized against Italian reference portion sizes (Reference Intake Levels of Nutrients and Energy [LARN]/Council for Agricultural Research and Economics [CREA] guidelines; e.g., ~100–150 g for fresh meat or fish, 50 g for cured/processed meats, 1 medium egg [~55–60 g], 125 mL milk/yogurt or 50–100 g fresh/aged cheese, 50 g dry or 150 g cooked legumes, and 100 g tofu/tempeh or 200 mL soy drink). Composite or mixed dishes (such as pasta with legumes or meat ragù) were assigned to the corresponding protein category whenever the protein ingredient reached at least half of a standard serving. Importantly, the 7-day food records were designed to quantify standardized weekly serving frequencies rather than weighed gram intakes linked to nutrient composition tables; therefore, total daily energy intake (kcal/day), absolute and body-weight-normalized protein intake (g/day and g/kg/day), total carbohydrate and fat intakes, saturated fatty acid intake, and dietary fiber intake were not collected. From these diary counts, we derived four composite metrics: total weekly protein occasions (sum of weekly servings across all seven categories), weekly protein source diversity (count from 0 to 7 of distinct protein sources consumed at least once per week, categorized into Low [≤3 sources/week], Moderate [4–5 sources/week], and High [≥6 sources/week] diversity), plant protein share (legumes plus soy servings expressed as a percentage of total weekly protein occasions), and processed meat share (processed meat servings expressed as a percentage of total weekly protein occasions).

2.3. Anthropometric and Body Composition Assessment

Anthropometric and body composition measurements were performed in the morning after an overnight fast, with participants barefoot and wearing minimal clothing. Body weight was recorded to the nearest 0.1 kg on a calibrated electronic scale, and standing height was measured to the nearest 0.1 cm with a wall-mounted stadiometer with the head aligned in the Frankfurt plane. BMI was calculated as weight (kg) divided by height squared (m^2). Abdominal circumference (AC) was measured to the nearest 0.5 cm at the midpoint between the lower costal margin and the iliac crest at the end of normal expiration.

Body composition was determined by single-frequency (50 kHz), tetrapolar foot-to-foot bioelectrical impedance analysis (BIA) using a Tanita BC-420 MA analyzer (Tanita Corporation, Tokyo, Japan), which has been validated against dual-energy X-ray absorptiometry (DXA) and multi-compartment reference models in adults [19]. The device measures whole-body electrical impedance (Z) and estimates fat mass (FM) and total body fat percentage (FM%) using the manufacturer's proprietary sex-, age-, height-, and weight-specific regression prediction equations calibrated against DXA reference standards [19]. To standardize hydration status, participants were instructed to fast for at least 3 h, refrain from strenuous physical exercise for 12 h, and avoid excessive fluid or alcohol consumption the evening before testing; premenopausal women were evaluated outside the menstrual phase. To ensure strict two-compartment mass conservation (FM + FFM = body weight and FMI + FFMI = BMI), fat-free mass was computed as FFM (kg) = body weight (kg) − FM (kg), and height-normalized indices were calculated as FMI = FM (kg)/height $(m)^2$ and FFMI = FFM (kg)/height $(m)^2$ [3]. Because two-compartment FFM represents the sum of

all non-fat body constituents—including skeletal muscle, visceral organs, bone mineral, and intracellular and extracellular water—FFMI reflects total fat-free tissue mass and should not be interpreted as a direct measure of skeletal muscle mass. Abdominal obesity was defined using thresholds of AC > 80 cm in females and AC > 94 cm in males [20]. Normal-weight obesity (NWO) was defined as BMI < 25.0 kg/m^2 paired with elevated body fat percentage (>35.0% in females and >25.0% in males) [21].

2.4. Sociodemographic and Lifestyle Covariates

Demographic and lifestyle covariates included age (years), annual household income (<€20,000; €20,000–€40,000; €40,000–€60,000; >€60,000; or not reported), employment status (paid employment, retired, unemployed, or not reported), and current smoking status (yes/no). Physical activity was characterized by regular sport participation (yes/no), weekly training volume (0 h/week, <5 h/week, 5–10 h/week, or >10 h/week), and primary sport modality. To account for distinct mechanical loading and energy-expenditure profiles, reported sports were classified into five functional categories: sedentary, resistance/strength training (e.g., bodybuilding, CrossFit, functional training, calisthenics), aerobic/endurance training (e.g., running, swimming, cycling, brisk walking), mind–body/low-impact disciplines (e.g., Pilates, yoga), and mixed/team sports.

2.5. Statistical Analysis

All analyses were conducted in Python (version 3.11) using the scipy.stats and statsmodels libraries. Continuous variables are reported as mean ± standard deviation (SD) and categorical variables as counts and percentages, n (%). Sex differences at baseline were tested using Mann–Whitney U tests for continuous variables and Pearson's chi-square (χ^2) tests for categorical variables. Behavioral concordance between harmonized preference categories on the self-developed questionnaire (No/Unfamiliar, Reluctantly, Yes) and observed 7-day diary servings was evaluated using Kruskal–Wallis tests (Supplementary Table S1).

Primary outcomes were defined a priori as FMI, FFMI, and AC, whereas FM%, BMI, abdominal obesity, and NWO were evaluated as secondary/exploratory outcomes. Differences in FMI, FFMI, FM%, AC, and BMI across weekly protein diversity tiers (≤3, 4–5, and ≥6 sources/week) were examined separately in females and males via unadjusted one-way analysis of variance (ANOVA) and multivariable analysis of covariance (ANCOVA) adjusted for age, income, employment status, smoking, sport modality, weekly sport volume, habitual preference/intake of cooked and raw vegetables, fruits, whole grains, and nuts, daily water intake, weekly alcohol intake, and daily sugary drinks; linear trends across continuous protein diversity were evaluated within the same fully adjusted model. Hierarchical multivariable linear regressions were then fitted for each protein exposure in relation to body composition outcomes: Model 1 adjusted for age and sex; Model 2 further adjusted for income, employment, smoking, sport modality, and weekly sport hours; and Model 3 (fully adjusted) additionally controlled for all background dietary indicators (Supplementary Table S2). Benjamini–Hochberg false discovery rate (FDR) q-values were computed across the 30 primary exposure–outcome models to account for multiple testing. Multiplicative protein-by-sex interaction terms were tested, and sex-stratified Model 3 regressions were estimated (Supplementary Table S3). Because soy consumption was right-skewed (9.9% consumers, n = 167), robustness was verified in sensitivity analyses modeling binary consumer status (>0 vs. 0 servings/week) and winsorizing intakes at ≥4 servings/week.

To statistically evaluate dietary displacement while keeping total weekly protein occasions fixed, pooled iso-frequency substitution models were constructed using a leave-one-out parameterization [22]. Specifically, total weekly protein occasions and six of the

seven individual protein sources were entered simultaneously into Model 3 while omitting fresh meat, so that the regression coefficient for each included protein source estimates the cross-sectional difference in body composition statistically associated with substituting 1 serving/week of that source for 1 serving/week of fresh meat. Because total daily energy intake (kcal/day) and macronutrient quantities (g/day) were not measured, this model represents a cross-sectional statistical substitution simulation on an equal-serving-frequency basis rather than an isocaloric or isoprotein dietary substitution, and is not equivalent to a real-world clinical dietary intervention. Finally, multivariable logistic regressions estimated adjusted odds ratios (aOR) and 95% confidence intervals (CI) for abdominal obesity (adjusted for all Model 3 covariates) and NWO (n = 27 events; parsimoniously adjusted for age, sex, smoking, regular sport participation, vegetables, fruits, and sugary drinks to preserve event-per-variable stability), and multivariable linear models evaluated habitual preferences for white meat, red meat, and processed meat modeled as a three-level ordered score (0 = No/Unfamiliar, 0.5 = Reluctantly, 1.0 = Yes), such that β estimates the full contrast between "Yes" and "No/Unfamiliar" across all available respondents (n = 1021 for white and red meat; N = 1694 for processed meat, including n = 85 "Reluctantly" respondents scored at 0.5). Two-sided p-values < 0.05 were considered statistically significant.

3. Results

3.1. Study Population, Baseline Characteristics, and Questionnaire Concordance

After excluding 85 minors (<18 years), 2 records missing age, 33 adults (21 females, 12 males) with incomplete body composition or abdominal circumference measurements, and 1 female adult with incomplete 7-day food record entries (eggs, legumes, and soy) from the initial 1815 screened records (Figure 1), the final complete-case cohort comprised 1694 adults: 972 females (57.4%) and 722 males (42.6%), with a mean age of 41.53 ± 13.52 years (median 40.0, range 18–83 years). Baseline characteristics stratified by sex are summarized in Table 1. Compared with males, females were slightly older (42.25 ± 13.56 vs. 40.57 ± 13.41 years, $p = 0.0115$) and reported lower regular sport participation (49.5% vs. 59.4%, $p < 0.0001$), particularly in resistance/strength training (20.3% vs. 28.3%). Pronounced sexual dimorphism was evident across all anthropometric and body composition measures ($p < 0.0001$ for all): males exhibited higher BMI (28.95 ± 5.12 vs. 27.71 ± 5.25 kg/m^2), two-compartment FFM (66.36 ± 8.62 vs. 46.76 ± 5.62 kg), FFMI (21.36 ± 2.12 vs. 17.69 ± 1.83 kg/m^2), and AC (101.96 ± 14.26 vs. 93.86 ± 13.14 cm), whereas females displayed higher FM% (34.94 ± 7.62% vs. 25.06 ± 7.52%), FMI (10.01 ± 3.91 vs. 7.59 ± 3.49 kg/m^2), sex-specific abdominal obesity (84.4% vs. 68.7%), and normal-weight obesity (2.2% vs. 0.8%, $p = 0.0495$).

In 7-day food records (Table 1), males reported a higher total number of weekly protein occasions than females (10.49 ± 2.90 vs. 8.73 ± 2.58 servings/week, $p < 0.0001$), driven by greater weekly consumption of fresh meat (2.84 ± 1.89 vs. 2.16 ± 1.56 servings/week), processed meat (0.89 ± 1.22 vs. 0.58 ± 0.84 servings/week), and fish (2.65 ± 1.67 vs. 2.11 ± 1.44 servings/week; all $p < 0.0001$). Conversely, females obtained a larger proportion of their weekly protein occasions from plant sources (20.49 ± 17.92% vs. 18.81 ± 18.59%, $p = 0.0038$) and a smaller proportion from processed meat (6.72 ± 9.80% vs. 8.41 ± 11.23%, $p = 0.0069$). Overall weekly protein source diversity averaged 4.27 ± 1.04 sources/week and was virtually identical between females and males (4.25 ± 1.02 vs. 4.28 ± 1.06, $p = 0.6225$). Comparison of harmonized responses on the self-developed food preference questionnaire against observed 7-day diary intake demonstrated strong behavioral concordance across every protein group, with mean weekly servings rising monotonically across No/Unfamiliar, Reluctantly, and Yes categories (Kruskal–Wallis $p < 0.0001$ for all; Supplementary Table S1).

Table 1. Baseline sociodemographic, anthropometric, two-compartment body composition, and 7-day dietary protein characteristics of the complete-case adult study cohort (N = 1694), overall and stratified by sex.

Characteristic	Overall (N = 1694)	Females (n = 972)	Males (n = 722)	*p*-Value
Sociodemographic & Lifestyle Characteristics				
Age (years)	41.53 ± 13.52	42.25 ± 13.56	40.57 ± 13.41	0.0115
Current smoker, n (%)	395 (23.3%)	230 (23.7%)	165 (22.9%)	0.7403
Regular sport participation, n (%)	910 (53.7%)	481 (49.5%)	429 (59.4%)	<0.0001
Resistance/strength modality, n (%)	401 (23.7%)	197 (20.3%)	204 (28.3%)	0.0002
Aerobic/endurance modality, n (%)	318 (18.8%)	188 (19.3%)	130 (18.0%)	0.5264
Anthropometry & Body Composition				
Weight (kg)	80.31 ± 17.80	73.21 ± 14.52	89.87 ± 17.33	<0.0001
Height (m)	1.68 ± 0.09	1.63 ± 0.06	1.76 ± 0.07	<0.0001
BMI (kg/m^2)	28.24 ± 5.23	27.71 ± 5.25	28.95 ± 5.12	<0.0001
Fat mass (kg)	25.20 ± 10.72	26.46 ± 10.43	23.51 ± 10.87	<0.0001
Fat mass percentage (%)	30.73 ± 9.02	34.94 ± 7.62	25.06 ± 7.52	<0.0001
Fat Mass Index (FMI, kg/m^2)	8.98 ± 3.92	10.01 ± 3.91	7.59 ± 3.49	<0.0001
Fat-free mass (kg)	55.11 ± 11.99	46.76 ± 5.62	66.36 ± 8.62	<0.0001
Fat-Free Mass Index (FFMI, kg/m^2)	19.26 ± 2.67	17.69 ± 1.83	21.36 ± 2.12	<0.0001
Abdominal circumference (AC, cm)	97.31 ± 14.20	93.86 ± 13.14	101.96 ± 14.26	<0.0001
Abdominal obesity (IDF criteria), n (%)	1316 (77.7%)	820 (84.4%)	496 (68.7%)	<0.0001
Normal-weight obesity (NWO), n (%)	27 (1.6%)	21 (2.2%)	6 (0.8%)	0.0495
7-Day Food Record Protein Intake & Diversity				
Fresh meat (servings/week)	2.45 ± 1.74	2.16 ± 1.56	2.84 ± 1.89	<0.0001
Processed meat (servings/week)	0.71 ± 1.03	0.58 ± 0.84	0.89 ± 1.22	<0.0001
Fish (servings/week)	2.34 ± 1.57	2.11 ± 1.44	2.65 ± 1.67	<0.0001
Eggs (servings/week)	0.65 ± 0.78	0.61 ± 0.71	0.70 ± 0.87	0.1737
Dairy products (servings/week)	1.42 ± 1.35	1.42 ± 1.27	1.42 ± 1.44	0.2470
Legumes (servings/week)	1.70 ± 1.65	1.65 ± 1.55	1.78 ± 1.77	0.3805
Soy products (servings/week)	0.21 ± 0.79	0.21 ± 0.76	0.20 ± 0.83	0.0914
Total protein occasions (servings/week)	9.48 ± 2.85	8.73 ± 2.58	10.49 ± 2.90	<0.0001
Weekly protein source diversity (0–7)	4.27 ± 1.04	4.25 ± 1.02	4.28 ± 1.06	0.6225
Plant protein share (% of occasions)	19.77 ± 18.23	20.49 ± 17.92	18.81 ± 18.59	0.0038
Processed meat share (% of occasions)	7.44 ± 10.46	6.72 ± 9.80	8.41 ± 11.23	0.0069

Values are mean ± SD for continuous variables and n (%) for categorical variables. From 1728 eligible adults (994 females, 734 males), 33 adults (21 females, 12 males) with missing anthropometric/BIA values and 1 female adult with incomplete 7-day food record entries (eggs, legumes, soy) were excluded, yielding N = 1694 (972 females, 722 males). Fat-free mass is computed via two-compartment mass conservation (FFM = body weight − fat mass, ensuring FM + FFM = weight and FMI + FFMI = BMI). Sex comparisons were evaluated via Mann–Whitney U tests for continuous variables and Pearson's χ^2 tests for categorical variables. Abbreviations: AC, abdominal circumference; BMI, body mass index; FFM, fat-free mass; FFMI, fat-free mass index; FMI, fat mass index; IDF, International Diabetes Federation; NWO, normal-weight obesity.

3.2. Body Composition Across Weekly Protein Source Diversity Tiers

Across the entire cohort, 21.5% of adults (n = 364) consumed ≤3 distinct protein sources per week (Low diversity), 67.1% (n = 1137) consumed 4–5 sources (Moderate diversity), and 11.4% (n = 193) consumed ≥6 sources (High diversity), with no difference in tier distribution between sexes (χ^2 $p = 0.1279$). As detailed in Table 2 and depicted in Figure 2a–d, neither unadjusted ANOVA nor fully adjusted ANCOVA models detected significant differences in FMI, FFMI, FM%, AC, or BMI across protein diversity tiers in either females (p ANCOVA ≥ 0.6181 across all outcomes) or males (p ANCOVA ≥ 0.4747 across all outcomes). When evaluated as a continuous variable, weekly protein diversity showed no linear trend with any body composition metric in females (p trend ≥ 0.6659) and only a borderline positive trend with FM% in males (β = +0.478% per additional source, p trend = 0.0487), indicating that greater numerical diversity across protein sources was not associated with lower adiposity or higher fat-free mass.

Table 2. Sex-stratified body composition indices across weekly protein source diversity tiers (N = 1694).

Outcome by Sex	Low Diversity (≤3 Sources)	Moderate Diversity (4–5 Sources)	High Diversity (≥6 Sources)	*p* ANOVA	*p* ANCOVA	*p* Trend
			Females (n = 972)			
FMI (kg/m^2)	9.92 ± 3.95	10.04 ± 3.81	9.99 ± 4.50	0.9206	0.8448	0.6659
FFMI (kg/m^2)	17.68 ± 2.06	17.68 ± 1.75	17.81 ± 1.84	0.7847	0.6181	0.7721
Fat mass (%)	34.80 ± 7.26	35.08 ± 7.55	34.25 ± 8.80	0.5746	0.8858	0.9568
AC (cm)	93.85 ± 13.91	93.99 ± 12.66	93.02 ± 14.73	0.7933	0.9009	0.9552
BMI (kg/m^2)	27.60 ± 5.50	27.72 ± 5.06	27.80 ± 6.00	0.9361	0.7709	0.6935
			Males (n = 722)			
FMI (kg/m^2)	7.45 ± 3.43	7.64 ± 3.52	7.55 ± 3.42	0.8409	0.6740	0.1110
FFMI (kg/m^2)	21.28 ± 2.14	21.41 ± 2.19	21.24 ± 1.70	0.6510	0.7999	0.4625
Fat mass (%)	24.75 ± 7.54	25.14 ± 7.54	25.16 ± 7.50	0.8438	0.4747	0.0487
AC (cm)	101.88 ± 15.11	101.98 ± 14.20	102.00 ± 13.27	0.9967	0.6879	0.1290
BMI (kg/m^2)	28.73 ± 5.17	29.05 ± 5.20	28.79 ± 4.66	0.7537	0.8105	0.1648

Values are unadjusted mean ± SD. Females: Low n = 207, Moderate n = 665, High n = 100. Males: Low n = 157, Moderate n = 472, High n = 93. ANCOVA and linear trend models (continuous diversity 0–7) are adjusted for age, income, employment status, smoking, sport modality, weekly sport hours, habitual intake/preference of cooked and raw vegetables, fruits, whole grains, and nuts, daily water, weekly alcohol, and daily sugary drinks.

3.3. Multivariable Associations Between Individual Protein Sources and Body Composition

Fully adjusted linear regression estimates (Model 3) for individual weekly protein sources and relative protein shares are presented in Table 3 and Figure 3a–c (with hierarchical Models 1–3 and sex-stratified estimates detailed in Supplementary Tables S2 and S3). Formal multiplicative interaction terms between individual protein sources and sex were non-significant (p interaction ≥ 0.06 for all). Each additional weekly serving of fresh meat was independently associated with higher FMI (β = +0.182 kg/m^2, 95% CI: +0.085 to +0.278, $p = 0.0002$; q FDR = 0.0044), FM% (β = +0.259%, 95% CI: +0.068 to +0.451, $p = 0.0079$), AC (β = +0.737 cm, 95% CI: +0.395 to +1.079, $p < 0.0001$; q FDR = 0.0011), BMI (β = +0.270 kg/m^2, 95% CI: +0.133 to +0.407, $p = 0.0001$), and FFMI (β = +0.089 kg/m^2, 95% CI: +0.035 to +0.143, $p = 0.0014$; q FDR = 0.0136). Higher weekly dairy consumption (+1 serving/week) showed a similar pattern, associating positively with FMI (β = +0.176 kg/m^2, $p = 0.0044$; q FDR = 0.0387), FM% (β = +0.288%, $p = 0.0192$), AC (β = +0.520 cm, $p = 0.0181$; q FDR = 0.0698), and BMI (β = +0.240 kg/m^2, $p = 0.0065$), with a non-significant positive trend for FFMI (β = +0.065 kg/m^2, $p = 0.0618$).

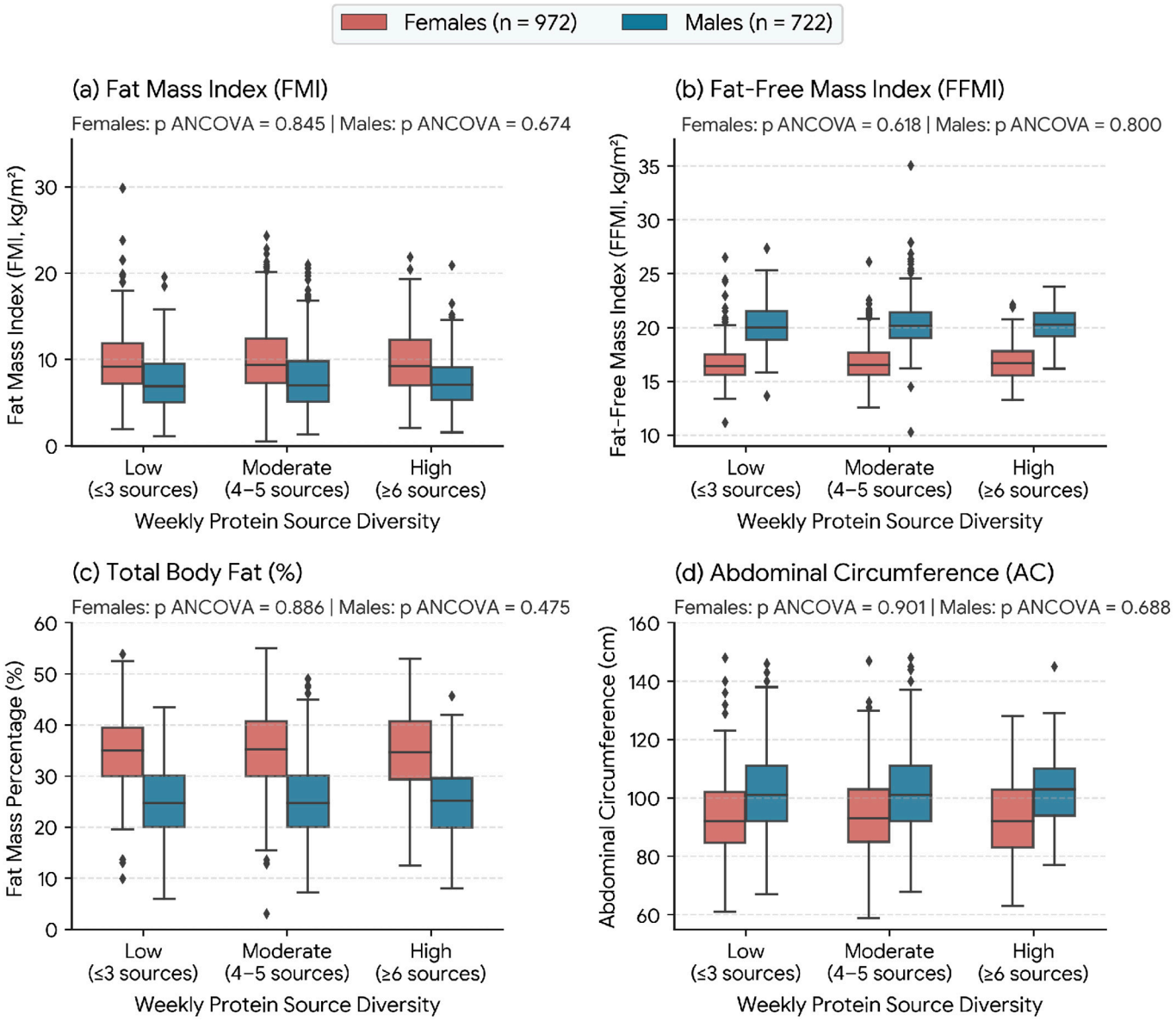


Figure 2. Sex-stratified distributions of (**a**) Fat Mass Index, (**b**) Fat-Free Mass Index, (**c**) Total Body Fat Percentage, and (**d**) Abdominal Circumference across weekly protein source diversity tiers (≤3, 4–5, and ≥6 sources/week) in 1694 adults (972 females, 722 males). Horizontal lines denote medians, boxes denote interquartile ranges (IQRs), whiskers denote 1.5 × IQR, diamond/square markers denote outliers beyond 1.5 × IQR, and p-values derive from fully adjusted ANCOVA models.

Table 3. Fully adjusted multivariable linear regression associations (Model 3) between individual weekly protein sources, protein diversity, and relative protein shares and body composition indices (N = 1694).

Dietary Protein Exposure	FMI (kg/m²) β (95% CI); *p*	FFMI (kg/m²) β (95% CI); *p*	Fat Mass (%) β (95% CI); *p*	AC (cm) β (95% CI); *p*	BMI (kg/m²) β (95% CI); *p*
Fresh meat (+1 serv./wk)	+0.182 (+0.085, +0.278) $p = 0.0002$	+0.089 (+0.035, +0.143) $p = 0.0014$	+0.259 (+0.068, +0.451) $p = 0.0079$	+0.737 (+0.395, +1.079) $p < 0.0001$	+0.270 (+0.133, +0.407) $p = 0.0001$
Processed meat (+1 serv./wk)	+0.124 (−0.037, +0.284) $p = 0.1319$	−0.014 (−0.105, +0.077) $p = 0.7645$	+0.199 (−0.120, +0.518) $p = 0.2221$	+0.215 (−0.357, +0.788) $p = 0.4606$	+0.108 (−0.121, +0.337) $p = 0.3531$

Table 3. *Cont.*

Dietary Protein Exposure	FMI (kg/m²) β (95% CI); *p*	FFMI (kg/m²) β (95% CI); *p*	Fat Mass (%) β (95% CI); *p*	AC (cm) β (95% CI); *p*	BMI (kg/m²) β (95% CI); *p*
Fish (+1 serv./wk)	−0.002 (−0.108, +0.104) $p = 0.9723$	−0.007 (−0.067, +0.053) $p = 0.8248$	+0.022 (−0.188, +0.233) $p = 0.8351$	−0.104 (−0.481, +0.273) $p = 0.5885$	−0.009 (−0.160, +0.142) $p = 0.9100$
Eggs (+1 serv./wk)	−0.208 (−0.418, +0.001) $p = 0.0509$	−0.141 (−0.259, −0.023) $p = 0.0192$	−0.338 (−0.753, +0.077) $p = 0.1106$	−0.726 (−1.470, +0.018) $p = 0.0559$	−0.354 (−0.651, −0.056) $p = 0.0198$
Dairy (+1 serv./wk)	+0.176 (+0.055, +0.298) $p = 0.0044$	+0.065 (−0.003, +0.134) $p = 0.0618$	+0.288 (+0.047, +0.528) $p = 0.0192$	+0.520 (+0.089, +0.952) $p = 0.0181$	+0.240 (+0.067, +0.412) $p = 0.0065$
Legumes (+1 serv./wk)	−0.045 (−0.145, +0.055) $p = 0.3803$	−0.013 (−0.069, +0.044) $p = 0.6642$	−0.098 (−0.296, +0.101) $p = 0.3340$	−0.272 (−0.628, +0.083) $p = 0.1334$	−0.055 (−0.197, +0.088) $p = 0.4517$
Soy (+1 serv./wk)	−0.274 (−0.482, −0.065) $p = 0.0103$	−0.091 (−0.209, +0.027) $p = 0.1298$	−0.650 (−1.064, −0.236) $p = 0.0021$	−0.656 (−1.400, +0.087) $p = 0.0836$	−0.361 (−0.659, −0.064) $p = 0.0172$
Protein diversity (+1 source)	+0.112 (−0.046, +0.270) $p = 0.1635$	+0.043 (−0.046, +0.132) $p = 0.3443$	+0.219 (−0.095, +0.532) $p = 0.1717$	+0.331 (−0.231, +0.894) $p = 0.2484$	+0.152 (−0.073, +0.377) $p = 0.1864$
Plant protein share (+10%)	−0.107 (−0.197, −0.016) $p = 0.0212$	−0.038 (−0.089, +0.013) $p = 0.1483$	−0.207 (−0.387, −0.028) $p = 0.0237$	−0.389 (−0.712, −0.067) $p = 0.0179$	−0.142 (−0.271, −0.013) $p = 0.0312$
Processed meat share (+10%)	+0.088 (−0.069, +0.245) $p = 0.2727$	−0.010 (−0.099, +0.079) $p = 0.8242$	+0.147 (−0.164, +0.459) $p = 0.3536$	+0.151 (−0.408, +0.710) $p = 0.5962$	+0.077 (−0.146, +0.301) $p = 0.4982$

In contrast, weekly soy intake (+1 serving/week) was nominally associated with lower FMI (β = −0.274 kg/m², 95% CI: −0.482 to −0.065, $p = 0.0103$), FM% (β = −0.650%, 95% CI: −1.064 to −0.236, $p = 0.0021$), and BMI (β = −0.361 kg/m², 95% CI: −0.659 to −0.064, $p = 0.0172$), without a significant difference in FFMI (β = −0.091 kg/m², $p = 0.1298$) or AC (β = −0.656 cm, $p = 0.0836$). Sensitivity analyses confirmed that the nominal inverse association of soy with FMI persisted both when modeling binary consumer status (>0 vs. 0 servings/week; β = −0.566 kg/m², $p = 0.0447$) and when winsorizing intakes at ≥4 servings/week (β = −0.299 kg/m², $p = 0.0185$). Egg intake (+1 serving/week) was inversely associated with overall BMI (β = −0.354 kg/m², $p = 0.0198$) and FFMI (β = −0.141 kg/m², $p = 0.0192$). Evaluated proportionally, every +10% increment in the share of plant-derived protein occasions (legumes plus soy) was nominally associated with lower FMI (β = −0.107 kg/m², $p = 0.0212$), lower FM% (β = −0.207%, $p = 0.0237$), smaller AC (β = −0.389 cm, $p = 0.0179$), and lower BMI (β = −0.142 kg/m², $p = 0.0312$), without a statistically significant difference in overall FFMI (β = −0.038 kg/m², $p = 0.1483$). However, after Benjamini–Hochberg false discovery rate adjustment across the 30 primary models, the inverse associations of soy with FMI (q FDR = 0.0698) and of plant protein share with FMI (q FDR = 0.0698) and AC (q FDR = 0.0698) remained suggestive rather than surviving the $q < 0.05$ threshold, whereas the positive associations of fresh meat (q FDR ≤ 0.0136) and dairy with FMI (q FDR = 0.0387) remained statistically significant. Continuous 7-day diary servings of fish ($p \geq 0.5885$), legumes ($p \geq 0.1334$), and processed meat ($p \geq 0.1319$) were not independently associated with body composition indices after full multivariable adjustment (Table 3).

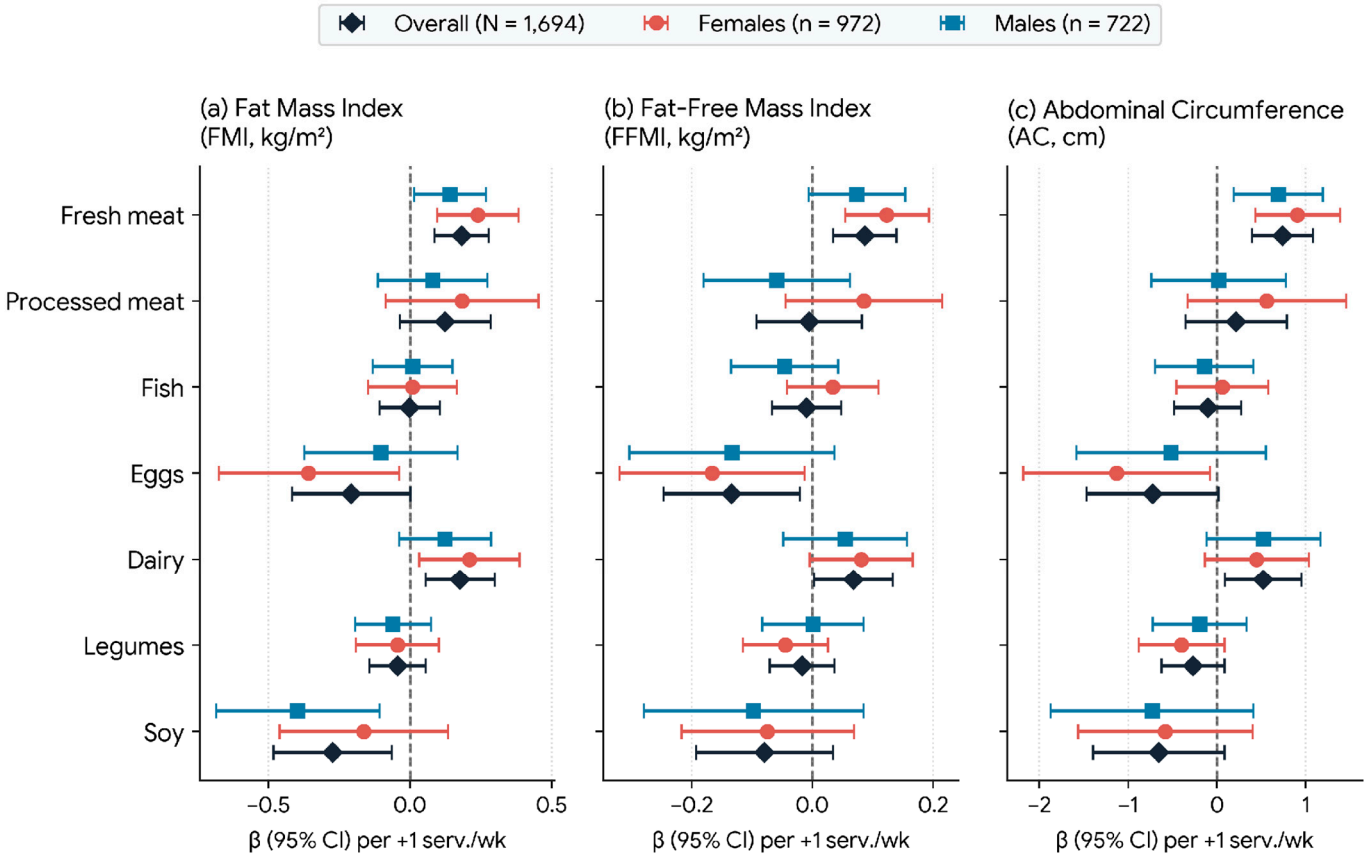


Figure 3. Forest plot of fully adjusted linear regression coefficients (β and 95% confidence intervals, Model 3) per +1 weekly serving of each protein source in relation to (**a**) Fat Mass Index, (**b**) Fat-Free Mass Index, and (**c**) Abdominal Circumference, overall (N = 1694) and stratified by sex (972 females, 722 males).

3.4. Iso-Frequency Substitution Models

When holding total weekly protein occasions constant in pooled statistical leave-one-out substitution models (Table 4 and Figure 4a–c), modeled replacement of 1 serving/week of fresh meat with 1 serving/week of soy, eggs, fish, or legumes was consistently associated with lower total and central adiposity alongside a smaller between-person difference in FFMI. Substituting soy for fresh meat was associated with the sharpest negative differences in FM% (β = −0.765%, 95% CI: −1.209 to −0.320, $p = 0.0008$), FMI (β = −0.368 kg/m^2, $p = 0.0013$), AC (β = −1.050 cm, $p = 0.0097$), and BMI (β = −0.517 kg/m^2, $p = 0.0014$), accompanied by a smaller difference in FFMI (β = −0.152 kg/m^2, $p = 0.0183$). Replacing 1 serving/week of fresh meat with eggs was associated with the largest negative difference in AC (β = −1.370 cm, $p = 0.0008$) as well as lower FMI (β = −0.368 kg/m^2, $p = 0.0013$), FM% (β = −0.552%, $p = 0.0150$), BMI (β = −0.595 kg/m^2, $p = 0.0003$), and FFMI (β = −0.222 kg/m^2, $p = 0.0006$).

Modeled substitution of 1 serving/week of fresh meat with fish or legumes was also associated with lower FMI (β fish = −0.185 kg/m^2, $p = 0.0109$; β legumes = −0.144 kg/m^2, $p = 0.0297$), AC (β fish = −0.836 cm, $p = 0.0013$; β legumes = −0.755 cm, $p = 0.0013$), and BMI (β fish = −0.284 kg/m^2, $p = 0.0061$; β legumes = −0.213 kg/m^2, $p = 0.0235$), accompanied by proportionally smaller differences in FFMI (β fish = −0.099 kg/m^2, $p = 0.0164$; β legumes = −0.072 kg/m^2, $p = 0.0544$). By contrast, substituting dairy or processed meat for fresh meat was not associated with significant differences in FMI, FM%, AC, or BMI ($p \geq 0.0836$), although processed meat substitution showed a nomi-

nal negative difference in FFMI (β = −0.112 kg/m^2, 95% CI: −0.218 to −0.005, p = 0.0402; Table 4 and Figure 4).

Table 4. Pooled iso-frequency substitution models estimating differences in two-compartment body composition associated with replacing 1 serving/week of fresh meat with 1 serving/week of alternative protein sources (Model 3, N = 1694).

Replacement Source (for 1 Serv./Wk Fresh Meat)	Δ FMI (kg/m^2) β (95% CI); p	Δ FFMI (kg/m^2) β (95% CI); p	Δ Fat Mass (%) β (95% CI); p	Δ AC (cm) β (95% CI); p	Δ BMI (kg/m^2) β (95% CI); p
Soy (+1 serv./wk)	−0.368 (−0.591, −0.145) p = 0.0013	−0.152 (−0.279, −0.026) p = 0.0183	−0.765 (−1.209, −0.320) p = 0.0008	−1.050 (−1.845, −0.255) p = 0.0097	−0.517 (−0.835, −0.199) p = 0.0014
Eggs (+1 serv./wk)	−0.368 (−0.592, −0.144) p = 0.0013	−0.222 (−0.349, −0.096) p = 0.0006	−0.552 (−0.997, −0.107) p = 0.0150	−1.370 (−2.167, −0.574) p = 0.0008	−0.595 (−0.913, −0.276) p = 0.0003
Fish (+1 serv./wk)	−0.185 (−0.328, −0.043) p = 0.0109	−0.099 (−0.179, −0.018) p = 0.0164	−0.238 (−0.522, +0.045) p = 0.0995	−0.836 (−1.343, −0.329) p = 0.0013	−0.284 (−0.486, −0.081) p = 0.0061
Legumes (+1 serv./wk)	−0.144 (−0.273, −0.014) p = 0.0297	−0.072 (−0.146, +0.001) p = 0.0544	−0.192 (−0.450, +0.065) p = 0.1435	−0.755 (−1.217, −0.294) p = 0.0013	−0.213 (−0.397, −0.029) p = 0.0235
Dairy (+1 serv./wk)	+0.029 (−0.119, +0.177) p = 0.7003	−0.006 (−0.090, +0.078) p = 0.8908	+0.097 (−0.197, +0.391) p = 0.5169	−0.096 (−0.622, +0.430) p = 0.7214	+0.022 (−0.189, +0.232) p = 0.8410
Processed meat (+1 serv./wk)	−0.073 (−0.262, +0.115) p = 0.4444	−0.112 (−0.218, −0.005) p = 0.0402	−0.080 (−0.455, +0.295) p = 0.6762	−0.592 (−1.263, +0.079) p = 0.0836	−0.185 (−0.453, +0.083) p = 0.1757

Pooled leave-one-out substitution models (N = 1694) simultaneously include total weekly protein occasions and all individual protein sources except fresh meat, adjusted for all Model 3 covariates. Abbreviations: CI, confidence interval; wk, week; Δ, estimated cross-sectional difference in the respective outcome associated with replacing 1 serving/week of fresh meat.

3.5. Odds of Abdominal Obesity and Habitual Meat Preferences

In fully adjusted logistic regression models (Table 5), each additional weekly serving of fresh meat was associated with 14.6% higher odds of abdominal obesity (aOR = 1.146, 95% CI: 1.060–1.239, p = 0.0006). Conversely, lower odds of abdominal obesity were observed for each additional weekly serving of eggs (aOR = 0.821, 95% CI: 0.702–0.961, p = 0.0139) and soy (aOR = 0.833, 95% CI: 0.719–0.965, p = 0.0147), as well as per +10% increase in plant protein share (aOR = 0.922, 95% CI: 0.862–0.986, p = 0.0182). None of the protein exposures were significantly associated with normal-weight obesity (n = 27/1694; $p \geq 0.0858$).

To distinguish habitual meat preferences from single-week diary fluctuations, we next analyzed responses from the self-developed food preference questionnaire (Table 6). Among the 1021 adults who completed the expanded poultry versus red meat preference items, habitual preference (Yes vs. No/Unfamiliar) for either white meat ($p \geq 0.1672$) or red meat ($p \geq 0.1427$) showed no significant association with any body composition index. Across the full cohort (N = 1694), however, habitual preference for processed meat (Yes vs. No/Unfamiliar) was strongly associated with higher FMI (β = +0.968 kg/m^2, 95% CI: +0.351 to +1.585, p = 0.0021), FM% (β = +1.516%, p = 0.0153), AC (β = +3.270 cm, 95% CI: +1.075 to +5.464, p = 0.0035), BMI (β = +1.612 kg/m^2, p = 0.0003), and FFMI (β = +0.627 kg/m^2, 95% CI: +0.279 to +0.975, p = 0.0004).

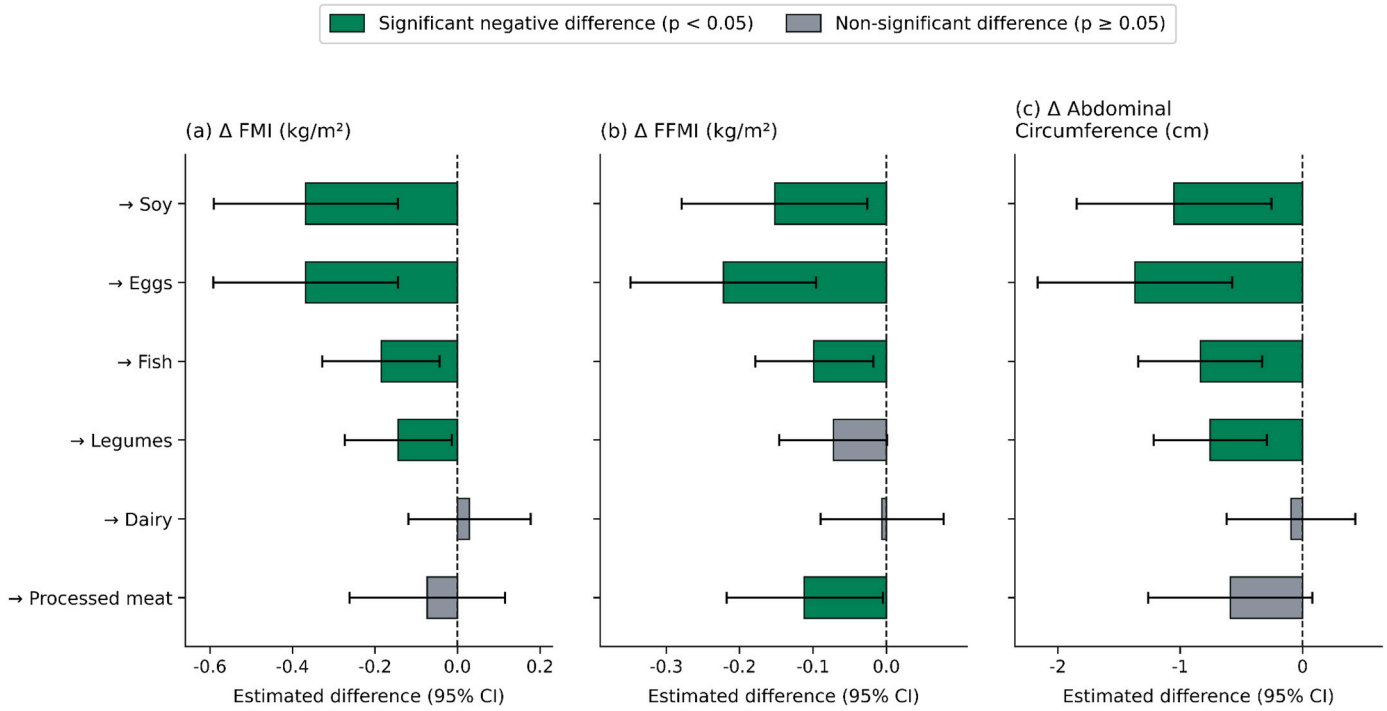


Figure 4. Pooled iso-frequency substitution analysis estimating differences (β and 95% confidence intervals, Model 3) in (**a**) Fat Mass Index, (**b**) Fat-Free Mass Index, and (**c**) Abdominal Circumference associated with replacing 1 serving/week of fresh meat with 1 serving/week of soy, eggs, fish, legumes, dairy, or processed meat while holding total weekly protein occasions constant (N = 1694). Green bars indicate statistically significant negative associations ($p < 0.05$); gray bars indicate non-significant associations ($p \geq 0.05$). In panel (**b**), replacing fresh meat with legumes was borderline non-significant ($p = 0.0544$), whereas replacing fresh meat with processed meat showed a nominal negative difference in FFMI ($p = 0.0402$) without significant differences in FMI, FM%, AC, or BMI. Right-pointing arrows (→) on the y-axis denote iso-frequency substitution of 1 serving/week of fresh meat with 1 serving/week of the indicated alternative protein source.

Table 5. Multivariable logistic regression models (Model 3) for abdominal obesity (central adiposity marker) and normal-weight obesity according to weekly protein exposures (N = 1694).

Dietary Protein Exposure	Abdominal Obesity aOR (95% CI)	*p*-Value	Normal-Weight Obesity aOR (95% CI)	*p*-Value
Fresh meat (+1 serv./wk)	1.146 (1.060–1.239)	0.0006	0.784 (0.594–1.035)	0.0858
Processed meat (+1 serv./wk)	0.939 (0.831–1.061)	0.3108	1.119 (0.768–1.631)	0.5582
Fish (+1 serv./wk)	1.065 (0.978–1.159)	0.1487	0.922 (0.699–1.215)	0.5631
Eggs (+1 serv./wk)	0.821 (0.702–0.961)	0.0139	1.371 (0.892–2.107)	0.1504
Dairy (+1 serv./wk)	1.068 (0.968–1.177)	0.1905	0.898 (0.659–1.223)	0.4944
Legumes (+1 serv./wk)	0.945 (0.877–1.017)	0.1301	1.039 (0.820–1.315)	0.7518
Soy (+1 serv./wk)	0.833 (0.719–0.965)	0.0147	0.666 (0.244–1.819)	0.4278
Protein diversity (+1 source)	1.124 (0.994–1.271)	0.0619	1.291 (0.876–1.902)	0.1970
Plant protein share (+10%)	0.922 (0.862–0.986)	0.0182	1.045 (0.850–1.285)	0.6744
Processed meat share (+10%)	0.924 (0.817–1.047)	0.2144	1.126 (0.809–1.569)	0.4815

Abdominal obesity (n = 1316/1694) defined as AC > 80 cm in females and >94 cm in males. Normal-weight obesity (n = 27/1694) defined as BMI < 25.0 kg/m^2 with body fat > 35.0% in females or >25.0% in males (parsimonious adjustment for age, sex, smoking, regular sport participation, vegetables, fruits, and sugary drinks to preserve event-per-variable stability). Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; wk, week.

Table 6. Fully adjusted associations (Model 3) between habitual meat preferences on the self-developed food preference questionnaire and body composition indices.

Habitual Questionnaire Item (Full Contrast: Yes vs. No/Unfamiliar)	n	FMI (kg/m^2) β (95% CI); *p*	FFMI (kg/m^2) β (95% CI); *p*	Fat Mass (%) β (95% CI); *p*	AC (cm) β (95% CI); *p*	BMI (kg/m^2) β (95% CI); *p*
White meat preference (Yes vs. No/Unfamiliar)	1021	+0.543 (−0.326, +1.411) $p = 0.2203$	+0.185 (−0.291, +0.661) $p = 0.4465$	+1.213 (−0.509, +2.936) $p = 0.1672$	+1.517 (−1.525, +4.558) $p = 0.3280$	+0.670 (−0.553, +1.892) $p = 0.2829$
Red meat preference (Yes vs. No/Unfamiliar)	1021	+0.281 (−0.435, +0.997) $p = 0.4414$	+0.292 (−0.098, +0.682) $p = 0.1427$	+0.212 (−1.209, +1.633) $p = 0.7695$	+1.365 (−1.142, +3.871) $p = 0.2855$	+0.594 (−0.414, +1.602) $p = 0.2475$
Processed meat preference (Yes vs. No/Unfamiliar)	1694	+0.968 (+0.351, +1.585) $p = 0.0021$	+0.627 (+0.279, +0.975) $p = 0.0004$	+1.516 (+0.292, +2.741) $p = 0.0153$	+3.270 (+1.075, +5.464) $p = 0.0035$	+1.612 (+0.735, +2.488) $p = 0.0003$

Bilingual questionnaire responses were harmonized into three ordered preference levels: 'Yes' ('Yes'/'SI', scored 1.0), 'Reluctantly' ('Reluctantly'/'Se proprio devo...', scored 0.5), and 'No/Unfamiliar' ('No'/'NO'/'Don't know'/'Non so cosa sia', scored 0.0). Modeling this three-level ordinal score linearly estimates the full contrast between 'Yes' (1.0) and 'No/Unfamiliar' (0.0) while retaining all respondents (n = 1021 for white and red meat; N = 1694 for processed meat, including n = 85 'Reluctantly' respondents scored at 0.5). Models adjust for all Model 3 covariates.

4. Discussion

4.1. Principal Findings: Protein Food Matrix over Numerical Diversity

In this adult cohort evaluated within a clinical-nutritional setting, increasing the simple weekly count of distinct protein sources showed no association with improvements in compartmentalized body composition or central adiposity in either women or men. Rather, morphological profiles were governed by the specific food matrix of the ingested proteins and by habitual inclinations toward industrially processed meats. This observation aligns with a recent scoping review by Prokopidis et al. [23], which emphasized that the physical structure, co-existing nutrients, and bioactive compounds embedded within a whole-food matrix—rather than isolated protein or amino acid content alone—dictate postprandial protein kinetics and metabolic responses. In our cohort, more frequent consumption of fresh meat and dairy products tracked with greater total and central adiposity, with higher odds of abdominal obesity observed specifically for fresh meat. Conversely, higher soy intake and a greater proportional share of plant-based protein occasions showed suggestive inverse associations with total and central adiposity in individual models (q FDR = 0.0698), while statistically modeled iso-frequency replacement of fresh meat with soy, eggs, fish, or legumes was consistently associated with lower fat mass and abdominal circumference—including a statistically significant inverse association with AC for soy substitution ($p = 0.0097$) that was not evident in isolation ($p = 0.0836$)—accompanied by null or proportionally smaller negative differences in FFMI, extending meta-analytic substitution evidence on animal-to-plant dietary shifts [17] directly to compartmentalized body composition outcomes. Nevertheless, because participants were recruited from an outpatient clinical nutrition and obesity center and evaluated cross-sectionally without total energy or macronutrient gram measurements, these statistical associations must be interpreted cautiously: iso-frequency substitution does not represent an isocaloric or isoprotein exchange, and reverse causality—whereby individuals presenting with excess adiposity had already modified their protein choices prior to consultation—may also contribute to the observed patterns.

4.2. Dietary Diversity, Caloric Displacement, and Protein Matrix Composition

The absence of morphological benefits derived solely from increasing the numerical variety of protein sources supports the American Heart Association Science Advisory on dietary diversity [13], which cautions that broadening the range of foods consumed fails to

prevent excess body weight when variety is achieved by adding energy-dense foods rather than displacing them. Among our participants, greater weekly diversification reflected an accumulation of total protein-containing eating occasions without any reduction in fresh or processed meat portions. These findings align with multi-criteria cluster analyses from the NutriNet-Santé cohort by Toujgani et al. [24], which demonstrated across 29,210 adults that the qualitative nature of dietary protein patterns—rather than mere variety—discriminates nutritional quality and health risk, with meat-dominant clusters exhibiting the lowest overall diet quality scores and the highest health risk profiles compared with healthy plant- and fish-based clusters.

Regarding protein origin and processing level, our proportional analyses converge closely with prospective data from the UK Biobank by de Fragas Hinnig et al. [25]. Over a 5.3-year follow-up of 17,374 adults, each 10% increase in energy intake from minimally processed plant-sourced foods lowered the hazard of clinically meaningful gains in BMI (HR 0.89) and waist circumference (HR 0.90), whereas a 10% higher intake of plant-sourced ultra-processed foods increased both risks (HR 1.10 and 1.09, respectively) [25]. Similarly, in our cohort, every +10% increment in minimally processed plant protein occasions (legumes and soy) showed suggestive inverse associations with FMI, FM%, and abdominal circumference (q FDR = 0.0698) alongside lower odds of abdominal obesity. The positive association between fresh meat intake and central adiposity also reinforces nationally representative US NHANES findings by Wang and Beydoun [26], who documented dose-dependent links between higher meat intake, elevated daily energy and fat intake, and central obesity, while large-scale prospective evidence from the NIH-AARP Diet and Health Study by Etemadi et al. [27] indicates that heme iron, nitrate/nitrite exposure, and saturated fatty acids substantially mediate the adverse cardiometabolic risks of meat matrices.

Conversely, the potential of plant-based protein patterns to attenuate body fat without disproportionate reductions in fat-free mass index (FFMI) aligns with established physiological and clinical syntheses. As detailed by Najjar and Feresin [28], plant-based diets promote reductions in body fat—even independently of energy restriction—through lower caloric density, improved gut microbiota symbiosis, enhanced insulin sensitivity, reduced trimethylamine-N-oxide (TMAO) generation, activation of peroxisome proliferator-activated receptors (PPARs), and upregulation of mitochondrial uncoupling proteins. Furthermore, our cross-sectional observation that higher habitual soy intake and plant protein share were not associated with lower FFMI in individual models—and that statistically modeled iso-frequency replacement of fresh meat yielded substantially smaller differences in FFMI than in FMI—aligns with the systematic review by Chan et al. [29], which reported favorable body composition profiles without detrimental fat-free mass loss in middle-aged and older adults adhering to plant-based patterns, as well as the comprehensive review by López-Moreno and Kraselnik [30], showing that combining diverse whole-food plant sources and culinary preparation methods (such as cooking and fermentation) within habitual diets supports muscle protein synthesis and fat-free mass maintenance.

4.3. Cultural Dairy Matrices, Dietary Substitution, and Population Context

Comparing our findings with recent observational and interventional literature highlights three distinctive nuances shaped by real-world dietary habits and analytical design. First, whereas several prospective cohorts and systematic reviews have reported neutral or modestly protective associations for specific dairy subtypes, total weekly dairy intake in our Italian cohort paralleled fresh meat in associating positively with total and abdominal adiposity. As shown in a recent dose–response meta-analysis of 29 prospective cohorts by Hu et al. [31], the health effects of dairy foods vary substantially by product type, fat content, and fermentation: yogurt (200 g/day) and modest cheese intake (15 g/day) were

associated with lower mortality, whereas total dairy exhibited a non-linear U-shaped relationship. Similarly, in the FinHealth study of 5096 adults, Wynne-Ellis et al. [32] reported inverse associations between fermented dairy and metabolic syndrome, whereas higher total and non-fermented dairy consumption was linked to adverse high-density lipoprotein cholesterol profiles and higher odds of metabolic syndrome in women. Within an Italian gastronomic context, habitual weekly dairy occasions recorded in 7-day diaries encompass substantial portions of calorie- and saturated-fat-dense fresh and aged cheeses alongside non-fermented milk, which likely outweighs the favorable profile of low-fat fermented matrices [23,31,32].

Second, while extensive literature links habitual seafood and legume intake to improved weight and metabolic regulation, neither fish nor legumes showed significant independent associations with body composition in our individual models when evaluated in isolation. Specifically, Liaset et al. [33] summarized clinical and experimental evidence showing that lean seafood—relative to terrestrial meats—reduces voluntary energy intake by 4–9%, improves insulin sensitivity, and enhances adiponectin signaling via marine n-3 polyunsaturated fatty acids and fish-derived proteins, while the dose–response meta-analysis by Mendes et al. [34] demonstrated lower coronary heart disease risk for regular legume intake up to ~400 g/week. In our cohort, however, the favorable associations of fish and legumes with FMI and abdominal circumference emerged robustly only in iso-frequency substitution models [22] when directly replacing fresh meat, indicating that adding fish or legumes on top of a meat-rich diet confers minimal morphological advantage unless true dietary displacement occurs. Furthermore, contrasting our cohort with the South Korean cross-sectional study by Kim et al. [35] underscores the role of baseline nutritional status: while Kim et al. [35] likewise linked red meat intake to higher body fat percentage, daily egg and poultry intake protected against sarcopenic obesity primarily among individuals with inadequate daily protein intake. In our Italian adult cohort—where weekly protein occasions were ample (~9.5 servings/week) and excess central adiposity was highly prevalent (77.7%)—surplus energy and lipid co-ingestion from fresh meat, rather than protein inadequacy, acted as the primary morphological driver. Crucially, however, this leave-one-out substitution model represents a statistical substitution simulation holding weekly protein serving frequency constant, and is not equivalent to an isocaloric or isoprotein exchange or to a real-world clinical dietary intervention. In actual clinical practice, replacing a serving of fresh meat with fish, legumes, eggs, or soy simultaneously alters total energy intake, total protein grams, amino acid composition, and accompanying meal ingredients; therefore, the estimated regression β coefficients reflect cross-sectional population contrasts and cannot be directly extrapolated as prescriptive clinical effect sizes for individual patients.

Third, our real-world observations complement recent randomized controlled trials pairing high-protein regimens with structured resistance exercise. For example, Bagherpour et al. [36] showed that an 8-week hypocaloric, high-protein intervention combined with time-restricted eating and resistance training markedly reduced visceral adipose tissue while increasing fat-free mass in women with overweight, and Fernandes [37] similarly reported that a 12-week low-calorie, high-protein diet alongside resistance training preserved fat-free mass and attenuated adaptive declines in resting energy expenditure. While elevated total protein intake is effective within controlled energy-deficit and mechanical-loading protocols, our data demonstrate that in free-living adults, the qualitative food matrix and displacement of energy-dense animal sources outweigh simply tallying multiple protein sources.

4.4. Compartmental Adipose–Lean Dynamics and Sex Consistency

Utilizing height-normalized compartmental indices (FMI and FFMI) alongside abdominal circumference overcomes the well-recognized inability of BMI to distinguish adipose

tissue from fat-free mass or capture visceral fat distribution [1–4,20,21]. A physiologically noteworthy finding was the modest positive slope of fresh meat and dairy intake with FFMI alongside FMI, particularly among women. This dual positive association is likely multifactorial and cannot be attributed solely to BIA estimation properties. First, individuals consuming fresh meat and dairy more frequently likely achieved higher absolute daily protein (g/day) and total energy intakes, which can genuinely coexist with greater total fat-free mass alongside larger overall body size. Second, in adults with overweight or obesity, excess adipose mass imposes chronic mechanical loading on the musculoskeletal system and is accompanied by an obligatory expansion of supporting stromal-vascular connective tissues [4]. Third, single-frequency BIA derives FFM indirectly from whole-body electrical impedance, which is sensitive to the elevated extracellular-to-intracellular water ratio often present in individuals with higher adiposity. In contrast, a higher relative share of plant-based proteins was selectively associated with lower total and central adiposity without a significant difference in FFMI, whereas statistically modeled iso-frequency replacement of fresh meat was accompanied by a smaller negative difference in FFMI proportional to lower overall body mass. Because FFMI captures total non-fat tissue rather than skeletal muscle specifically, and because these estimates reflect cross-sectional between-person differences rather than longitudinal within-person changes, lower FFMI in substitution models does not indicate skeletal muscle loss, nor does higher FFMI with meat or dairy intake necessarily denote greater skeletal muscle mass.

These sex-stratified patterns also resonate with longitudinal findings from the 20-year ATTICA Mediterranean cohort study by Kechagia et al. [38]. In that cohort of 2000 adults, red meat intake increased type 2 diabetes incidence across both sexes, while total animal protein strongly elevated diabetes risk in women—particularly those with central obesity (OR 2.06)—whereas plant protein conferred marked protection (OR 0.24) [38]. Our cross-sectional observations appear to capture the upstream morphological stage of this cardiometabolic trajectory: frequent fresh meat consumption tracked with higher FMI and abdominal circumference (with steeper point estimates in women), whereas plant-based protein sources attenuated central fat accumulation. Although baseline body composition and dietary choices differed markedly by sex [18], the absence of statistically significant protein-by-sex interaction terms (p interaction ≥ 0.06) indicates that the underlying biological direction of these protein matrices is conserved across both women and men.

4.5. Habitual Processed Meat Exposure and Fresh Meat Subtypes

Integrating a 7-day food record with a structured food preference questionnaire resolved an apparent discrepancy regarding processed meats. Because cured and processed meat intake is episodic over a single week (median 0 servings/week), 7-day diary counts exhibited wide dispersion that diluted continuous regression estimates. Conversely, habitual preference for processed meat on the questionnaire captured a stable behavioral orientation and identified individuals with markedly larger abdominal circumference (+3.27 cm) and FMI (+0.97 kg/m^2). Consistent with prospective evidence on ultra-processed and processed meat matrices [11,25,27], sustained inclination toward industrially processed meats—characterized by high energy density, sodium, nitrites, and saturated fats—serves as a more sensitive indicator of chronic exposure than a single-week observation window. By contrast, within the sub-cohort distinguishing habitual preferences for white versus red fresh meat (n = 1021), no differential association with body composition was observed; unlike long-term cardiovascular cohorts reporting lower risk for poultry relative to red meat [8,11], everyday culinary preparations, added cooking fats, and accompaniments likely equalize the net morphological impact of fresh poultry and red meat in routine diets [23].

4.6. Limitations

Several major limitations warrant careful consideration when interpreting these findings. First and foremost, although the clinician-reviewed 7-day food records quantified exact weekly serving frequencies across seven protein groups, total daily energy intake (kcal/day), total protein intake (g/day and g/kg body weight/day), total carbohydrate and fat intakes, saturated fat intake, and dietary fiber intake were not collected. Consequently, our substitution models represent food-frequency (serving-for-serving) statistical simulations rather than isocaloric or isoprotein substitutions, and residual confounding from energy intake, added cooking fats, sauces, or refined carbohydrate accompaniments cannot be excluded. Second, 7-day food records reflect dietary intake over a single one-week observation window and therefore have limited representativeness for habitual long-term dietary patterns over months or years. Third, the cross-sectional study design precludes causal inference, and reverse causality is a particularly salient concern given that participants were recruited from an outpatient clinical nutrition and obesity center rather than a representative community sample; patients seeking clinical weight-management counseling may have recently increased their intake of perceived leaner or plant-based protein foods or reduced meat consumption prior to baseline assessment. Fourth, single-frequency bioelectrical impedance relies on manufacturer-specific prediction equations to estimate two-compartment FFM—which includes body water, organs, and bone alongside skeletal muscle—and remains sensitive to hydration shifts despite strict pre-test standardization. Finally, the self-developed food preference questionnaire lacked formal test–retest reliability validation, and recruitment from a single clinical center in Rome may limit generalizability to unselected general populations or regions with different dietary traditions.

5. Conclusions

Among Italian adults, increasing the numerical count of distinct protein sources consumed on a weekly basis—without altering the underlying protein food matrices—was not associated with more favorable two-compartment body composition or lower central adiposity in either women or men. Conversely, higher habitual soy intake and a greater proportional share of plant-based protein occasions (which showed suggestive inverse associations with adiposity after multiple-testing adjustment), together with statistically modeled iso-frequency replacement of weekly fresh meat servings with soy, eggs, fish, or legumes—and limiting habitual preference for processed meats—were associated with lower total adiposity and smaller abdominal circumference alongside null or proportionally smaller negative differences in FFMI. These findings derive from cross-sectional observational data using food-frequency substitution modeling and require confirmation in prospective cohort studies and randomized controlled dietary trials before establishing causal clinical prescriptions. Moreover, because the study cohort was recruited from Italian adults attending an outpatient clinical nutrition center, these conclusions may not directly generalize to unselected community populations or individuals following other regional dietary patterns.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/nu18234008/s1: Table S1. Behavioral concordance between harmonized habitual food preference categories on the self-developed questionnaire and observed 7-day food record consumption frequencies. Table S2. Hierarchical multivariable linear regression models (Models 1–3) examining associations between weekly protein exposures and Fat Mass Index (FMI), Fat-Free Mass Index (FFMI), and Abdominal Circumference (AC) (N = 1694). Table S3. Sex-stratified fully adjusted associations (Model 3) and protein-by-sex interaction p-values across weekly protein exposures in females (n = 972) and males (n = 722).

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Lazio Area 5 Territorial Ethics Committee (protocol code N.57/SR/23 and date of approval 7 November 2023). This study is registered under ClinicalTrials.gov ID NCT06654674 (registered on 22 October 2024) and conducted by San Raffaele Open University.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The de-identified data supporting the findings of this study are available from the corresponding author upon reasonable request to protect participant confidentiality.

Acknowledgments: The author would like to thank Arianna Lombardo and Tommaso Lombardo for their valuable help in compiling the subject database. During the preparation of this manuscript, the author used generative artificial intelligence tools (Gemini Hydrogen 4, Google; ChatGPT 6.2, OpenAI) solely for English language editing, stylistic refinement, and manuscript structuring. These tools were not used for study design, data curation, statistical modeling, numerical computations, or data interpretation. The author thoroughly reviewed, verified, and edited all text and takes full responsibility for the content and scientific integrity of this publication.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

AC	Abdominal circumference
ANCOVA	Analysis of covariance
ANOVA	Analysis of variance
aOR	Adjusted odds ratio
BIA	Bioelectrical impedance analysis
BMI	Body mass index
CI	Confidence interval
CREA	Council for Agricultural Research and Economics
DXA	Dual-energy X-ray absorptiometry
FDR	False discovery rate
FFM	Fat-free mass
FFMI	Fat-free mass index
FM	Fat mass
FMI	Fat mass index
HR	Hazard ratio
IDF	International Diabetes Federation
IQR	Interquartile range
LARN	Reference Intake Levels of Nutrients and Energy
NWO	Normal-weight obesity
PPAR	Peroxisome proliferator-activated receptor
SD	Standard deviation
TMAO	Trimethylamine-N-oxide

References

1. Lee, D.H.; Keum, N.; Hu, F.B.; Orav, E.J.; Rimm, E.B.; Willett, W.C.; Giovannucci, E.L. Predicted lean body mass, fat mass, and all cause and cause specific mortality in men: Prospective US cohort study. *BMJ* **2018**, *362*, k2575. [CrossRef] [PubMed]
2. Sedlmeier, A.M.; Baumeister, S.E.; Weber, A.; Fischer, B.; Thorand, B.; Ittermann, T.; Dörr, M.; Felix, S.B.; Völzke, H.; Peters, A.; et al. Relation of body fat mass and fat-free mass to total mortality: Results from 7 prospective cohort studies. *Am. J. Clin. Nutr.* **2021**, *113*, 639–646. [CrossRef] [PubMed]
3. Suthahar, N.; Lau, E.S.; Savarese, G. Relative Fat Mass: Refining Adiposity Measurement in the Era Beyond Body Mass Index. *Curr. Heart Fail. Rep.* **2025**, *22*, 22. [CrossRef] [PubMed]
4. Müller, M.J.; Heymsfield, S.B.; Bosy-Westphal, A. Do We Need Body Composition Analysis in Patients with Obesity? A Rethinking of Body Composition Assessment in Preclinical and Clinical Obesity. *Obes. Facts* **2026**, adzag006. [CrossRef] [PubMed]

5. Reytor-González, C.; Loor-Cedeño, A.; Gavilanes, D.J.; Matos, A.; Parise-Vasco, J.M.; Angamarca-Iguago, J.; Cagua-Ordoñez, J.; Campuzano-Donoso, M.; Simancas-Racines, D. Higher-Protein Nutrition and Concurrent Exercise in Obesity: A Narrative Review of Body Composition, Metabolic Health, and Physical Function. *Nutrients* **2026**, *18*, 2280. [CrossRef] [PubMed]
6. Leidy, H.J.; Clifton, P.M.; Astrup, A.; Wycherley, T.P.; Westerterp-Plantenga, M.S.; Luscombe-Marsh, N.D.; Woods, S.C.; Mattes, R.D. The role of protein in weight loss and maintenance. *Am. J. Clin. Nutr.* **2015**, *101*, 1320S–1329S. [CrossRef] [PubMed]
7. Kitada, M.; Ogura, Y.; Monno, I.; Koya, D. The impact of dietary protein intake on longevity and metabolic health. *eBioMedicine* **2019**, *43*, 632–640. [CrossRef] [PubMed]
8. Bernstein, A.M.; Sun, Q.; Hu, F.B.; Stampfer, M.J.; Manson, J.E.; Willett, W.C. Major dietary protein sources and risk of coronary heart disease in women. *Circulation* **2010**, *122*, 876–883. [CrossRef] [PubMed]
9. Zheng, J.S.; Steur, M.; Imamura, F.; Freisling, H.; Johnson, L.; van der Schouw, Y.T.; Tong, T.Y.; Weiderpass, E.; Bajracharya, R.; Crous-Bou, M.; et al. Dietary intake of plant- and animal-derived protein and incident cardiovascular diseases: The pan-European EPIC-CVD case-cohort study. *Am. J. Clin. Nutr.* **2024**, *119*, 1164–1174. [CrossRef] [PubMed]
10. Ferrari, L.; Panaite, S.-A.; Bertazzo, A.; Visioli, F. Animal- and Plant-Based Protein Sources: A Scoping Review of Human Health Outcomes and Environmental Impact. *Nutrients* **2022**, *14*, 5115. [CrossRef] [PubMed]
11. Mozaffarian, D.; Hao, T.; Rimm, E.B.; Willett, W.C.; Hu, F.B. Changes in diet and lifestyle and long-term weight gain in women and men. *N. Engl. J. Med.* **2011**, *364*, 2392–2404. [CrossRef] [PubMed]
12. Apicella, M.C.A.; Korzepa, M.; Breen, L. Does protein source influence ageing muscle? A contemporary physiological perspective. *J. Nutr. Physiol.* **2026**, *7*, 100043. [CrossRef]
13. de Oliveira Otto, M.C.; Anderson, C.A.M.; Dearborn, J.L.; Ferranti, E.P.; Mozaffarian, D.; Rao, G.; Wylie-Rosett, J.; Lichtenstein, A.H.; American Heart Association Behavioral Change for Improving Health Factors Committee of the Council on Lifestyle and Cardiometabolic Health and Council on Epidemiology and Prevention; Council on Cardiovascular and Stroke Nursing; et al. Dietary Diversity: Implications for Obesity Prevention in Adult Populations: A Science Advisory From the American Heart Association. *Circulation* **2018**, *138*, e160–e168. [CrossRef] [PubMed]
14. Layman, D.K. Impacts of protein quantity and distribution on body composition. *Front. Nutr.* **2024**, *11*, 1388986. [CrossRef] [PubMed]
15. Hudson, J.L.; Bergia, R.E.; Campbell, W.W. Protein Distribution and Muscle-Related Outcomes: Does the Evidence Support the Concept? *Nutrients* **2020**, *12*, 1441. [CrossRef] [PubMed]
16. Mendes, B.R.; Correia, J.M.; Dos Santos, I.R.; Schoenfeld, B.J.; Swinton, P.A.; de Mendonca, G.V. Effects of Plant- vs Animal-Based Proteins on Muscle Protein Synthesis: A Systematic Review with Meta-Analysis. *J. Acad. Nutr. Diet.* **2026**, *126*, 156365. [CrossRef] [PubMed]
17. Neuenschwander, M.; Stadelmaier, J.; Eble, J.; Grummich, K.; Szczerba, E.; Kiesswetter, E.; Schlesinger, S.; Schwingshackl, L. Substitution of animal-based with plant-based foods on cardiometabolic health and all-cause mortality: A systematic review and meta-analysis of prospective studies. *BMC Med.* **2023**, *21*, 404. [CrossRef] [PubMed]
18. Gorini, S.; Camajani, E.; Cava, E.; Feraco, A.; Armani, A.; Amoah, I.; Filardi, T.; Wu, X.; Strollo, R.; Caprio, M.; et al. Gender differences in eating habits and sports preferences across age groups: A cross-sectional study. *J. Transl. Med.* **2025**, *23*, 312. [CrossRef] [PubMed]
19. Thajer, A.; Vasek, M.; Schneider, S.; Kautzky-Willer, A.; Kainberger, F.; Durstberger, S.; Kranzl, A.; Horsak, B.; Greber-Platzer, S. Comparing Bioelectrical Impedance Analysis, Air Displacement Plethysmography, and Dual-Energy X-Ray Absorptiometry for Body Composition in Pediatric Obesity. *Nutrients* **2025**, *17*, 971. [CrossRef] [PubMed]
20. De Matteis, C.; Petruzzelli, S.; Graziano, G.; Novielli, F.; Di Buduo, E.; Cantatore, S.; Berardi, E.; Antonica, G.; Arconzo, M.; Cariello, M.; et al. Improving cardiovascular risk stratification: The role of abdominal obesity in predicting MACEs. *Cardiovasc. Diabetol.* **2025**, *24*, 328. [CrossRef] [PubMed]
21. Liu-Galvin, R.; Orlando, F.A.; Saguil, A.A.; Jo, A.; Smith, K.B.; Miller, A.M.; Nelson, D.S.; Sanders, E.C.; Mainous, A.G., III. More evidence of the health risks of normal weight obesity: The association with systemic inflammation. *Front. Med.* **2025**, *12*, 1695935. [CrossRef] [PubMed]
22. Roosdorp, T.; Fridén, M.; Ibsen, D.B.; Rosqvist, F. Food Substitution Modeling Approaches: A Methodological Study. *Curr. Dev. Nutr.* **2026**, *10*, 109396. [CrossRef] [PubMed]
23. Prokopidis, K.; Brouer, I.C.; Lett, A.M. Food matrix in the context of muscle and whole-body protein synthesis: A scoping review. *Nutr. Metab.* **2025**, *22*, 151. [CrossRef] [PubMed]
24. Toujgani, H.; Brunin, J.; Perraud, E.; Allès, B.; Touvier, M.; Lairon, D.; Mariotti, F.; Pointereau, P.; Baudry, J.; Kesse-Guyot, E. The nature of protein intake as a discriminating factor of diet sustainability: A multi-criteria approach. *Sci. Rep.* **2023**, *13*, 17850. [CrossRef] [PubMed]
25. de Fragas Hinnig, P.; Forjaz Grassi, A.G.; Chang, K.; Vamos, E.P.; Bertazzi Levy, R.; Rauber, F. The association of plant or animal food origin and processing level with BMI and waist circumference: A prospective cohort study of the UK Biobank. *eClinicalMedicine* **2026**, *97*, 104050. [CrossRef] [PubMed]

26. Wang, Y.; Beydoun, M.A. Meat consumption is associated with obesity and central obesity among US adults. *Int. J. Obes.* **2009**, *33*, 621–628. [CrossRef] [PubMed]
27. Etemadi, A.; Sinha, R.; Ward, M.H.; Graubard, B.I.; Inoue-Choi, M.; Dawsey, S.M.; Abnet, C.C. Mortality from different causes associated with meat, heme iron, nitrates, and nitrites in the NIH-AARP Diet and Health Study: Population based cohort study. *BMJ* **2017**, *357*, j1957. [CrossRef] [PubMed]
28. Najjar, R.S.; Feresin, R.G. Plant-Based Diets in the Reduction of Body Fat: Physiological Effects and Biochemical Insights. *Nutrients* **2019**, *11*, 2712. [CrossRef] [PubMed]
29. Chan, H.H.L.; Ribeiro, R.V.; Haden, S.; Hirani, V. Plant-Based Dietary Patterns, Body Composition, Muscle Strength and Function in Middle and Older Age: A Systematic Review. *J. Nutr. Health Aging* **2021**, *25*, 1012–1022. [CrossRef] [PubMed]
30. López-Moreno, M.; Kraselnik, A. The Impact of Plant-Based Proteins on Muscle Mass and Strength Performance: A Comprehensive Review. *Curr. Nutr. Rep.* **2025**, *14*, 37. [CrossRef] [PubMed]
31. Hu, X.; Wang, K.; Ji, X.; Wang, X.; Bai, P.; Huang, K.; Lu, A.; Li, J.; Wu, H. The dose-response relationship between dairy product intake and all-cause and cardiovascular mortality risk: A systematic review and meta-analysis of prospective cohort studies. *Front. Nutr.* **2026**, *13*, 1731841. [CrossRef] [PubMed]
32. Wynne-Ellis, M.; Tuure, T.; Männistö, S.; Kaartinen, N.E.; Maukonen, M. Fermented Dairy Consumption and Metabolic Syndrome in Finnish Men and Women. *J. Nutr.* **2026**, *156*, 101464. [CrossRef] [PubMed]
33. Liaset, B.; Øyen, J.; Jacques, H.; Kristiansen, K.; Madsen, L. Seafood intake and the development of obesity, insulin resistance and type 2 diabetes. *Nutr. Res. Rev.* **2019**, *32*, 146–167. [CrossRef] [PubMed]
34. Mendes, V.; Niforou, A.; Kasdagli, M.I.; Ververis, E.; Naska, A. Intake of legumes and cardiovascular disease: A systematic review and dose–response meta-analysis. *Nutr. Metab. Cardiovasc. Dis.* **2023**, *33*, 22–37. [CrossRef] [PubMed]
35. Kim, J.; Jeong, K.; Lim, S.; Lee, S.; Baek, Y. Association of Dietary Protein Sources and Their Adequacy, Body Composition and Risk of Sarcopenic Obesity in South Korean Populations: A Cross-Sectional Study. *Metabolites* **2024**, *14*, 130. [CrossRef] [PubMed]
36. Bagherpour, F.; Arazi, H.; Rajabi, H.; Campbell, B.I. High-Protein Time-Restricted Eating Alongside Resistance Training Reduces Adipose Tissue While Preserving Fat-Free Mass in Women with Overweight: A Randomized Controlled Trial. *Int. J. Sport Nutr. Exerc. Metab.* **2025**, *35*, 493–509. [CrossRef] [PubMed]
37. Fernandes, H. Effects of a high-protein hypocaloric diet combined with resistance training on resting energy expenditure and body composition: A 12-week randomized controlled trial. *Sci. Sports* **2026**, *41*, 614–619. [CrossRef]
38. Kechagia, I.; Barkas, F.; Yannakoulia, M.; Liberopoulos, E.; Sfikakis, P.P.; Pitsavos, C.; Panagiotakos, D. The moderating role of central adiposity, sex and age, on the association between animal- and plant-based protein intake and the 20-year cumulative incidence of type 2 diabetes: The ATTICA cohort study (2002–2022). *Eur. J. Nutr.* **2026**, *65*, 155. [CrossRef] [PubMed]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.