The Journal of Nutrition, Health and Aging 28 (2024) 100406

Contents lists available at ScienceDirect

The Journal of Nutrition, Health and Aging

journal homepage: www.elsevier.com/locate/jnha

Original Article

Breakfast energy intake and dietary quality and trajectories of cardiometabolic risk factors in older adults

Karla-Alejandra Pérez-Vega [a,b,c], Camille Lassale [a,b,d,e], María-Dolores Zomeño [a,b,f], Olga Castañer [a,g], Jordi Salas-Salvadó [b,h,i], F. Javier Basterra-Gortari [j,k], Dolores Corella [b,l], Ramón Estruch [b,m,n], Emilio Ros [b,n], Francisco J. Tinahones [b,o], Gemma Blanchart [a], Mireia Malcampo [a,b], Daniel Muñoz-Aguayo [a,b], Helmut Schröder [a,g], Montserrat Fitó [a,b], Álvaro Hernáez [a,f,p,*]

[a] Hospital del Mar Research Institute (IMIM), Carrer Doctor Aiguader 88, 08003 Barcelona, Spain
[b] Consorcio Centro de Investigación Biomédica En Red (CIBER), M.P. Fisiopatología de la Obesidad y Nutrición (CIBEROBN), Instituto de Salud Carlos III, Avenida Monforte de Lemos 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain
[c] PhD Program in Food Science and Nutrition, Universitat de Barcelona, Campus Diagonal, Avinguda Joan XXIII 27-31, 08028 Barcelona, Spain
[d] Barcelona Institute for Global Health (ISGlobal), Carrer Doctor Aiguader 88, 08003 Barcelona, Spain
[e] Universitat Pompeu Fabra (UPF), Carrer Ramon Trias Fargas 25-27, 08005 Barcelona, Spain
[f] Blanquerna School of Health Sciences, Universitat Ramon Llull, Carrer Padilla 326, 08025 Barcelona, Spain
[g] Consorcio Centro de Investigación Biomédica En Red (CIBER), M.P. Epidemiología y Salud Pública (CIBERESP), Instituto de Salud Carlos III, Avenida Monforte de Lemos 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain
[h] Universitat Rovira i Virgili, Departament de Bioquimica i Biotecnologia, Alimentaciò, Nutrició, Desenvolupament i Salut Mental ANUT-DSM, Carrer Sant Llorenç 21, 43201 Reus, Spain
[i] Institut d'Investigació Pere Virgili, Carrer Sant Llorenç 21, 43201 Reus, Spain
[j] University of Navarra, Department of Preventive Medicine and Public Health, IdiSNA, Calle Irunlarrea 1, 31008 Pamplona, Spain
[k] Department of Endocrinology and Nutrition, Hospital Universitario de Navarra, IdiSNA, Universidad Pública de Navarra, Calle Irunlarrea 3, 31008 Pamplona, Spain
[l] Department of Preventive Medicine, Universidad de Valencia, Avinguda Vicent Andrés Estellés s/n, 46100 Valencia, Spain
[m] Internal Medicine Service, Hospital Clinic, Carrer Villarroel 170, 08036 Barcelona, Spain
[n] August Pi i Sunyer Biomedical Research Institute (IDIBAPS), Carrer Rosselló 149, 08036 Barcelona, Spain
[o] Virgen de la Victoria Hospital, Department of Endocrinology, Biomedical Research Institute of Málaga, University of Málaga, Campus de Teatinos s/n, 29010 Málaga, Spain
[p] Consorcio Centro de Investigación Biomédica En Red (CIBER), M.P. Enfermedades Cardiovasculares (CIBERCV), Instituto de Salud Carlos III, Avenida Monforte de Lemos 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain

ARTICLE INFO

Keywords:
Breakfast
Body mass index
Waist circumference
Triglycerides
HDL cholesterol
Glomerular filtration rate

ABSTRACT

Objectives: Not skipping breakfast is associated with a better overall diet quality and lower cardiometabolic risk. However, the impact of calorie intake and dietary quality of breakfast on cardiovascular health remains unexplored. We aimed to study the associations between breakfast energy intake and quality and time trajectories of cardiometabolic traits in high cardiovascular risk participants.
Design: Prospective observational exploratory study with repeated measurements.
Setting: Spanish older adults.
Participants: 383 participants aged 55–75 with metabolic syndrome from PREDIMED-Plus, a clinical trial involving a weight-loss lifestyle intervention based on the Mediterranean diet.
Measurements: Participants were followed for 36 months. Longitudinal averages of breakfast energy intake and quality were calculated. Three categories were defined for energy intake: 20−30% (reference), <20% (low), and >30% (high). Quality was estimated using the Meal Balance Index; categories were above (reference) or below the median score (low). Natural cubic spline mixed effects regressions described trajectories of cardiometabolic indicators (anthropometry, blood pressure, lipids, glucose, glycated hemoglobin, and kidney function) in breakfast groups. Inter-group differences in predicted values were estimated by linear regressions. Analyses were adjusted for age, sex, PREDIMED-Plus intervention group, education, smoking, physical activity, and total daily kilocalorie intake. Lipid profile analyses were further adjusted for baseline hypercholesterolemia, blood pressure analyses for baseline hypertension, and glucose/glycated hemoglobin analyses for baseline diabetes. Breakfast energy intake analyses were adjusted for breakfast quality, and vice versa.

* Corresponding author.
E-mail address: ahernaez@researchmar.net (Á. Hernáez).

http://doi.org/10.1016/j.jnha.2024.100406
Received 4 June 2024; Received in revised form 21 October 2024; Accepted 25 October 2024
Available online 5 November 2024

Results: At 36 months, compared to the reference, low- or high-energy breakfasts were associated with differences in body mass index (low: 0.61 kg/m^2 [95% confidence interval: 0.19; 1.02]; high: 1.18 kg/m^2 [0.71; 1.65]), waist circumference (low: 2.22 cm [0.96; 3.48]; high: 4.57 cm [3.13; 6.01]), triglycerides (low: 13.8 mg/dL [10.8; 16.8]; high: 28.1 cm [24.7; 31.6]), and HDL cholesterol (low: −2.13 mg/dL [−3.41; −0.85]; high: −4.56 mg/dL [−6.04; −3.09]). At 36 months, low-quality breakfast was associated with higher waist circumference (1.50 cm [0.53; 2.46]), and triglycerides (5.81 mg/dL [3.50; 8.12]) and less HDL cholesterol (−1.66 mg/dL [−2.63; −0.69]) and estimated glomerular filtration rate (−1.22 mL/min/1.73m^2 [−2.02; −0.41]).
Conclusions: Low- or high-energy and low-quality breakfasts were associated with higher adiposity and triglycerides, and lower HDL cholesterol in high-risk older adults. Low-quality breakfasts were also linked to poorer kidney function.

1. Introduction

Breakfast is a pivotal meal because it breaks the longest fasting time in the day [1]. According to dietary recommendations, an adequate breakfast provides 20–25% of energy intake [2]. Skipping breakfast has been associated to higher prevalence of obesity [3], risk of diabetes [4], and metabolic conditions [5]. On the contrary, eating breakfast has been associated with a better quality of the whole diet [6]. Frequent breakfast consumption (three or more times/week, compared to less than three times/week) is related to less risk of obesity, metabolic syndrome, hypertension, type II diabetes, stroke, and cardiovascular mortality [7]. Regarding quality, there is no clear definition or official recommendations for what constitutes a high-quality breakfast, leading to inconsistencies in how studies assess it. Existing indices vary in criteria such as nutrient composition, food groups included, and portion sizes. Ideally, a quality breakfast should offer energy and essential nutrients in balance with daily requirements [1]. Only two cross-sectional studies have assessed the relationship between qualitative measurements of breakfast and cardiometabolic health. One study found an association between better a score of breakfast quality (which positively weighted high intakes of fruits, vegetables, whole grains, nuts, and polyunsaturated fats and low intakes of red/processed meat and sugar-sweetened beverages/juices [8]) and better values of a composite cardiometabolic risk score based on high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), triglycerides, and glycated hemoglobin (Hb1Ac) in older men with overweight [9]. The other study, conducted in a general adult population, reported a relationship between high breakfast quality (assessed with the Brazilian Breakfast Quality Index, which positively scored high breakfast intakes of fruits, vegetables, cereals, dairy products, calcium, and total fiber, low intakes of free sugar, saturated fats, and sodium, and 15–25% of daily energy in breakfast [10]) and lower blood pressure, fasting plasma glucose, insulin resistance, total cholesterol, and LDL-C, and risk of being overweight [11]. To the best of our knowledge, no prospective studies have assessed calorie intake in breakfast or the dietary quality of this meal as the exposure. Additionally, none have used repeated measurements of cardiometabolic risk factors over time as the outcome in a well-characterized population.

Our aim was to examine, in older adults with overweight or obesity and metabolic syndrome, the relationship of the proportion of daily energy consumed at breakfast or the dietary quality of breakfast with time-dependent trajectories of a set of cardiometabolic traits: body mass index (BMI), waist circumference (WC), blood triglycerides, HDL-C, LDL-C, systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting plasma glucose, Hb1Ac, and estimated glomerular filtration rate (eGFR).

2. Material and methods

2.1. Study design and population

This work was performed in a subsample of individuals recruited in the Prevención con Dieta Mediterránea-Plus (PREDIMED-Plus) study, and we used the study data for a set of exploratory observational analyses. PREDIMED-Plus is a randomized clinical trial that compares the effect of a lifestyle intervention with an energy reduced Mediterranean diet (MedDiet) plus physical activity with an ad libitum MedDiet without advice on exercise (control group) on the incidence of cardiovascular disease [12]. Eligible participants were women between 60 and 75 years and men between 55 and 75 years with BMI between 27 and 40 kg/m^2 and at least three criteria for metabolic syndrome: (1) triglycerides ≥150 mg/dL or triglyceride-lowering medication; (2) fasting glucose ≥100 mg/dL or glucose-lowering medication; (3) SBP/DBP ≥ 130/85 mmHg or antihypertensive medication; (4) HDL-C <50 mg/dL in women and < 40 mg/dL in men; and/or (5) WC ≥ 88 cm in women and ≥102 cm in men [12]. Complementary information of the protocol (setting, locations, relevant dates, periods of recruitment, follow-up) and details of the intervention are available elsewhere [12,13]. Participants in the two arms of the study received no instructions on how to prepare breakfast other than structuring it following a MedDiet. They were advised to consume low-fat dairy products, whole grain cereal or bread, a protein rich food, extra virgin olive oil and/or nuts as a source of fat, and a fresh seasonal fruit, and to avoid ultra-processed foods [14]. This means that while general MedDiet principles were emphasized, participants had full discretion over the specific foods and portions they chose for breakfast. Participants in both arms of the trial experienced weight loss in the first 12 months of the study and an associated improvement in some parameters such as lipid profile and blood pressure, although the improvements were significantly greater in the energy reduced MedDiet group [13].

This sub-study was conducted in PREDIMED-Plus participants recruited at Hospital del Mar Research Institute (Barcelona, Spain) who had completed at least one three-day food record (Fig. 1). Our analyses are reported following the guidelines described by the STrengthening the Reporting of OBservational studies in Epidemiology statement (Supplementary Table S1) [15].

2.2. Breakfast data

We first assessed dietary intake with three-day food records at three time points: baseline (before the start of the interventions), 24 months, and 36 months of follow-up. Before each visit, a nutritionist facilitated a pre-structured paper form to record everything the participant ate and drank in the following meals: first meal of the day, morning snack, lunch, afternoon snack, dinner, and night snack. We considered as breakfast any food or beverage intake reported in the morning, as defined by O'Neil et al. [1]. This included what participants indicated as first meal of the day and morning snack. In Spain, breakfast can be either a traditional early meal ("*desayuno*") or a delayed meal ("*almuerzo*"), both considered part of the breakfast or first meal of the day and happen between 7 and 10 am. They are distinct from the more substantial lunch ("*comida*"), which follows a structured multi-course format and occurs later in the day compared to other cultures (between 1 and 3 pm). Participants were instructed to self-report consumption of all foods and beverages in two labor days and one weekend day, with detailed descriptions using household measures or weighted food, and explain the ingredients in recipes or brands of processed food. Trained nutritionists reviewed the

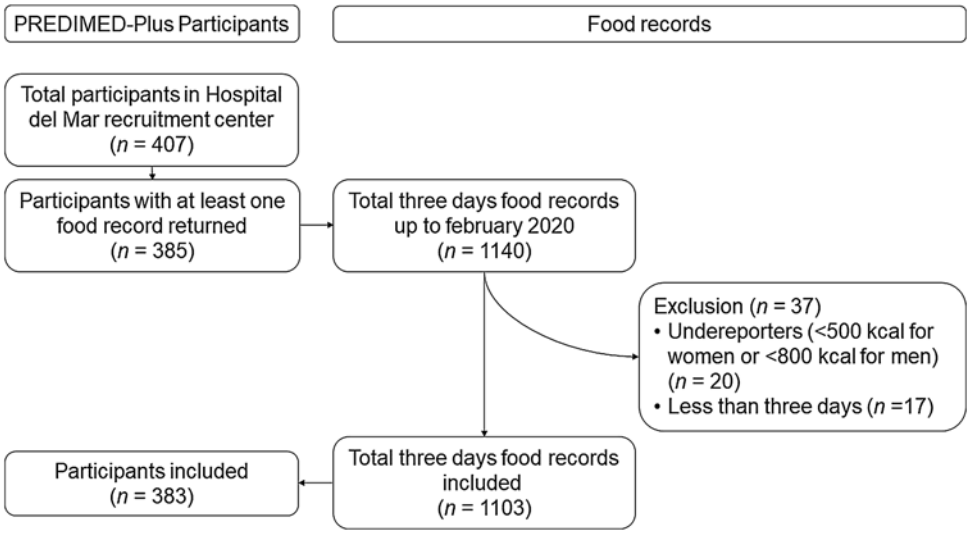

Fig. 1. Study flow chart.

food records together with the participants to check for completeness, searching particularly unrecorded items such as sugar, bread, oil, or butter. Non-caloric ingredients like herbs and spices were left out of the analysis. Reviewed food records were computerized and analyzed in the PCN Pro 1.0 software [16] (University of Barcelona, Barcelona, Spain), with Spanish-specific nutritional composition table [17]. We obtained total energy (kcal) and macronutrients (g) from the whole day and separately for breakfast. Food records with an average daily energy intake of <500 and >3,500 kcal for women or <800 and >4,200 for men [18] were discarded and participants with less than one full record (three days) were excluded. For each participant, we estimated the proportion of energy they ate at breakfast and mid-morning snack.

We used these data to calculate the proportion of energy consumed at breakfast relative to the total daily energy intake. We also used it to estimate the breakfast quality using the Meal Balance Index [19]. This score informs of the quality of a meal according to the content of nine nutrients (proteins, total fat, fiber, potassium, calcium, iron, sodium, added sugars and saturated fat). It uses: 1) Acceptable Macronutrient Distribution Ranges as reference for proteins and fats; 2) Daily Values for fiber, potassium, calcium, and iron; and 3) World Health Organization recommendations for proportions of added sugars, saturated fats, and sodium. We estimated the amount of the nutrients ingested at breakfast and expressed it per 2,000 kcal, compared it to the reference values, and assigned a score (ranging from 0 to 100 for each nutrient) according to these levels. The translation of the intake values of the nine nutrients or food groups into scores is described in Supplementary Table S2. Finally, we calculated the breakfast quality score as the weighted average of the nine nutrient/food group scores (scores for potassium and saturated fat weighed double). Total score ranged from 0 to 100. Higher scores mean greater quality of the meal [19].

2.3. Cardiometabolic risk factors

Trained healthcare professionals measured weight, height and WC using calibrated equipment and following the study protocol (www.predimedplus.com) [13]. Participants' weight was recorded without shoes and with light clothing using a calibrated high-quality electronic scale. Height was measured with a calibrated stadiometer at the beginning of the study. BMI was calculated as weight (kg) divided by height squared (m^2). WC was determined in the midpoint between the lowest rib and the iliac crest using an anthropometric tape. Blood pressure (BP) was measured in triplicate using a calibrated automated oscillometer (Omron HEM-705CP, Netherlands) with participants seated and after five minutes of rest, and the mean of the three measurements was calculated [13]. All the previous measurements were collected at baseline and in the follow-up visits at six, 12, 24 and 36 months.

We collected fasting serum at baseline and in the follow-up visits at six, 12, and 36 months and measured triglycerides (Triglycerides CP, Horiba ABX), total cholesterol (Cholesterol CP, Horiba ABX), HDL-C (HDL Direct CP, Horiba ABX), glucose (Glucose HK CP, Horiba ABX), and creatinine (Creatinine 120 CP, Horiba ABX), and HbA1c (HbA1c WB, Horiba ABX) in whole blood collected in an EDTAK2 tube in an autoanalyzer ABX Pentra (Horiba ABX SAS, Spain). The PREDIMED-Plus samples were analyzed in different batches as they were collected. To ensure the accuracy of the autoanalyzer results, we consistently analyzed internal controls from the commercial supplier, an internal pool from the same matrix as the samples, and external controls together with the samples. We calculated LDL-C with the Friedewald formula only when triglycerides were < 300 mg/dL, higher values (≥300 mg) implied a missing value for LDL-C. eGFR was estimated using plasma creatinine, sex, and age in the equation for European population [20].

2.4. Other variables

Healthcare professionals collected data at baseline on age, sex, educational level (elementary school, middle/high school or higher education), smoking habit (never smoker, current smoker or former smoker), and prevalence of diabetes, hypercholesterolemia, and hypertension as previously described [13].

2.5. Ethical aspects

This study follows the Declaration of Helsinki for Medical Research on human subjects. Before the study started, local institutional ethic committees (Hospital del Mar Research Institute) approved the protocol (reference number: 2005/2074/I). All participants signed an informed consent before enrolling in the study. The protocol was registered in the ISRCTN Registry (PREDIMED-Plus: ISRCTN89898870). We followed the EQUATOR Network principles for guidance on study ethics and reporting.

2.6. Statistical analysis

We described normally distributed continuous variables using means and standard deviations (SD), non-normally distributed continuous variables using medians and 1st-3rd quartiles, and categorical variables as proportions. We analyzed the association between the percentage of energy consumed at breakfast and the breakfast quality score by a Spearman's Rank correlation coefficient.

We evaluated the association of energy intake at breakfast or the dietary quality of breakfast with time-dependent trajectories of cardiometabolic risk factors. We first calculated the longitudinal average of the percentage of energy consumed at breakfast and the breakfast quality score through all food records available for a given participant. We then defined three categories according to the longitudinal average of the breakfast energy intake: 20−30% (reference group), <20% (low intake), and >30% (high intake). Although recommendations suggest 20–25% of daily energy intake for breakfast, we widened the range up to 30% to consider morning snacks. Similarly, we defined two categories according to breakfast quality: score above the median (reference group) and below the median (low quality). We assessed the trajectories of each cardiometabolic risk factor using linear mixed models with natural cubic splines to model follow-up time, including participant as a random effect and an interaction term between age at every follow-up visit (as the time variable) and breakfast-related groups to allow for different trajectories among participants in the different groups [21]. Analyses were adjusted for age, sex, PREDIMED-Plus intervention group, educational level, smoking, the longitudinal average of physical activity, and the longitudinal average of total daily intake of kilocalories. Analyses that used lipid profile biomarkers as outcomes were further adjusted for prevalence of hypercholesterolemia at baseline, those that assessed BP were adjusted for hypertension at baseline, and those on glucose and Hb1Ac were adjusted for diabetes at baseline. Analyses on breakfast energy intake groups were further adjusted for breakfast quality, and those on breakfast quality groups were further adjusted for the percentage of energy consumed at breakfast. We used predicted values to plot mean trajectories in the different groups. Non-normally distributed variables (triglycerides, glucose, Hb1Ac) were log-transformed prior to the linear mixed model analyses and transformed back to common units after calculating the predicted values. We calculated the mean inter-group differences in cardiometabolic risk factors at baseline, six, 12, 18, 24, 30 and 36 months using linear regressions. Additionally, we studied whether there was any interaction between energy intake and breakfast quality affecting the trajectories of cardiometabolic risk factors. We tested whether energy intake in breakfast and breakfast quality were synergistically associated with differences in the trajectories by applying a likelihood ratio test between the models with and without the interaction product-term "breakfast energy intake × breakfast quality". Furthermore, we modelled the trajectories for the participants with low energy intake in breakfast combined with a low-quality breakfast and for those with a high energy intake combined with a low-quality breakfast (compared to participants with an adequate energy intake in breakfast plus a high- quality breakfast).

Analyses were performed in R Software, version 4.1.2.

3. Results

3.1. Study population

Our study subjects were 383 participants of the PREDIMED-Plus study with available and plausible 1,103 diet records (Fig. 1). By study design, all participants were older adults (51.4% women), had overweight (19.3%) or obesity (80.7%), and harbored the metabolic syndrome. Consequently, participants presented a high prevalence of cardiovascular risk factors (Table 1). We found no clinically meaningful differences in baseline characteristics among participants in different breakfast energy intake groups and different breakfast quality categories.

Average energy intake at breakfast was 23% at baseline, 24% at 24 months of follow-up, and 25% at 36 months of follow-up. We found no association between the percentage of energy consumed at breakfast and breakfast quality ($r = -0.037$, p-value = 0.47).

3.2. Breakfast and adiposity

Participants with low and high breakfast energy intake showed a more pronounced rebound in BMI values after the first year of the study and higher BMI values over time compared to the reference group (inter-

Table 1
Characteristics of study participants.

	All	Groups by % of energy intake at breakfast				Groups by breakfast quality score		
	n = 383	<20% (n = 65)	20−30% (n = 271)	>30% (n = 47)	p-value	Low score (n = 199)	High score (n = 184)	p-value
Age (years, mean ± SD)	65.4 ± 4.60	65.1 ± 4.24	65.7 ± 4.61	64.5 ± 4.97	0.235	65.1 ± 4.67	65.8 ± 4.53	0.142
Women (n, %)	197 (51.4%)	31 (47.7%)	146 (53.9%)	20 (42.6%)	0.287	87 (47.3%)	110 (55.3%)	0.144
Education					0.873			0.323
Elementary school (n, %)	163 (42.6%)	30 (46.2%)	116 (42.8%)	17 (36.2%)		72 (39.1%)	91 (45.7%)	
Middle/ High school (n, %)	133 (34.7%)	22 (33.8%)	93 (34.3%)	18 (38.3%)		65 (35.3%)	68 (34.2%)	
Higher education (n, %)	87 (22.7%)	13 (20.0%)	62 (22.9%)	12 (25.5%)		47 (25.5%)	40 (20.1%)	
Tobacco use					0.003			0.116
Never smoker (n, %)	187 (48.8%)	27 (41.5%)	136 (50.2%)	24 (51.1%)		81 (44.0%)	106 (53.3%)	
Current smoker (n, %)	33 (8.62%)	14 (21.5%)	14 (5.17%)	5 (10.6%)		20 (10.9%)	13 (6.53%)	
Former smoker (n, %)	163 (42.6%)	24 (36.9%)	121 (44.6%)	18 (38.3%)		83 (45.1%)	80 (40.2%)	
Type-2 diabetes mellitus (n, %)	136 (35.5%)	26 (40.0%)	91 (33.6%)	19 (40.4%)	0.470	61 (33.2%)	75 (37.7%)	0.412
Hypercholesterolemia (n, %)	267 (69.7%)	50 (76.9%)	182 (67.2%)	35 (74.5%)	0.511	130 (70.7%)	137 (68.8%)	0.584
Hypertension (n, %)	328 (85.6%)	56 (86.2%)	229 (84.5%)	43 (91.5%)	0.448	162 (88.0%)	166 (83.4%)	0.253
Body mass index (kg/m^2, mean ± SD)	33.4 ± 3.54	33.3 ± 3.43	33.3 ± 3.57	34.1 ± 3.52	0.391	33.3 ± 3.51	33.5 ± 3.57	0.532
Body mass index categories					0.272			0.999
Overweight (n, %)	74 (19.3%)	13 (20.0%)	56 (20.7%)	5 (10.6%)		38 (19.1%)	36 (19.6%)	
Obesity (n, %)	309 (80.7%)	52 (80.0%)	215 (79.3%)	42 (89.4%)		161 (80.9%)	148 (80.4%)	
Energy intake per day (kcal, longitudinal mean ± SD)	1,630 ± 300	1,609 ± 288	1,635 ± 291	1,634 ± 368	0.821	1,671 ± 320	1,593 ± 276	0.011

Notes: SD; standard deviation.

group difference at 36 months, low energy intake: +0.61 kg/m^2, 95% confidence interval (CI) 0.19–1.02; high energy intake: +1.18 kg/m^2, 95% CI 0.71–1.65; Fig. 2A–C). No sustained inter-group differences according to breakfast quality were found (Fig. 2D–E). Participants with low and high energy intake at breakfast also showed a more pronounced rebound in WC values after the first year of the study and increasing differences over time (inter-group difference at 36 months: low energy intake: +2.22 cm, 95% CI 0.96–3.48; high energy intake: +4.57 cm, 95% CI 3.13–6.01; Fig. 2F–H). Participants with low breakfast quality also showed higher WC (inter-group differences at 36 months: +1.50 cm, 95% CI 0.53–2.46) (Fig. 2I–J).

3.3. Breakfast and lipid profile

Participants with low and high energy intake at breakfast showed a rebound in triglyceride values after six months of follow-up (particularly for those with high energy intake) that was not evident under the reference energy consumption at breakfast (Fig. 3A). Triglyceride values were higher and inter-group differences grew over time in low and high energy intake (inter-group difference at 36 months, low energy intake: +13.8 mg/dL, 95% CI 10.8–16.8; high energy intake: +28.1 mg/dL, 95% CI 24.7–31.6; Fig. 3B–C). Participants with low breakfast quality also showed an early rebound in triglyceride concentrations after the decrease in the first months of the PREDIMED-Plus intervention (Fig. 3D) and higher mean triglyceride values (inter-group difference at 36 months: +5.81 mg/dL, 95% CI 1.3.50 to 8.12) (Fig. 3E).

The shape of HDL-C trajectories in all breakfast groups was similar, but predicted mean HDL-C levels were consistently lower in both low and high breakfast energy groups compared to the reference group (inter-group difference at 36 months, low energy intake: −2.13 mg/dL, 95% CI −3.41 to −0.85; high energy intake: −4.56 mg/dL, 95% CI −6.04 to −3.09; Fig. 3F–H). Predicted mean HDL-C concentrations were also lower in participants with low breakfast quality (inter-group difference at 36 months, −1.66 mg/dL, 95% CI −2.63 to −0.69) (Fig. 3I–J).

LDL-C trajectories were comparable across breakfast energy intake groups and breakfast quality groups, and no inter-group differences were observed (Supplementary Fig. S1A–1E).

3.4. Breakfast and blood pressure

There were no differences in the SBP trajectories according to energy intake at breakfast (Supplementary Fig. S2A–2C). Regarding breakfast quality, slightly higher mean predicted values of SBP were observed at 12–18 months of follow-up in participants with low breakfast quality (Supplementary Fig. S2D–2E). Similarly, DBP trajectories were comparable for energy intake groups (Supplementary Fig. S2F–2H) and slightly higher mean predicted values of DBP were reported at 12–18 months in participants with low breakfast quality (Supplementary Fig. S2I–2J).

3.5. Breakfast and glucose metabolism

Glucose levels were not different between in groups according to energy intake at breakfast (Supplementary Fig. S3A–3C) and breakfast quality (Supplementary Fig. S3D–3E). Hb1Ac trajectory curves were similar among groups of breakfast energy intake and breakfast quality (Supplementary Fig. S3F–3J). Nonetheless, fasting plasma glucose and Hb1Ac values were slightly higher in participants with a low-quality breakfast, although differences were neither significant nor clinically relevant.

3.6. Breakfast and estimated glomerular filtration rate

eGFR trajectories in the groups of energy intake had a similar shape (Fig. 4A–C). In relation to breakfast quality, participants in the group with a low-quality breakfast had lower mean predicted eGFR (inter-group differences at 36 months, −1.22 mL/min/1.73 m^2, 95% CI −2.02 to −0.41; Fig. 4D–E).

3.7. Interaction between energy intake and breakfast quality

The interaction between energy and breakfast quality was not significant for any of the cardiometabolic markers in the study (Supplementary Table S3). The combination of low or high energy intake at breakfast and low breakfast quality was additive on the magnitude of associations with differences in cardiometabolic risk factors (Supplementary Figures S4–8).

4. Discussion

4.1. Summary of main results

In older adults at high cardiovascular risk, the energy consumed at breakfast and its nutritional quality are linked to differences in cardiometabolic health. Compared to a breakfast containing 20−30% of daily energy intake, participants consuming either low or high energy breakfasts displayed higher values of BMI, WC, and triglycerides, and lower HDL-C. Additionally, they showed a rebound in WC and triglycerides after the first year of intervention that was not evident in participants with an adequate energy intake at breakfast. When focusing on the quality of breakfast, participants with poor breakfast quality also had higher WC and triglycerides and lower HDL-C and eGFR than those with a higher breakfast quality.

4.2. Interpretation of results

Our findings show that an insufficient energy intake at breakfast is associated with greater adiposity, which concurs with previous evidence. Adults consuming less than 22% of their daily energy at breakfast in a cohort study had a higher BMI regardless of their total intake of energy when compared to consumers of higher intakes [22]. In a retrospective cross-sectional study, men who ate a small breakfast had higher BMI than those who had standard or large breakfasts [23]. Finally, in a clinical trial involving women participating in a 12-week isocaloric weight loss program, those who consumed 14% of energy intake at breakfast and 50% at dinner achieved less weight loss and lower decreases in WC compared to those who had 50% at breakfast and 14% at dinner [24]. Eating breakfast has been linked to increased satiety, which in turn leads to reduced total energy intake [25] and greater postprandial thermogenesis [26], providing a possible mechanism for less adiposity. On the other hand, our results on an association between high energy intakes at breakfast (>30%) with greater adiposity are novel. Unlike previous studies, we distinguished between reference and high energy intakes at breakfast and adjusted our analyses for the total energy intake in the day and the quality of the breakfast, which may explain our capacity to detect these differences. Having 20−30% of daily calories for breakfast was also associated with favorable changes in other cardiovascular risk factors related to adiposity, such as lower levels of triglycerides (triglyceride differences were clinically relevant, up to 28 mg/dL) and higher concentrations of HDL-C. These results align with one cross-sectional study reporting that participants eating breakfast had lower levels of triglycerides and higher HDL-C than those skipping breakfast [27].

In terms of the quality of breakfast, higher scores were also associated with lower adiposity (lower WC). While the ideal breakfast composition is debatable and there is no consensus on how to assess it, our findings are in line with another study suggesting that people who choose to consume fruit, unprocessed and unsweetened cereal flakes, nuts, and yogurt for breakfast tend to have lower abdominal obesity [28]. Breakfast quality could modulate factors that may impact adiposity, as a high-quality breakfast (rich in protein and carbohydrates) decreased appetite, cravings, and postprandial ghrelin levels in a randomized controlled

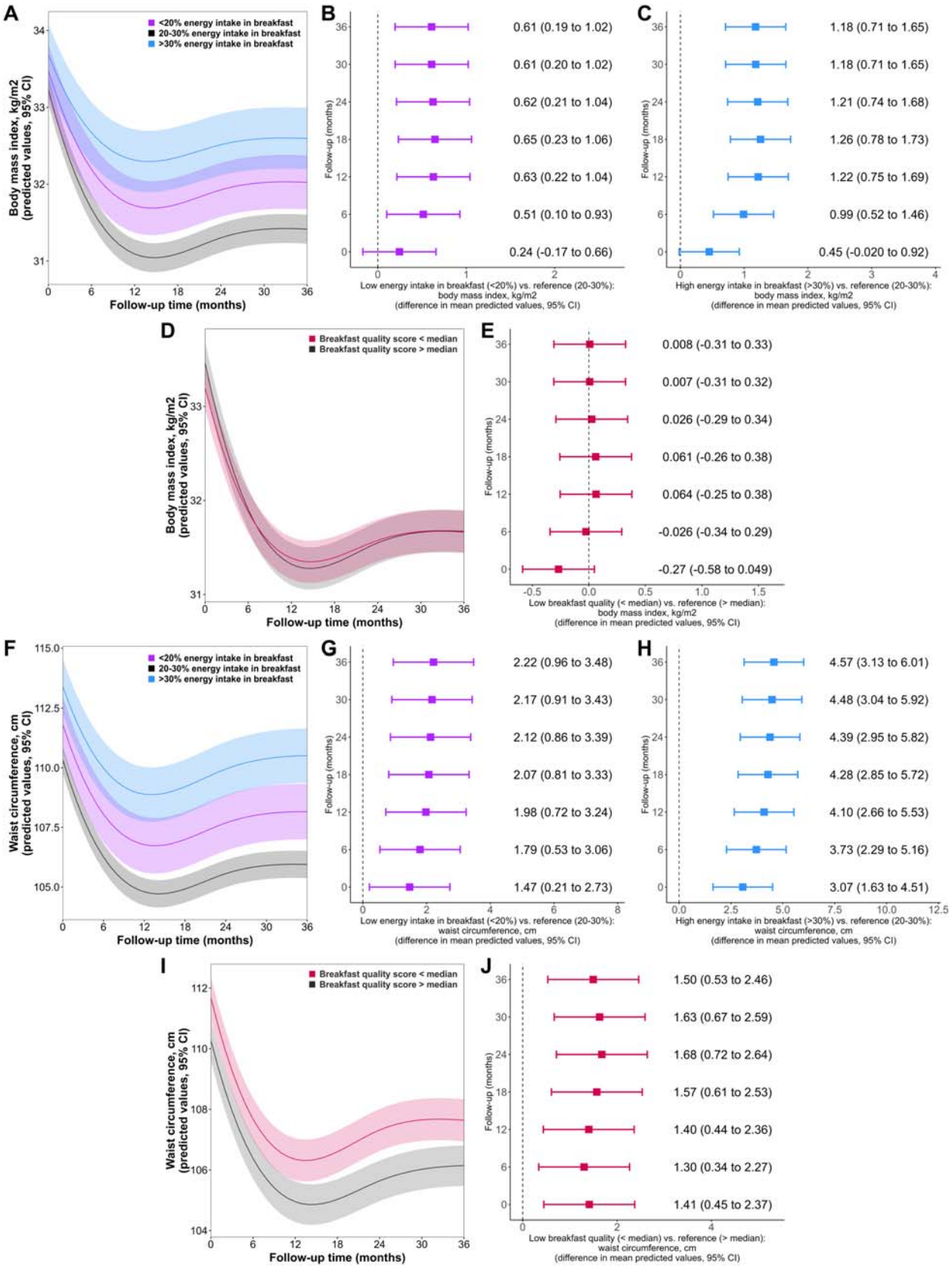

Fig. 2. Trajectories for adiposity measurements. (A, B, and C) Trajectories for breakfast energy intake groups and intergroup differences for BMI. (D and E) Trajectories for breakfast quality groups and intergroup differences for BMI. (F, G, and H) Trajectories for breakfast energy intake groups and intergroup differences for WC. (I and J) Trajectories for breakfast quality groups and intergroup differences for WC. CI, confidence intervals.

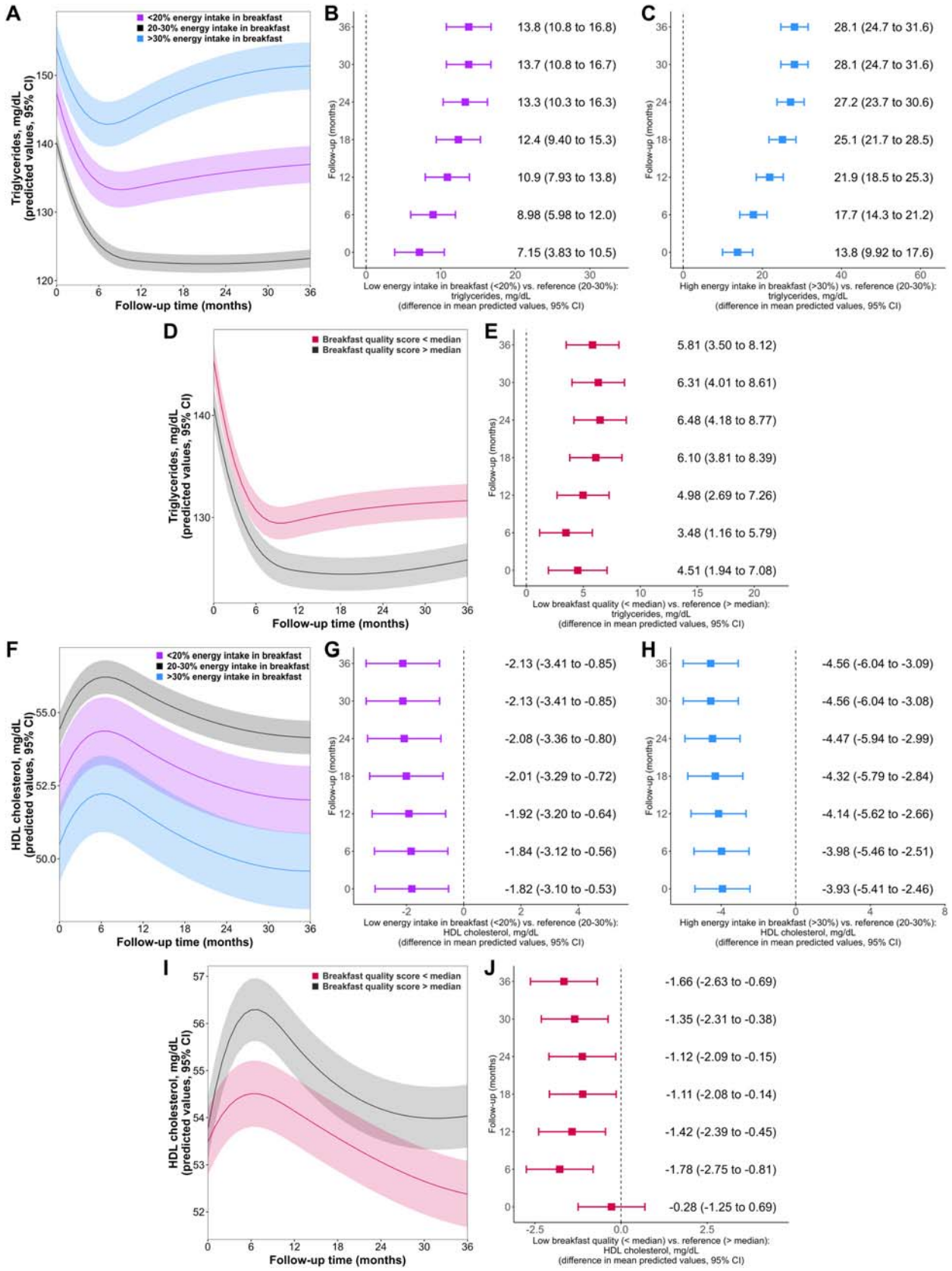

Fig. 3. Trajectories for triglycerides and HDL-C. (A, B, and C) Trajectories for breakfast energy intake groups and intergroup differences for triglycerides. D and E: Trajectories for breakfast quality groups and intergroup differences for triglycerides. (F, G, and H) Trajectories for breakfast energy intake groups and intergroup differences for HDL-C. (I and J) Trajectories for breakfast quality groups and intergroup differences for HDL-C. CI, confidence intervals; HDL, high density lipoproteins.

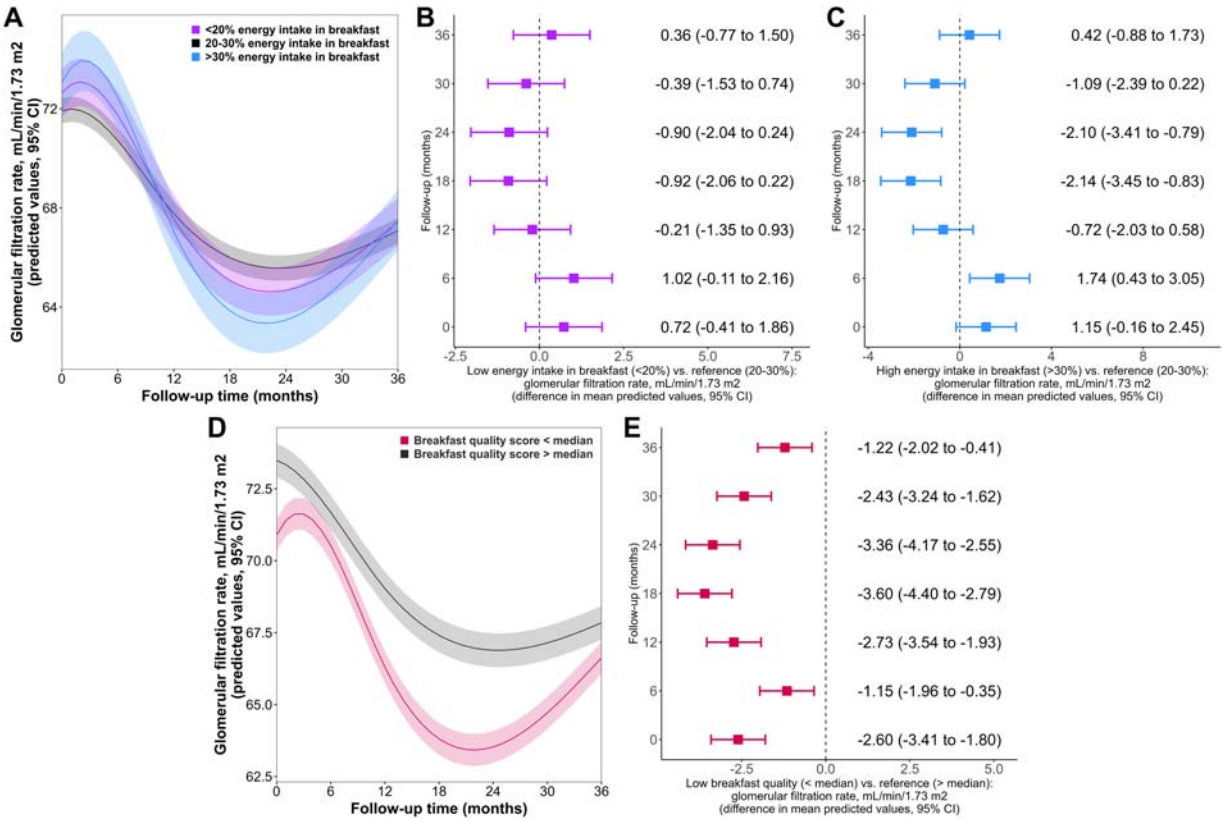

Fig. 4. Trajectories for eGFR. (A, B, and C) Trajectories for breakfast energy intake groups and intergroup differences for eGFR. (D and E) Trajectories for breakfast quality groups and intergroup differences eGFR. CI, confidence intervals; eGFR, estimated glomerular filtration rate.

trial with adults with obesity [29]. Our study is the first to associate a high-quality breakfast with lower triglyceride and higher HDL-C levels, something that can be explained by the association between lower adiposity and a better triglyceride and HDL-C status [30]. Besides, we also observed for the first time, that participants following a high-quality breakfast had higher eGFR than people in the low-quality breakfast group. Evidence on breakfast and renal function is mainly focused on studies about skipping breakfast, as adults who omitted breakfast had greater odds of chronic kidney disease and proteinuria in cross-sectional studies [31,32]. Lower adiposity in individuals with a high-quality breakfast may explain better kidney function [33].

We observed no clear differences in BP according to energy intake at breakfast, despite the slightly higher BP levels in participants with low-quality breakfast in some time points. These differences were not clinically relevant ($\leq$3 mmHg), as opposed to those observed for BMI, WC, triglycerides and HDL-C. Compared to skipping breakfast, eating breakfast has been associated with lower SBP (differences of $\leq$5 mmHg) and DBP (differences of $\leq$2 mmHg) in previous studies [34,35]. We also observed no clear differences for fasting plasma glucose or Hb1Ac levels, apart from a non-clinically relevant difference in fasting plasma glucose and Hb1Ac values in those with a low-quality breakfast. These slight differences could be explained by the greater content of fiber in a healthy breakfast, which could delay the absorption of carbohydrates and optimize insulin sensitivity through a wide range of molecular mechanisms [36]. The lack of robust differences in parameters related to glucose metabolism does not concur with previous studies that have reported an increased risk of developing type II diabetes among adults who skip breakfast [37,38]. Irregular eating patterns, which may include skipping breakfast, have also been linked to higher risk of metabolic syndrome in a large sample of older Chinese adults [39]. Discrepancies between previous studies and our results can be explained by the different definition of exposure (previous studies are focused on skipping breakfast and our exposures were energy consumed at breakfast or breakfast quality), the fact that some of these studies were cross-sectional, the different definitions and tools for assessing quality, and the fact that their participants were younger and had fewer cardiovascular risk factors.

4.3. Strength and limitations

Our study had some limitations. First, this study is observational, and we do not know whether the associations between the quantity and quality of breakfast and the risk factors trajectories of breakfast are causal or whether they may be explained by residual confounding. We tried to minimize this source of bias by adjusting for several covariates (e.g., age, sex, intervention group, education level, smoking habit, physical activity, total daily intake of energy, and diet quality). Nevertheless, these relationships should be verified in future nutritional intervention studies. In particular, smoking was linked to lower energy intake in breakfast (and tentatively to lower breakfast quality) in our data, consistent with previous evidence showing that smoking tends to cluster with unhealthy dietary habits [40]. Although smoking was included as a covariate in our analyses, future research on its relationship with breakfast-related traits is warranted. Second, participants in this study were undergoing a weight loss intervention. This implied that cardiometabolic trajectories improved in the whole population, particularly during the first 12 months of follow-up, as observed in the shape of the curves. However, our analyses focused on the differences among participants that showed different energy intake in breakfast and breakfast quality, and were adjusted for the intervention group of the PREDIMED-Plus study. Nevertheless, verifying our associations in a study that is not affected by a concomitant lifestyle intervention would be advisable. Third, nutritional assessment was based on three-day food diaries. Although it is the gold standard, it may imply some bias due to the subjective nature of participants' self-reporting. We tried to minimize this limitation by reviewing the food records with the participants and by excluding energy under- and over-reporters before statistical analyses. Fourth, while we adjusted for total daily energy intake

in our analyses, we were unable to assess the percentage of energy intake and the dietary quality in other meals besides breakfast. Future studies adjusting for detailed assessments of energy and quality in all meals are warranted. Fifth, the score selected to measure meal quality may have some limitations for breakfast. A healthy breakfast may imply a low intake of iron-rich foods, which may decrease the overall score even though the breakfast may still meet requirements for a healthy meal. Finally, our findings only apply to older adults with excess body weight and metabolic syndrome and cannot be generalized to other populations. Despite these limitations, our research offers a novel approach to the study of the health implications of breakfast that goes beyond the mere consideration of its intake.

5. Conclusion

Individuals at high cardiovascular risk may benefit from a balanced breakfast to maintain a healthy body weight, waist circumference, lipid profile, and renal function. A breakfast containing 20−30% of total caloric intake was linked to lower values of BMI, WC, triglycerides, and higher HDL-C concentrations, and a high-quality breakfast was associated with healthier values of WC, HDL-C, and eGFR. Our findings highlight the importance of not just eating breakfast, but paying attention to the quantity and quality of what is consumed. Promoting healthy breakfast habits may contribute to healthy aging by reducing the risk of metabolic syndrome and associated chronic diseases, thereby enhancing quality of life. More studies are needed to clarify the role of breakfast quantity and quality in cardiovascular outcomes and other chronic diseases, which could help refine dietary recommendations.

CRediT authorship contribution statement

K.A.P.V.: Investigation, Formal analysis, Methodology, Data Curation, Writing - Original Draft. C.L.: Methodology, Data Curation, Writing - Review & Editing. M.D.Z.: Investigation, Data Curation, Writing - Review & Editing, O.C: Data Curation, Writing - Review & Editing. J.S.S.: Funding acquisition, Data Curation, Project administration, Writing - Review & Editing. F.J.B.G.: Data Curation, Writing - Review & Editing. D.C: Funding acquisition, Data Curation, Project administration, Writing - Review & Editing. R.E.: Funding acquisition, Data Curation, Project administration, Writing - Review & Editing. E.R.: Funding acquisition, Data Curation, Project administration, Writing - Review & Editing. F.J.T.: Funding acquisition, Data Curation, Project administration, Writing - Review & Editing. G.B.: Investigation, Writing - Review & Editing. M.M.: Investigation, Writing - Review & Editing. D.M.A.: Investigation, Writing - Review & Editing. H.S.: Data Curation, Writing - Review & Editing. M.F.: Conceptualization, Data Curation, Methodology, Project administration, Supervision, Writing - Review & Editing. A.H.: Conceptualization, Data Curation, Formal analysis, Methodology, Visualization, Supervision, Writing - Review & Editing. A.H. is the guarantor of this study, accept full responsibility for the work, had access to the data, and controlled the decision to publish. All authors read and approved the final version of the manuscript.

Funding

This work was supported by the Instituto de Salud Carlos III [grant numbers IFI20/00002, PI19/00017, PI15/00047, PI18/00020, PI16/00533, PI13/00233, PI21/00024, PI20/00012, and CP21/00097] and co-funded by the European Union, the European Research Council [grant number #340918], and the Government of Catalonia [grant number 2021 SGR 00144]. Publication fees were covered by the Blanquerna School of Health Sciences, University Ramon Llull in Barcelona. The funders played no role in study design, collection, analysis, or interpretation of data, and neither in the process of writing the manuscript and the publish process.

Data availability statement

The generation and analysis of the data sets within this study are not projected to be open to access beyond the core research group. This is because the participants' consent forms and ethical approval did not include provisions for public accessibility. However, we follow a controlled data-sharing collaboration model, as the informed consent documents signed by the participants allowed for regulated collaboration with other researchers for study-related research. Following an application and approval process by the PREDIMED-Plus Steering Committee, the data described in the manuscript, together with the codebook and analytic code, will be available upon request. Researchers interested in this study can reach out to the Committee by sending a request letter to predimed_plus_scommittee@googlegroups.com. For those proposals that gain approval, a data-sharing agreement, outlining the specifics of the collaboration and data management, will be prepared and finalized.

The code for these analyses is available in: https://github.com/alvarohernaez/Breakfast_trajectories/.

Declaration of competing interest

J.S.-S. reports being a board member and personal fees from Instituto Danone Spain; being a board member and grants from the International Nut and Dried Fruit Foundation. R.E. reports being a board member of the Research Foundation on Wine and Nutrition, the Beer and Health Foundation, and the European Foundation for Alcohol Research; personal fees from KAO Corporation; lecture fees from Instituto Cervantes, Fundación Dieta Mediterranea, Cerveceros de España, Lilly Laboratories, AstraZeneca, and Sanofi; and grants from Novartis, Amgen, Bicentury, and Grand Fountaine. E.R. reports personal fees, grants, and nonfinancial support from the California Walnut Commission and Alexion; and nonfinancial support from the International Nut Council. All other authors report no conflicts of interest.

Acknowledgements

The authors especially thank the PREDIMED-Plus participants for the enthusiastic collaboration, the PREDIMED-Plus personnel for outstanding support, and the personnel of all associated primary care centers for the exceptional effort. A full list of names of all PREDIMED-Plus study collaborators is available in the Supplementary Files. The authors also thank the PREDIMED-Plus Biobank Network as a part of the National Biobank Platform of the ISCIII for storing and managing the PREDIMED-Plus biological samples. Furthermore, we thank the Patrimonio Comunal Olivarero for the olive oil donation to the study. CIBER de Fisiopatología de la Obesidad y Nutrición (CIBEROBN; group code: CB06/03/0028), CIBER de Epidemiología y Salud Pública (CIBERESP; group code: CB06/02/0029), and CIBER de Enfermedades Cardiovasculares (CIBERCV; group code: CB16/11/00229) are initiatives of Instituto de Salud Carlos III (Madrid, Spain) and are financed by the European Union (FEDER).

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jnha.2024.100406.

References

[1] O'Neil CE, Byrd-Bredbenner C, Hayes D, Jana L, Klinger SE, Stephenson-Martin S. The role of breakfast in health: definition and criteria for a quality breakfast. J Acad Nutr Diet 2014;114:S8–26, doi:http://dx.doi.org/10.1016/j.jand.2014.08.022.

[2] Ruiz E, Ávila JM, Valero T, Rodriguez P, Varela-Moreiras G. Breakfast consumption in Spain: patterns, nutrient intake and quality. Findings from the ANIBES study, a study from the international breakfast research initiative. Nutrients 2018;10:1324, doi:http://dx.doi.org/10.3390/nu10091324.

[3] Otaki N, Obayashi K, Saeki K, Kitagawa M, Tone N, Kurumatani N. Relationship between breakfast skipping and obesity among elderly: cross-sectional analysis of the HEIJO-KYO study. J Nutr Health Aging 2017;21:501–4, doi:http://dx.doi.org/10.1007/s12603-016-0792-0.

[4] Mekary RA, Giovannucci E, Cahill L, Willett WC, Van Dam RM, Hu FB. Eating patterns and type 2 diabetes risk in older women: breakfast consumption and eating frequency. Am J Clin Nutr 2013;98:436–43, doi:http://dx.doi.org/10.3945/ajcn.112.057521.
[5] Odegaard AO, Jacobs DR, Steffen LM, Van Horn L, Ludwig DS, Pereira MA. Breakfast frequency and development of metabolic risk. Diabetes Care 2013;36:3100–6, doi:http://dx.doi.org/10.2337/dc13-0316.
[6] Wang W, Grech A, Gemming L, Rangan A. Breakfast size is associated with daily energy intake and diet quality. Nutrition 2020;75–6, doi:http://dx.doi.org/10.1016/j.nut.2020.110764 110764.
[7] Li ZH, Xu L, Dai R, Li LJ, Wang HJ. Effects of regular breakfast habits on metabolic and cardiovascular diseases: a protocol for systematic review and meta-analysis. Med Baltim 2021;100:e27629, doi:http://dx.doi.org/10.1097/MD.0000000000027629.
[8] Chiuve SE, Fung TT, Rimm EB, Hu FB, McCullough ML, Wang M, et al. Alternative dietary indices both strongly predict risk of chronic disease. J Nutr 2012;142:1009–18, doi:http://dx.doi.org/10.3945/jn.111.157222.
[9] Iqbal K, Schwingshackl L, Gottschald M, Knüppel S, Stelmach-Mardas M, Aleksandrova K, et al. Breakfast quality and cardiometabolic risk profiles in an upper middle-aged German population. Eur J Clin Nutr 2017;71:1312–20, doi:http://dx.doi.org/10.1038/ejcn.2017.116.
[10] Pereira JL, Castro MA, Hopkins S, Gugger C, Fisberg RM, Fisberg M. Proposal for a breakfast quality index for brazilian population: rationale and application in the Brazilian National Dietary Survey. Appetite 2017;111:12–22, doi:http://dx.doi.org/10.1016/j.appet.2016.12.023.
[11] Félix PV, Pereira JL, Leme ACB, De Castro MA, Fisberg RM. Nutritional breakfast quality and cardiometabolic risk factors: Health Survey of São Paulo, a population-based study. Public Health Nutr 2021;24:4102–12, doi:http://dx.doi.org/10.1017/S1368980020002748.
[12] Martínez-González MA, Buil-Cosiales P, Corella D, Bulló M, Fitó M, Vioque J, et al. Cohort Profile: design and methods of the PREDIMED-Plus randomized trial. Int J Epidemiol 2019;48:387–8, doi:http://dx.doi.org/10.1093/ije/dyy225.
[13] Salas-Salvadó J, Díaz-López A, Ruiz-Canela M, Basora J, Fitó M, Corella D, et al. Effect of a lifestyle intervention program with energy-restricted mediterranean diet and exercise on weight loss and cardiovascular risk factors: one-year results of the PREDIMED-plus trial. Diabetes Care 2019;42:777–88, doi:http://dx.doi.org/10.2337/dc18-0836.
[14] Barcelona: Agència de Salut Pública de Catalunya. Petits canvis per menjar millor 2018.
[15] Elm EV, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for Reporting Observational Studies. J Clin Epidemiol 2008;61:344–9, doi:http://dx.doi.org/10.1016/j.jclinepi.2007.11.008.
[16] Cantós López D, Farran A, Palma Linares I. Programa de Càlcul Nutricional Professional (PCN Pro). 2013.
[17] Farrán Andreu, Zamora Raúl, Cervera Pilar. Tablas de composición de alimentos del CESNID. Barcelona, España: Mc- Graw-Hill / Interamericana y Edicions Universitat de Barcelona; 2003.
[18] Banna JC, McCrory MA, Fialkowski MK, Boushey C. Examining plausibility of self-reported energy intake data: considerations for method selection. Front Nutr 2017;4, doi:http://dx.doi.org/10.3389/fnut.2017.00045.
[19] Mainardi F, Prozorovscaia D, Sweeney G, Green H. Development and validation of a meal quality index with applications to NHANES 2005-2014. PLoS One 2021;15:e0244391, doi:http://dx.doi.org/10.1371/journal.pone.0244391.
[20] Inker LA, Schmid CH, Tighiouart H, Eckfeldt JH, Feldman HI, Greene T, et al. Estimating glomerular filtration rate from serum creatinine and cystatin C. N Engl J Med 2012;367:20–9, doi:http://dx.doi.org/10.1056/nejmoa1114248.
[21] Elhakeem A, Hughes RA, Tilling K, Cousminer DL, Jackowski SA, Cole TJ, et al. Using linear and natural cubic splines, SITAR, and latent trajectory models to characterise nonlinear longitudinal growth trajectories in cohort studies. BMC Med Res Methodol 2022;22:68, doi:http://dx.doi.org/10.1186/s12874-022-01542-8.
[22] Purslow LR, Sandhu MS, Forouhi N, Young EH, Luben RN, Welch AA, et al. Energy intake at breakfast and weight change: prospective study of 6,764 middle-aged men and women. Am J Epidemiol 2008;167:188–92, doi:http://dx.doi.org/10.1093/aje/kwm309.
[23] Kent LM, Worsley A. Breakfast size is related to body mass index for men, but not women. Nutr Res 2010;30:240–5, doi:http://dx.doi.org/10.1016/j.nutres.2010.03.006.
[24] Jakubowicz D, Barnea M, Wainstein J, Froy O. High caloric intake at breakfast vs. dinner differentially influences weight loss of overweight and obese women. Obesity 2013;21:2504–12, doi:http://dx.doi.org/10.1002/oby.20460.
[25] de Castro JM. The time of day and the proportions of macronutrients eaten are related to total daily food intake. Br J Nutr 2007;98:1077–83, doi:http://dx.doi.org/10.1017/S0007114507754296.
[26] Farshchi HR, Taylor MA, Macdonald IA. Beneficial metabolic effects of regular meal frequency on dietary thermogenesis, insulin sensitivity, and fasting lipid profiles in healthy obese women. Am J Clin Nutr 2005;81:16–24, doi:http://dx.doi.org/10.1093/ajcn/81.1.16.
[27] Chen L, Li X, Du X, Liu W, Du J, Guo L, et al. Cross-sectional association of meal skipping with lipid profiles and blood glucose in Chinese adults. Nutrition 2021;90:111245, doi:http://dx.doi.org/10.1016/J.NUT.2021.111245.
[28] Chatelan A, Castetbon K, Pasquier J, Allemann C, Zuber A, Camenzind-Frey E, et al. Association between breakfast composition and abdominal obesity in the Swiss adult population eating breakfast regularly. Int J Behav Nutr Phys Act 2018;15:115, doi:http://dx.doi.org/10.1186/s12966-018-0752-7.
[29] Jakubowicz D, Froy O, Wainstein J, Boaz M. Meal timing and composition influence ghrelin levels, appetite scores and weight loss maintenance in overweight and obese adults. Steroids 2012;77:323–31, doi:http://dx.doi.org/10.1016/j.steroids.2011.12.006.
[30] Cornier MA, Després JP, Davis N, Grossniklaus DA, Klein S, Lamarche B, et al. Assessing adiposity: a scientific statement from the American heart association. Circulation 2011;124:1996–2019, doi:http://dx.doi.org/10.1161/CIR.0b013e318233bc6a.
[31] Gahm C, Park S. The association between skipping breakfast and chronic kidney disease. Int Urol Nephrol 2023;55:3209–15, doi:http://dx.doi.org/10.1007/s11255-023-03590-5.
[32] Tokumaru T, Toyama T, Hara A, Kitagawa K, Yamamura Y, Nakagawa S, et al. Association between unhealthy dietary habits and proteinuria onset in a Japanese general population: a retrospective cohort study. Nutrients 2020;12:2511, doi:http://dx.doi.org/10.3390/nu12092511.
[33] Chang AR, Grams ME, Ballew SH, Bilo H, Correa A, Evans M, et al. Adiposity and risk of decline in glomerular filtration rate: meta-analysis of individual participant data in a global consortium. BMJ 2019;364:k5301, doi:http://dx.doi.org/10.1136/bmj.k5301.
[34] Almoosawi S, Prynne CJ, Hardy R, Stephen AM. Time-of-day of energy intake: association with hypertension and blood pressure 10 years later in the 1946 British Birth Cohort. J Hypertens 2013;31:882–92, doi:http://dx.doi.org/10.1097/HJH.0b013e32835ecc06.
[35] di Giuseppe R, Di Castelnuovo A, Melegari C, De Lucia F, Santimone I, Sciarretta A, et al. Typical breakfast food consumption and risk factors for cardiovascular disease in a large sample of Italian adults. Nutr Metab Cardiovasc Dis 2012;22:347–54, doi:http://dx.doi.org/10.1016/j.numecd.2010.07.006.
[36] Goff HD, Repin N, Fabek H, El Khoury D, Gidley MJ. Dietary fibre for glycaemia control: towards a mechanistic understanding. Bioact Carbohydr Diet Fibre 2018;14:39–53, doi:http://dx.doi.org/10.1016/j.bcdf.2017.07.005.
[37] Bi H, Gan Y, Yang C, Chen Y, Tong X, Lu Z. Breakfast skipping and the risk of type 2 diabetes: a meta-analysis of observational studies. Public Health Nutr 2015;18:3013–9, doi:http://dx.doi.org/10.1017/S1368980015000257.
[38] Uemura M, Yatsuya H, Hilawe EH, Li Y, Wang C, Chiang C, et al. Breakfast skipping is positively associated with incidence of type 2 diabetes mellitus: Evidence from the Aichi Workers' Cohort Study. J Epidemiol 2015;25:351–8, doi:http://dx.doi.org/10.2188/jea.JE20140109.
[39] Li Y, Sun Y, Wu H, Yang P, Huang X, Zhang L, et al. Metabolic syndromes increase significantly with the accumulation of bad dietary habits. J Nutr Health Aging 2024;28:100017, doi:http://dx.doi.org/10.1016/j.jnha.2023.100017.
[40] Meader N, King K, Moe-Byrne T, Wright K, Graham H, Petticrew M, et al. A systematic review on the clustering and co-occurrence of multiple risk behaviours. BMC Public Health 2016;16:657, doi:http://dx.doi.org/10.1186/s12889-016-3373-6.