

Targeting food addiction through an intensive energy-reduced Mediterranean diet lifestyle intervention: evidence from the 3-year PREDIMED-plus trial

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Abstract

Background Food addiction (FA) has been proposed as a behavioural phenotype linked to obesity, potentially influencing adherence and response to lifestyle interventions. Its role within long-term, multicomponent weight-loss programmes remains unclear. This study evaluated the impact of an intensive lifestyle intervention based on an energy-reduced Mediterranean diet (MedDiet) on FA symptomatology and examined whether baseline FA predicts adherence and weight-loss outcomes.

Methods A total of 448 older adults (mean age = 65.3 ± 4.6 years) with overweight/obesity and metabolic syndrome from the PREDIMED-Plus Cognition sub-study were randomised to an intensive intervention (IIG; energy-reduced MedDiet, physical activity, behavioural support) or a control group (CG; ad libitum MedDiet). FA (measured using the Yale Food Addiction Scale 2.0), anthropometric measures, MedDiet and physical activity adherence, and quality of life (QoL) were assessed at baseline, 1- and 3-years follow-up. Longitudinal changes were analysed using repeated-measures ANOVA. Logistic and Cox regression models evaluated predictors and time-to-achievement of clinically meaningful outcomes. Structural equation modelling (SEM) explored 3-year pathways linking anthropometric measures, MedDiet adherence, QoL, and intervention group according to FA status.

Results FA severity decreased in both groups, but reductions were sustained only in the IIG, which showed lower FA scores than the CG at 3 years ($p=0.011$). The IIG increased the likelihood of achieving clinically meaningful reductions in weight and waist circumference, particularly among participants without FA at baseline ($\geq 8\%$ weight loss: OR = 2.87, 95%CI 1.99–4.14; $\geq 5\%$ waist circumference reduction: OR = 3.01, 95%CI 2.20–4.11). Improvements in MedDiet adherence were markedly greater in the IIG, with effects strongest among individuals without FA (OR = 5.82, $p < 0.001$). SEM indicated that adherence mediated long-term improvements in weight, waist circumference, and QoL only in individuals without FA.

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Jordi Salas-Salvadó and Fernando Fernández-Aranda contributed equally to this work.



Conclusions An intensive energy-reduced MedDiet-based intervention improves FA symptoms and cardio-metabolic outcomes. However, baseline FA appears to limit adherence and attenuates long-term benefits. FA may represent a clinically relevant phenotype for personalising obesity treatment and enhancing intervention effectiveness.

Trial registration International Standard Randomized Controlled Trial Number (ISRCTN): 89,898,870. Registration date: 24 July 2014.

Keywords Obesity · Metabolic syndrome · Food addiction · Weight-loss intervention · Mediterranean diet

Background

Overweight and obesity represent major global public health challenges, contributing substantially to the burden of non-communicable diseases, including cardiovascular disorders, diabetes, cancers, neurological and gastroenterological conditions [1–3]. They are also associated with a broad range of psychological and social burdens, as well as impairments in health-related quality of life (QoL) [4, 5].

Lifestyle interventions incorporating healthful nutrition, physical activity, and behavioural support remain the primary strategy for obesity management. In this context, energy-reduced Mediterranean dietary patterns have been associated with beneficial effects on weight loss, cardiometabolic risk, and long-term sustainability [6, 7]. Nevertheless, there is substantial interindividual variability in treatment response, with adherence emerging as a pivotal factor in weight-loss success [8]. This underscores the necessity to identify the psychological and behavioural mechanisms underlying treatment outcomes.

Among these factors, the construct of food addiction (FA) has received increasing attention in recent years. The FA model has been proposed as a pattern of compulsive overeating similar to addictive behaviours characterised by impaired cognitive control, craving, and continued consumption despite adverse consequences, particularly in environments with high availability of ultra-processed foods (UPFs) [9, 10]. Recent meta-analytic evidence estimated a pooled prevalence of approximately 14% across non-clinical populations, with substantially higher rates reported among individuals with overweight/obesity of 24% [11]. Neurobiological models suggest that addictive-like eating behaviour may involve alterations in mesolimbic reward circuits, with UPFs potentially engaging dopaminergic pathways involved in reward processing, with some parallels to mechanisms implicated in substance use disorders, although this remains debated. Such mechanisms may contribute to compulsive intake and reduced inhibitory control [12–14].

A growing body of evidence indicates that FA is associated with higher body mass index (BMI), emotional eating, and increased psychopathological burden, including impulsivity and affective dysregulation [15, 16]. Older adults with obesity and metabolic syndrome who present with FA exhibit higher depressive symptomatology, neurocognitive deterioration, and poorer QoL than those without FA, according to a prior study done within this study population [17]. Although the presence of FA was associated with higher BMI and waist circumference, no differences were observed in other metabolic comorbidities, suggesting that its role in obesity-related complications may depend on additional factors.

Nevertheless, the role of FA in weight-loss interventions remains unclear, with findings showing considerable variability across studies. Recent evidence, including a systematic review and meta-analysis [18], suggest that FA may act as a prognostic factor for weight-loss outcomes, although the magnitude of its effect appears to vary across intervention types. Some studies report poorer outcomes among individuals with FA [19–21], whereas others indicate that comprehensive interventions incorporating behavioural or psychological components may reduce FA symptoms and attenuate its impact on outcomes [22]. These discrepancies highlight the need for further investigation into the mechanisms linking FA to treatment response.

Importantly, FA may represent a potentially modifiable phenotype in obesity. Understanding its role in adherence and weight-loss success could support the development of more tailored interventions, potentially improving

cardiometabolic outcomes and QoL beyond standard lifestyle programmes. While bariatric surgery has been associated with significant reductions in FA symptoms [23], evidence from lifestyle intervention remains limited, particularly in older non-clinical populations and within comprehensive, real-world programmes.

Taking all this into account, the present study aimed to evaluate the effects of a psychosocial lifestyle weight-loss intervention programme with energy-reduced MedDiet and physical activity on the presence and severity of FA symptoms; and to test a mediational model examining whether baseline FA predicts intervention adherence and weight-loss outcomes. We hypothesised that participants in the intensive intervention group will exhibit greater reductions in FA symptomatology compared to controls, and that baseline FA would be associated with lower adherence and poorer weight-loss outcomes.

Methods

Study design and participants

This study was conducted within the framework of the PREDIMED-Plus Cognition project, sub-study of the PREDIMED-Plus trial, a large-scale, multicentre, randomised, parallel-group clinical trial including 6874 participants recruited across 23 centres in Spain. The design, rationale, and methodology of the parent trial have been described in detail elsewhere [24, 25]. Briefly, the PREDIMED-Plus trial was designed to evaluate the long-term effects of an intensive lifestyle intervention based on an energy-reduced MedDiet, physical activity promotion, and behavioural support on cardiovascular disease prevention, weight loss, and metabolic outcomes.

Eligible participants were community-dwelling adults at high cardiovascular risk, specifically men aged 55–75 years and women aged 60–75 years, with overweight or obesity ($\text{BMI} \geq 27$ and $< 40 \text{ kg/m}^2$), and meeting at least three criteria for metabolic syndrome according to the harmonized criteria of the International Diabetes Federation and the American Heart Association and National Heart, Lung and Blood Institute (including elevated waist circumference, hyperglycaemia, hypertension, hypertriglyceridemia, and low HDL cholesterol levels) [26]. Exclusion criteria included prior cardiovascular disease (e.g., myocardial infarction, stroke, or revascularization procedures), severe chronic illness, active malignancy, severe psychiatric or cognitive disorders, institutionalization, substance abuse, inability to provide informed consent, or any condition limiting adherence to dietary or physical activity recommendations.

Participants were recruited through primary care centres using population registries and medical records, and were invited via telephone contact, informational sessions, or referral by healthcare professionals. Eligibility was confirmed during a screening visit.

The initial sample of eligible participants comprised $n=487$ individuals. The present analysis was conducted on the subsample with complete baseline data ($n=448$). No significant differences were observed between included and excluded participants in group allocation (CG vs. IIT; $p=0.552$), sex ($p=0.117$), age ($p=0.805$), or BMI ($p=0.788$). At the 3-year follow-up, data were available for $n=434$ participants, corresponding to an attrition rate of 3.1%. No significant differences were observed between completers and dropouts in group allocation ($p=0.798$), sex ($p=0.165$), age ($p=0.215$), or BMI ($p=0.785$). The participants' flowchart is provided in the Figure S1, additional file 1: Fig.S1.

The present analysis includes a subsample of participants recruited from four centres (Hospital del Mar Medical Research Institute, Bellvitge University Hospital, Universitat Rovira i Virgili, and Universitat de València) participating in the PREDIMED-Plus Cognition 3-year sub-study. Assessments were conducted at baseline, 1-year, and 3-year follow-up visits, allowing for the evaluation of both short-term and longer-term effects of the intervention. The subsample was comparable to the overall PREDIMED-plus cohort in key baseline characteristics.

Randomisation and intervention

Participants were randomised in the parent trial using a centralised, computer-generated allocation sequence, stratified by recruiting centre, sex, and age group. Allocation concealment was ensured using a secure web-based system.

Intensive intervention group (IIG)

Participants assigned to the IIG received an intensive, multicomponent lifestyle intervention aimed at achieving weight loss and improving cardiometabolic health. The intensive intervention included: (i) Energy-reduced Mediterranean diet (MedDiet): an individualized hypocaloric diet with an estimated energy deficit of 500–750 Kcal/day, based on Mediterranean dietary principles. Recommendations emphasised high consumption of plant-based foods, preferential use of extra virgin olive oil, moderate intake of fish, and reduced consumption of red and processed meats, refined grains, sugary beverages, and ultra-processed foods. Personalized meal plans and educational materials were provided by trained dietitians, taking into account baseline dietary habits, cultural preferences, and metabolic needs. Participants received detailed dietary guidance, recipes, shopping lists, and behavioural strategies to facilitate adherence. (ii) Physical activity promotion: participants were encouraged to progressively increase their physical activity levels, with the goal of achieving at least 150–200 min/week of moderate-to-vigorous physical activity, including aerobic and muscle-strengthening activities, and to reduce sedentary behaviour. Physical activity goals were individualized and monitored through self-reports and, where available, objective tools such as pedometers or accelerometers. (iii) Behavioural support: A structured behavioural intervention was delivered through a combination of individual and group sessions led by trained health professionals (dietitians, psychologists, and nurses). These sessions incorporated evidence-based behavioural change techniques, including: motivational interviewing, goal setting, self-monitoring (e.g., dietary logs, physical activity tracking), problem-solving, cognitive restructuring, and relapse prevention strategies. Although behavioural strategies were delivered to support dietary and lifestyle change, no intervention components were specifically designed to address FA or addictive-like eating behaviours. Participants attended frequent group and individual meetings. During the first year of the follow-up period, they were monitored on three occasions per month via individual motivational interviews, telephone consultation and group sessions, resulting in 36 contacts per year. Subsequently, the participants received monthly group sessions, individual sessions every three months, and two phone calls every three months, resulting in 24 contacts per year.

To enhance adherence, participants in the IIG were provided free supplies of extra virgin olive oil, reinforcing key components of the Mediterranean dietary pattern.

Control group (CG)

Participants assigned to the CG received an active comparator intervention consisting of general advice to follow a traditional MedDiet without energy restriction, consistent with the original PREDIMED trial [27]. This included general advice to follow a Mediterranean dietary pattern, educational materials (printed and/or digital), periodic group sessions promoting healthy eating habits, no specific caloric restriction or structured weight-loss goals. Recommendations were delivered by trained health professionals involved in the PREDIMED-Plus programme, primarily dietitians and nursing staff, through one individual visit and one group session every six months, resulting in two contacts per year. Participants also received general healthy lifestyle recommendations, including advice to remain physically active and maintain healthy eating habits, without the structured behavioural support, specific caloric restriction or weight-loss goals provided in the intervention arm.

As in the IIG, participants were provided with extra virgin olive oil. Therefore, the control group represents an active, evidence-based comparator rather than a no-treatment condition. While both groups received

Mediterranean diet counselling and lifestyle recommendations, only the IIG received an energy-restricted dietary prescription, intensive behavioural support, and a structured physical activity programme.

Psychometric and behavioural measures

The assessment of FA was conducted using the Spanish-validated version of the Yale Food Addiction Scale 2.0 (YFAS 2.0) [28, 29], a 35-item self-report questionnaire designed to operationalise addictive-like eating behaviour in accordance with the criteria for substance use disorders as defined in 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), with adaptations made to align with food consumption. The YFAS 2.0 is based on an eight-level Likert scale that ranges from 0 = never to 7 = every day. The present study employs two approaches that are derived from the scale. Firstly, a symptom count score ranging from 0 to 11 is employed, with higher scores indicating greater severity of addictive-like eating behaviour. Secondly, a diagnostic classification (binary outcome: presence or absence of FA) is based on the presence of clinically significant impairment or distress in addition to symptom criteria. The instrument has demonstrated good psychometric properties in Spanish populations, including high internal consistency, convergent validity with related constructs (e.g., emotional eating, binge eating), and sensitivity to change. In the present sample, internal consistency was high (Cronbach's $\alpha = 0.914$).

Health-related QoL was assessed using the Short Form-36 Health Survey (SF-36) [30], a widely used instrument consisting of 36 items grouped into eight domains: physical functioning, role limitations due to physical health, bodily pain, general health perceptions, vitality, social functioning, role limitations due to emotional problems, mental health. Scores for each domain are transformed to a 0–100 scale, with higher scores indicating better perceived health status. Physical and mental component summary scores can also be derived. The SF-36 has been extensively validated in Spanish populations and demonstrates high reliability and validity. In the present study, internal consistency was high (Cronbach's $\alpha = 0.933$).

Leisure-time physical activity was assessed using the validated Minnesota-REGICOR leisure-time physical activity questionnaire, which captures the frequency, duration, and intensity of a wide range of leisure-time and daily activities. Total physical activity was estimated as metabolic equivalent task minutes per week (MET-min/week), computed by weighting each activity by its estimated energy expenditure. This measure has been previously validated and widely used in epidemiological studies within Spanish populations [31].

Adherence to the intervention

Adherence to the MedDiet intervention was assessed using the 17-item MedDiet Adherence Screener (er-MEDAS), a questionnaire specifically developed and validated within the PREDIMED-Plus framework [32] and used to guide dietary recommendations. The questionnaire evaluates compliance with key aspects of the Med-Diet. Each item is scored dichotomously (0 or 1), yielding a total score ranging from 0 to 17, with higher scores indicating greater adherence. For descriptive and analytical purposes, adherence levels can be categorized as: low adherence (0–7 points), moderate adherence (8–10 points), high adherence (11–17 points).

Anthropometric and clinical outcomes

Anthropometric measurements were obtained by trained personnel following standardized operating procedures to ensure reliability and reproducibility across centres.

Body weight was measured using calibrated electronic scales, with participants wearing light clothing and no shoes. Height was measured using a wall-mounted stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared (Kg/m^2). Waist circumference was measured at the midpoint between the lowest rib and the iliac crest using a non-elastic tape. All measurements were performed in duplicate, and the average value was used for analyses.

Therapeutic success was operationalised on the basis of clinically meaningful changes in anthropometric parameters, as established by protocol at the beginning of the study in accordance with the predefined objectives of the PREDIMED-Plus trial. The weight-loss objectives were specifically defined as follows: to achieve an average weight loss reduction of $\geq 8\%$ in baseline body weight, a waist circumference decrease of $\geq 5\%$ from baseline, and a final objective of a between group average absolute difference in weight loss and waist circumference reduction of over 5% [25].

Other variables

Additional clinical and sociodemographic data were collected at baseline using structured questionnaires administered by trained staff. Sociodemographic variables included age (continuous variable, recorded in years), sex (binary, with values male and female), educational level (categorical, with values: primary, secondary or university), marital status (categorical, with values: single, married/cohabiting, separated/divorced, or widowed), and employment status (categorical, with values: employed, homemaker, retired, unemployed with income, or unemployed without income).

Statistical analysis

All statistical analyses were conducted using Stata version 19.0 for Windows. Baseline comparability between the IIG and CG was assessed using chi square (χ^2) tests for categorical variables and analysis of variance (ANOVA) for quantitative variables.

Changes over time in FA severity, assessed using the YFAS-2 total score, as well as changes in body weight, waist circumference, adherence to the MedDiet, leisure-time physical activity, and health-related QoL, were examined using repeated-measures ANOVA. Time (baseline, 1-year, and 3-year follow-up) was included as a within-subjects factor, while intervention group (control vs. experimental) and baseline FA status were included as between-subjects factors. All models were adjusted for sex, age, and baseline BMI. Post hoc pairwise comparisons were conducted to examine within- and between-group differences over time.

To identify predictors of clinically meaningful treatment outcomes, a series of logistic regression models were fitted. The primary outcomes were defined as: (a) achieving a $\geq 8\%$ reduction in body weight; (b) achieving a $\geq 5\%$ reduction in waist circumference; (c) achieving a simultaneous $\geq 5\%$ reduction in both body weight and waist circumference; (d) high adherence to the MedDiet; and (e) improvements in selected dimensions of health-related QoL. Each model included intervention group, baseline FA status, and their interaction (group $\times$ FA) as independent variables, and was adjusted for sex, age, and baseline BMI.

To evaluate the rate of achieving clinically meaningful reductions in weight and waist circumference, Cox proportional hazards regression models were used. This approach, commonly employed in time-to-event (survival) analysis, estimates the hazard (i.e., the instantaneous probability) of achieving a given outcome over time while accounting for differences in follow-up duration and censoring. Time was defined as the duration from baseline to the first observation meeting the predefined reduction criteria. All models included intervention group, FA status, and their interaction (group $\times$ FA), and were adjusted for sex, age, and baseline BMI.

To explore the longitudinal relationships between anthropometric variables, dietary adherence, QoL, and intervention allocation, path analysis was performed within a structural equation modelling (SEM) framework. Separate models were estimated for participants with and without FA at baseline. The models included baseline measures of weight, waist circumference, and QoL, as well as adherence to the MedDiet as a potential mediating variable, and the corresponding outcomes measured at the 3-year follow-up. The SEM analyses were adjusted for sex, age, and baseline BMI. Models were estimated using maximum likelihood procedures, and only statistically significant paths were retained in the final models. Model fit was evaluated using standard indices, including the χ^2 test, root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker–Lewis index

(TLI), and standardized root mean square residual (SRMR). Adequate model fit was defined as non-significant result in the χ^2 test ($p > 0.05$), $RMSEA \leq 0.08$, CFI and $TLI \geq 0.90$, and $SRMR \leq 0.10$.

This study included 14 couples, resulting in a nested data structure where observations elements are clustered within higher-level units. However, hierarchical-multilevel modelling was not conducted because the number of clusters was very small, which can lead to unreliable estimates of higher-level variance components [33].

Missing data were handled following widely used procedures for intention-to-treat (ITT) analyses. Specifically, when data for a given time point were missing, the value from the preceding assessment was carried forward. For participants who permanently dropped out, the last available observation was retained for all subsequent time points (last observation carried forward, LOCF).

Results

Descriptive characteristics at baseline

Table 1 displays the distribution of the sociodemographic variables and weight status at baseline. Overall, the sample showed a relatively even sex distribution, with a slight predominance of women. Participants were predominantly of European origin, and most were married. In terms of educational level, over half of the sample had primary education, followed by secondary education, while a smaller proportion had completed university studies. Regarding employment status, the majority of participants were retired (smaller proportions were unemployed or engaged in domestic work). In terms of weight status, nearly half of the participants were classified as having class I obesity, with the remainder distributed between overweight and class II obesity categories. Mean age was around 65 years old. Based on the YFAS 2.0 classification, 26 participants (5.8%) met the criteria for FA, whereas 422 participants (94.2%) were classified as not meeting the criteria.

No statistically significant differences were observed between the IIG and CG for any of these baseline variables, suggesting that the randomization procedure was successful in generating comparable and well-balanced groups at baseline prior to the intervention.

Evolution of the FA severity

Table 2 presents the results of a repeated-measures ANOVA with three assessment points (baseline, 1-year follow-up, and 3-year follow-up), one between-subject factor (IIG vs. CG), and three adjustment covariates (sex, age, and baseline BMI) (see also Fig. 1). The outcome variable corresponds to the YFAS 2.0 total score, which reflects the severity of FA symptoms. Within-group comparisons showed a statistically significant reduction in FA severity from baseline to 1-year and from baseline to 3-year follow-up in both intervention groups. In the IIG, an additional significant decrease was observed between the 1-year and 3-year assessments, whereas this change was not significant in the CG. Between-group comparisons indicated no significant differences at baseline or at the 1-year follow-up. However, at the 3-year follow-up, FA severity was significantly lower in the IIG compared to the CG.

Inspection of the mean trajectories over time revealed distinct patterns (trends) across groups (dash lines in Fig. 1). In the CG, the evolution followed a quadratic trend, characterised by an initial decrease from baseline to 1-year followed by a slight increase at 3-year follow-up. In contrast, the IIG showed a more linear pattern, with a progressive decrease over time. These patterns are consistent with the pairwise comparisons, which revealed significant differences between baseline and both follow-up assessments (1 year and 3 years) in the CG, whereas no significant differences were observed between the 1-year and 3-year follow-ups. This suggests that FA severity improved between baseline and the 1-year follow-up and then remained relatively stable through the 3-year follow-up.

Table 1 General characteristics of the PREDIMED-Plus Cognition participants at baseline

	Total sample (<i>n</i> = 448)		CG (<i>n</i> = 229)		IIG (<i>n</i> = 219)		χ^2	df	<i>p</i> ¹
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%			
Sex									
Male	217	48.4%	109	47.6%	108	49.3%	0.13	1	0.716
Female	231	51.6%	120	52.4%	111	50.7%			
Origin									
Europe	440	98.2%	224	97.8%	216	98.6%	0.42	1	0.516
South-America	8	1.8%	5	2.2%	3	1.4%			
Marital status									
Single	17	3.8%	7	3.1%	10	4.6%	4.03	3	0.258
Married	351	78.3%	187	81.7%	164	74.9%			
Divorced-separated	30	6.7%	11	4.8%	19	8.7%			
Widowed	50	11.2%	24	10.5%	26	11.9%			
Education level									
University (high)	42	9.4%	24	10.5%	18	8.2%	1.98	3	0.576
University (grade)	37	8.3%	22	9.6%	15	6.8%			
Secondary	129	28.8%	64	27.9%	65	29.7%			
Primary	240	53.6%	119	52.0%	121	55.3%			
Employment									
Unemployed	80	17.9%	39	17.0%	41	18.7%	7.80	4	0.099
Work at home	46	10.3%	23	10.0%	23	10.5%			
Retired	288	64.3%	149	65.1%	139	63.5%			
Unemployed (incomes)	21	4.7%	15	6.6%	6	2.7%			
Unemployed (no-incomes)	13	2.9%	3	1.3%	10	4.6%			
Group weight									
Over-weight	123	27.5%	59	25.8%	64	29.2%	1.16	2	0.559
Obesity I (BMI 30–35)	218	48.7%	117	51.1%	101	46.1%			
Obesity II (BMI ≥ 35)	107	23.9%	53	23.1%	54	24.7%			
Food Addiction									
Positive	26	5.8%	15	6.6%	11	5.0%	0.48	1	0.625
Negative	422	94.2%	214	93.4%	208	95.0%			
	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>Mean</i>	<i>SD</i>	<i>F</i>	<i>df</i>	<i>p</i>
Age (years-old)	65.25	4.63	65.15	4.73	65.35	4.53	0.21	1;446	0.650

Note. BMI, Body Mass Index; CG, Control Group. IIG, Intensive Intervention Group. SD: standard deviation. df: degrees of freedom. ¹*P*-values based on the comparison between the intervention groups: χ^2 tests (categorical variables) and ANOVA (quantitative variables)

Table 2 Evolution of the FA severity (YFAS-2 total score): results obtained in mixed ANOVA adjusted by sex, age and BMI at baseline

	Descriptives						Multivariate tests				
	Baseline (BS)		1-year		3-years			F	df	p	η^2
	Mean	SD	Mean	SD	Mean	SD	Time-by-Group	1.60	2;431	0.205	0.004
CG	1.85	1.39	1.57	1.16	1.62	1.13	Time	0.42	2;431	0.644	0.001
IIG	1.68	1.19	1.51	1.14	1.38	0.97	Group	3.25	1;431	0.072	0.007
Contrast	Time (within CG)			MD	p	η^2	Time (within IIG)	MD	p	η^2	
	1-year vs. BS			0.28	0.001*	0.030	1-year vs. BS	0.17	0.034*	0.032	
	3-years vs. BS			0.23	0.002*		3-years vs. BS	0.30	0.001*		
	3-years vs. 1-year			0.05	0.422		3-years vs. 1-year	0.13	0.035*		
Contrast	Group (IIG - CG)			MD	p	η^2					
	At Baseline			0.173	0.143	0.005					
	At 1-year			0.063	0.555	0.001					
	At 3 years			0.246	0.011*	0.014					

Note. BS, Baseline; CG, Control Group; IIG, Intensive Intervention Group. MD: mean difference. SD: standard deviation. df: degrees of freedom. η^2 : partial eta-squared. *Bold: significant comparison. Sample size: *n* = 434

Fig. 1 Evolution of the FA severity (YFAS-2 total score). Note: FA severity: mean registered in the YFAS-2 total score. Mean estimates obtained in mixed ANOVA adjusted by sex, age and BMI at baseline. Dash line: polynomial quadratic trend within the control group, and lineal trend within the experimental group. Sample size: $n=434$

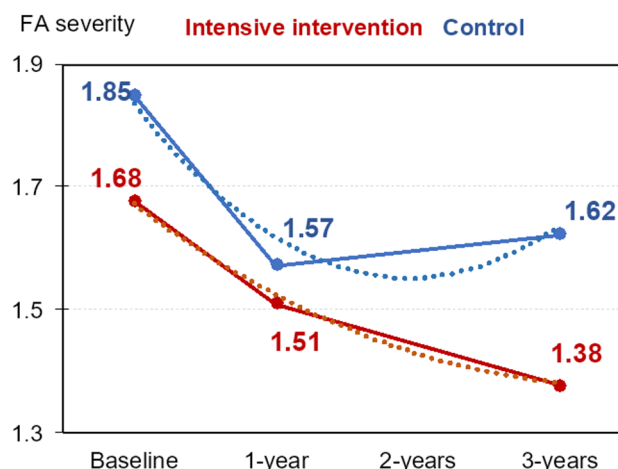


Table 3 Evolution in weight, waist, adherence and quality of life: mean and SD estimates adjusted by sex, age and BMI at baseline

			Descriptives					
			Baseline		1-year		3-years	
			Mean	SD	Mean	SD	Mean	SD
Weight	CG	FA-	85.18	12.89	83.07*	12.94	83.39*	13.46
		FA+	86.18	11.25	84.45	9.78	86.05	9.69
	IGG	FA-	86.25	13.90	80.18*	13.10	80.66*	13.45
		FA+	87.25	18.45	81.56*	18.94	83.32†	19.04
Waist	CG	FA-	107.60	9.57	105.79*	9.62	106.38*	9.78
		FA+	107.37	11.90	107.56	10.71	107.92	8.99
	IGG	FA-	108.00	10.73	100.98*	9.88	102.24*†	9.50
		FA+	107.77	10.21	102.75	12.09	103.78	11.07
Adherence MedDiet (er-MEDAS score)	CG	FA-	7.78	2.43	10.67*	2.64	10.72*	2.75
		FA+	7.84	2.92	10.25*	2.94	10.22*	2.78
	IGG	FA-	7.62	2.40	12.93*	2.59	12.71*	2.47
		FA+	7.68	2.90	12.51*	2.29	12.21*	2.21
Leisure-time physical activity (total energy expenditure, MET · min/week)	CG	FA-	2284.40	1900.15	2792.85*	2424.82	2830.08*	1900.28
		FA+	2981.20	3285.82	3283.97	3199.03	3248.49	2480.42
	IGG	FA-	2408.42	2075.08	3592.26*	2738.16	3639.77*	2491.28
		FA+	3105.22	1794.90	4083.38	1412.45	4058.19	963.54
Quality of life SF-36	CG	FA-	78.40	15.96	77.47	16.81	78.06	15.05
		FA+	66.04	19.04	65.07	19.47	71.42	19.26
	IGG	FA-	77.99	16.77	81.09*	14.39	80.37*	15.03
		FA+	65.64	17.38	68.68	13.65	73.73†	10.77

Note. CG: Control Group; IIG: Intensive Intervention Group; SD, Standard Deviation

Evolution of weight, waist circumference, adherence to MedDiet and physical activity, and QoL

The evolution of weight, waist circumference, adherence to the MedDiet, physical activity, and QoL is summarized in Table 3 and displayed in Fig. 2. Statistical significance tests were performed for all outcomes presented in Table 3 using repeated-measures ANOVAs analogous to those described for FA severity in Table 2. To facilitate presentation of the results, Table 3; Fig. 2 report adjusted means and trajectories, while the complete statistical results, including post-hoc pairwise comparisons, are provided in Additional File 1: Table S1. Overall, these results support a consistent pattern across outcomes, with more favourable trajectories in the IIG compared to the CG, particularly among participants without FA at baseline.

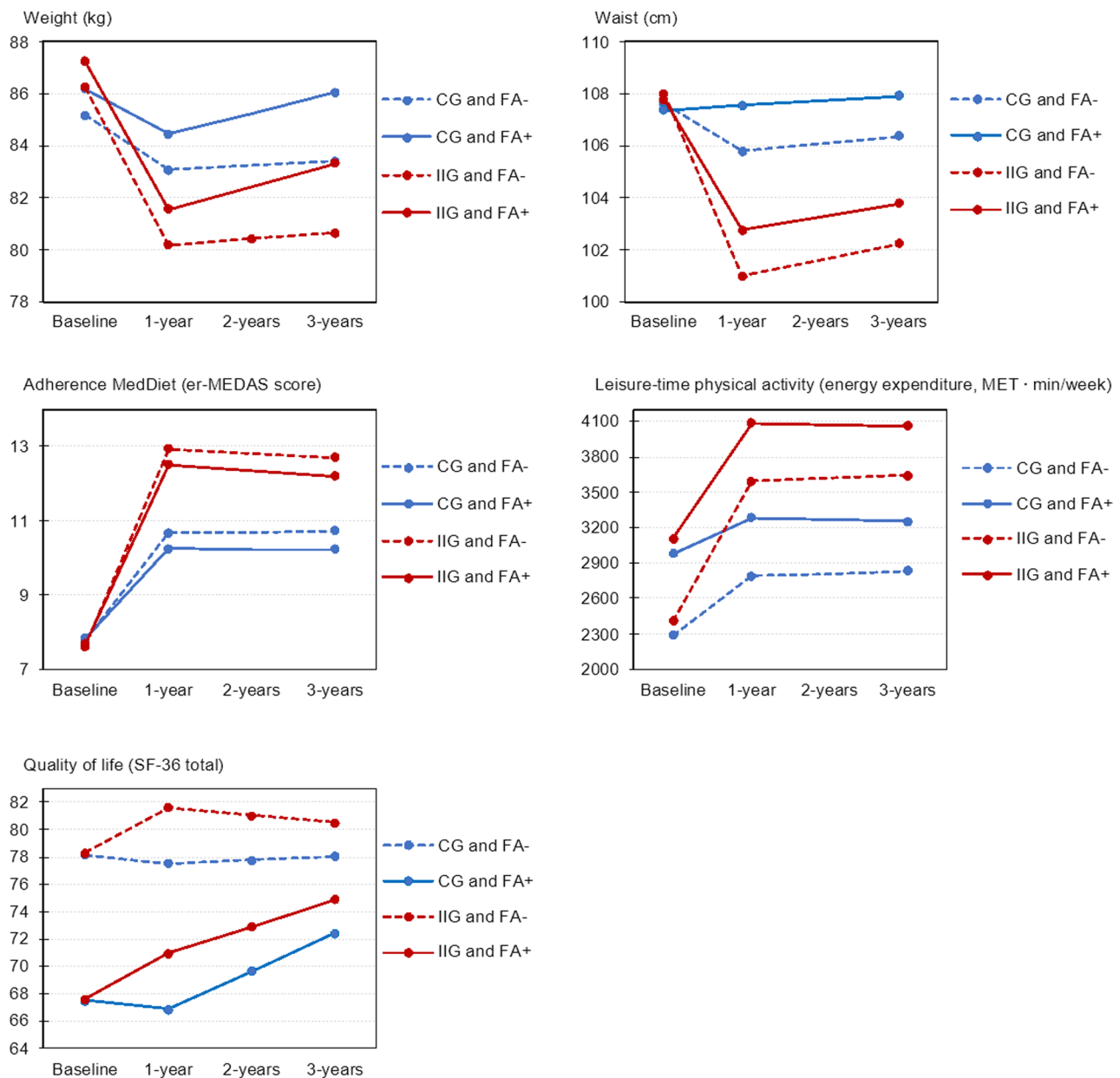


Fig. 2 Evolution in weight, waist, adherence and quality of life. Note: CG and FA-: Control group and food addiction negative screening group. CG and FA+: Control group and food addiction positive screening group. IIG and FA-: Intensive intervention group and food addiction negative screening group. IIG and FA+: Intensive intervention and food addiction positive screening group. Results obtained in mixed ANOVA adjusted by sex, age and baseline BMI

FA-: Food addiction negative screening group at baseline. FA+: Food addiction positive screening group at baseline.

*Significant change from baseline ($p < 0.05$). † Significant change from 1-year ($p < 0.05$).

Regarding anthropometric measures (labelled as weight and waist in Table 3; Fig. 2), body weight decreased at the 1-year follow-up across all groups, with more pronounced reductions observed in the IIG and among participants without FA at baseline. These improvements were maintained at 3 years in those participants without FA at baseline, whereas participants with FA exhibited a tendency toward partial weight regain over time. Notably,

participants in the IIG with FA at baseline reached mean weight values comparable to those of participants in the control group without FA (83.3 kg vs. 83.4 kg, respectively).

Waist circumference showed a pattern similar to that observed for body weight. Mean values decreased at the 1-year follow-up across all groups, with more pronounced reductions in the IIG and among participants with FA—at baseline. These improvements were generally maintained at 3 years, although a slight regain was observed.

Adherence to the MedDiet (labelled as er-MEDAS score in Table 3; Fig. 2) increased markedly from baseline to 1 year in both groups, with higher levels consistently observed in the IIG. These improvements were largely maintained at 3 years. Notably, participants in the IIG achieved higher adherence scores regardless of FA status, suggesting a robust intervention effect.

For leisure-time physical activity (labelled as MET min/week in Table 3; Fig. 2), all groups showed increases at the 1-year follow-up, which were maintained over the remaining follow-up period. These increases were more pronounced in the IIG. Notably, baseline levels of leisure-time physical activity were strongly associated with baseline FA status, with higher values observed among participants with FA at baseline. From the 1-year follow-up onward, participants in the IIG consistently reported higher mean values compared to those in the CG.

In terms of QoL (as measured in the SF-36, as labelled in Table 3; Fig. 2), baseline differences between participants with and without FA at baseline were evident, with lower scores observed among those with FA. The longitudinal trajectories suggested more favorable outcomes in the IIG than in the CG, particularly among participants without FA at baseline.

Predictors of good outcomes after the intervention

The results of the logistic regression analyses adjusted for sex, age, and baseline BMI are presented in Table 4 and graphically illustrated in Fig. 3. Overall, the intervention effect was consistently observed among participants without FA at baseline, whereas findings were weaker and more heterogeneous among those with FA.

Adherence based on the er-MEDAS score: Low: 0 to 7, mean: 8 to 10, high: 11 to 17. Quality of life based on the SF-36: the cut-off for considering bad versus good is based on the percentile 75 for old age populations.

For weight loss, FA– participants in the IIG were 2.97 times more likely than FA– participants in the CG to achieve a weight reduction of at least 8% ($OR=2.97$, $p<0.001$). No significant intervention effect was observed among participants with FA at baseline.

For waist circumference, FA– participants in the IIG were 5.91 times more likely than FA– participants in the CG to achieve a reduction of at least 5% ($p<0.001$). In contrast, among participants in the IIG, those with FA at baseline were significantly less likely to achieve this outcome than those without FA ($OR=0.21$, $p=0.018$).

When considering the combined criterion of achieving both a $\geq 5\%$ reduction in body weight and waist circumference, FA– participants in the IIG were 4.75 times more likely than FA– participants in the CG to meet this target ($p<0.001$), whereas no significant differences were observed among participants with FA at baseline.

Regarding adherence to the Mediterranean diet, FA– participants in the IIG were 5.82 times more likely than FA– participants in the CG to achieve high adherence ($p<0.001$). However, among participants in the IIG, those with FA at baseline were significantly less likely to achieve high adherence than those without FA ($OR=0.183$, $p=0.023$). Moreover, a significant Group $\times$ FA interaction was observed ($p=0.032$), indicating that the beneficial effect of the intervention on Mediterranean diet adherence was attenuated among participants presenting FA at baseline.

Finally, no significant effects of group, baseline FA status, or their interaction were observed for any of the QoL dimensions assessed (all $p>0.05$).

Results of the Cox proportional hazards models conducted to examine the rate of achieving clinically meaningful reductions in weight and waist circumference are displayed in Table 5; Fig. 4. Overall, these results reinforce the findings from previous analyses, suggesting that the IIG not only increases the likelihood of achieving

Table 4 Logistic regression: results adjusted by sex, age and BMI at baseline

Criteria	Predictors	B	SE	<i>p</i>	OR	95% CI OR	
Decrease $\geq$ 8% weight <i>I = Yes versus 0 = No</i>	Group Within FA-	1.090	0.222	0.001*	2.973	1.925	4.592
	Within FA+	1.349	0.989	0.172	3.854	0.555	26.769
	FA Within CG	-0.642	0.786	0.414	0.526	0.113	2.456
	Within IIG	-0.383	0.652	0.557	0.682	0.190	2.449
	Interaction: Group-by-FA	0.259	1.014	0.798	1.296	0.178	9.448
Decrease $\geq$ 5% waist <i>I = Yes versus 0 = No</i>	Group Within FA-	1.776	0.218	0.001*	5.907	3.853	9.056
	Within FA+	0.116	0.840	0.890	1.123	0.216	5.828
	FA Within CG	0.106	0.582	0.855	1.112	0.355	3.482
	Within IIG	-1.554	0.658	0.018*	0.211	0.058	0.767
	Interaction: Group-by-FA	-1.660	0.868	0.056	0.190	0.035	1.043
Decrease $\geq$ 5% weight and waist <i>I = Yes versus 0 = No</i>	Group Within FA-	1.558	0.223	0.001*	4.749	3.066	7.358
	Within FA+	1.349	0.988	0.172	3.854	0.555	26.751
	FA Within CG	-0.571	0.786	0.468	0.565	0.121	2.638
	Within IIG	-0.780	0.652	0.232	0.458	0.128	1.646
	Interaction: Group-by-FA	-0.209	1.013	0.837	0.812	0.111	5.914
Adherence MedDiet <i>I = High versus 0 = Mean/Low</i>	Group Within FA-	1.762	0.326	0.001*	5.824	3.072	11.042
	Within FA+	-0.371	0.942	0.693	0.690	0.109	4.369
	FA Within CG	0.434	0.674	0.520	1.543	0.411	5.788
	Within IIG	-1.699	0.749	0.023*	0.183	0.042	0.793
	Interaction: Group-by-FA	-2.133	0.997	0.032*	0.118	0.017	0.836
Quality of life: SF-36 mental health <i>I = Bad 0 = Good</i>	Group Within FA-	0.029	0.274	0.916	1.029	0.601	1.762
	Within FA+	-0.205	0.957	0.831	0.815	0.125	5.316
	FA Within CG	0.444	0.647	0.493	1.559	0.438	5.546
	Within IIG	0.211	0.769	0.784	1.234	0.273	5.576
	Interaction: Group-by-FA	-0.233	0.996	0.815	0.792	0.112	5.574
Quality of life: SF-36 role-emotional <i>I = Bad 0 = Good</i>	Group Within FA-	-0.162	0.278	0.561	0.851	0.493	1.467
	Within FA+	-1.261	1.020	0.216	0.283	0.038	2.093
	FA Within CG	0.686	0.640	0.284	1.985	0.566	6.959
	Within IIG	-0.414	0.851	0.627	0.661	0.125	3.505
	Interaction: Group-by-FA	-1.099	1.058	0.299	0.333	0.042	2.650
Quality of life: SF-36 social <i>I = Bad 0 = Good</i>	Group Within FA-	0.302	0.366	0.410	1.352	0.660	2.773
	Within FA+	-1.144	1.262	0.365	0.318	0.027	3.781
	FA Within CG	1.091	0.712	0.125	2.977	0.738	12.007
	Within IIG	-0.355	1.123	0.752	0.701	0.078	6.336
	Interaction: Group-by-FA	-1.446	1.314	0.271	0.235	0.018	3.096

Note. CG: Control Group. IIG: Intensive Intervention Group. FA: Food addiction at baseline (1 = Positive *versus* 0 = Negative). OR: odds ratio. 95%CI: 95% confidence interval. *Significant parameter

clinically meaningful improvements but also accelerates their occurrence, primarily among individuals without FA at baseline.

Specifically, participants in the IIG showed a significantly higher rate of achieving a $\geq$ 8% weight reduction compared to their counterparts in the CG. For this measure, the absence of FA was related to little increase in the rate of occurrence. For the waist circumference, the IIG without FA subgroup reached a $\geq$ 5% reduction more rapidly than other groups. Moreover, the IIG subgroup of patients with FA displayed a survival function similar to the CG. For the combined outcome (simultaneous $\geq$ 5% reduction in weight and waist circumference), the IIG without FA group again showed a significantly higher rate of achieving this target relative to both CG subgroups.

Path analysis

Figure 5 displays the path-diagrams obtained in the SEM estimated separately for participants with and without FA and adjusted for sex, age, and baseline BMI. Standardized coefficients are reported.

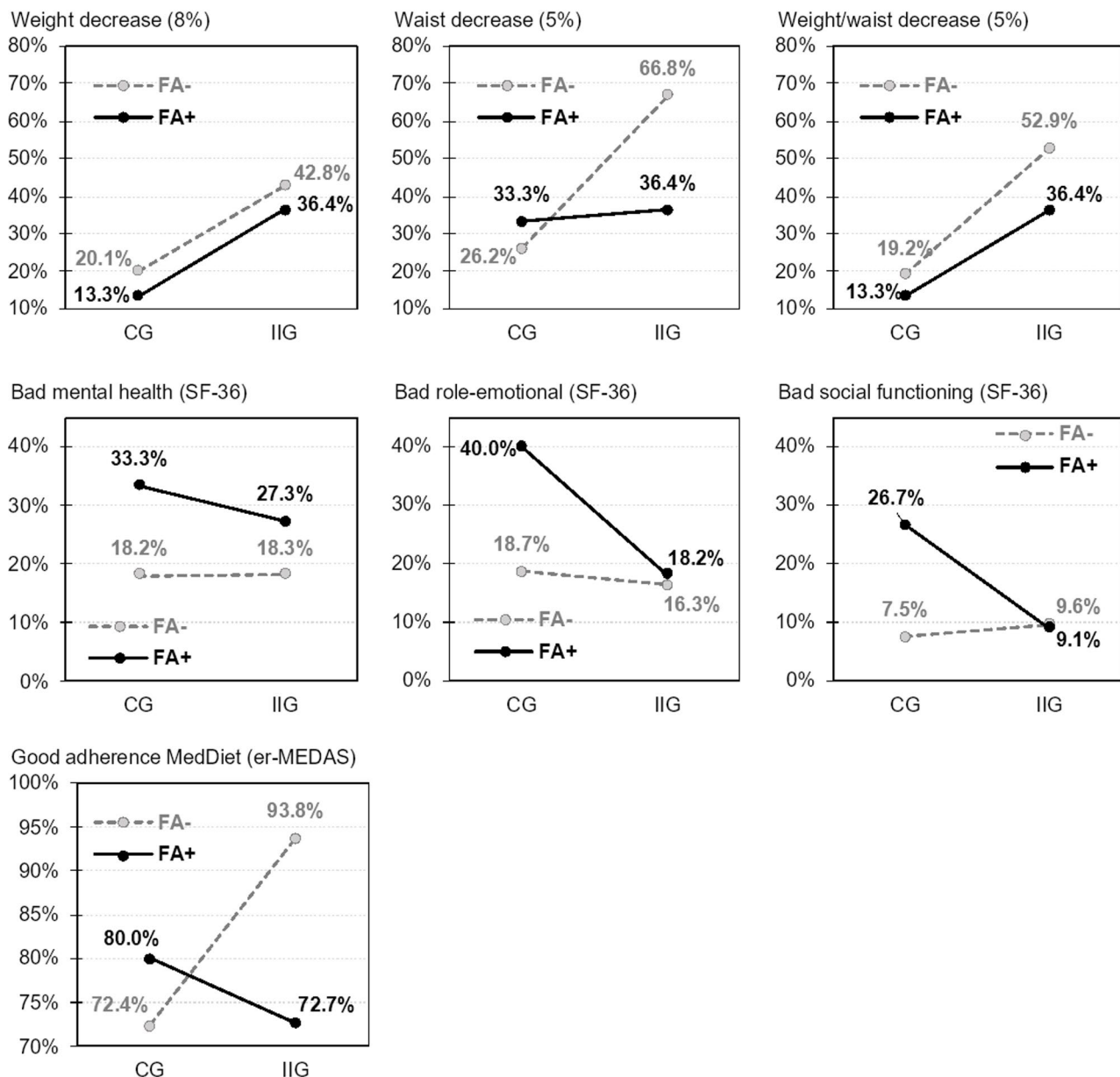


Fig. 3 Therapy outcomes in the study: good adherence to the different elements of the intervention. Note: CG: control group. IIG: intensive intervention group. FA-: Food addiction negative screening group. FA+: Food addiction positive screening group. Good adherence MedDiet based on the er-MEDAS score: Low: 0 to 7, mean: 8 to 10, high: 11 to 17

The model for participants without FA at baseline showed good fit to the data: $\chi^2 = 26.46$ ($p=0.118$), RMSEA=0.031, CFI=0.995, TLI=0.991, and SRMR=0.026. Strong temporal stability was observed for anthropometric and QoL measures across the 3-year follow-up. In addition, several cross-domain associations emerged. Higher baseline body weight was associated with greater waist circumference and lower QoL at 3 years. Allocation to the IIG was positively associated with greater adherence to the MedDiet, as well as with lower body weight and waist circumference at the 3-year follow-up. Higher baseline QoL was also significantly associated with greater MedDiet adherence. In turn, MedDiet adherence showed significant associations with all three 3-year outcomes, such that greater adherence to the MedDiet was associated with lower body weight, smaller waist circumference, and better QoL at follow-up.

Table 5 Cox regression exploring the rate to the outcomes: results adjusted by sex, age and BMI at baseline

Decrease	Predictors	Wald (df=1)	<i>p</i>	OR	95% CI OR	
Weight (8%)	*Condition	35.019	0.001			
<i>I = Yes / 0 = No</i>	IIG and FA− <i>versus</i> CG and FA−	31.557	0.001	2.865	1.985	4.136
	IIG and FA− <i>versus</i> CG and FA+	5.105	0.024	5.082	1.240	20.823
Waist (5%)	*Condition	50.252	0.001			
<i>I = Yes / 0 = No</i>	IIG and FA− <i>versus</i> CG and FA−	47.403	0.001	3.005	2.197	4.110
	IIG and FA− <i>versus</i> CG and FA+	4.357	0.037	2.608	1.060	6.415
Weight and waist (5%)	*Condition	42.283	0.001			
<i>I = Yes / 0 = No</i>	IIG and FA− <i>versus</i> CG and FA−	40.274	0.001	2.297	1.777	2.970
	IIG and FA− <i>versus</i> CG and FA+	4.750	0.029	2.336	1.089	5.010

Note. CG and FA−: Control group and food addiction negative screening group. CG and FA+: Control group and food addiction positive screening group. IIG and FA−: Intensive intervention group and food addiction negative screening group. IIG and FA+: Intensive intervention group and food addiction positive screening group. OR: odds ratio. 95%CI: 95% confidence interval. *Significant contrasts are displayed

The model for participants with FA at baseline also showed adequate goodness-of-fit: $\chi^2 = 23.67$ ($p = 0.539$), RMSEA = 0.001, CFI = 0.999, TLI = 0.998, and SRMR = 0.084. As in the group without FA, strong stability effects were observed over time for body weight, waist circumference, and QoL. Significant cross-lagged associations between anthropometric measures were also identified: higher baseline body weight was associated with greater waist circumference and poorer QoL at 3 years. Higher baseline QoL was also related to greater adherence to the MedDiet. Allocation to the IIG was positively associated with adherence to the MedDiet. However, in contrast to the SEM results obtained for participants without FA at baseline, adherence to the MedDiet was not significantly associated with weight, waist circumference, or QoL at 3 years among participants with FA.

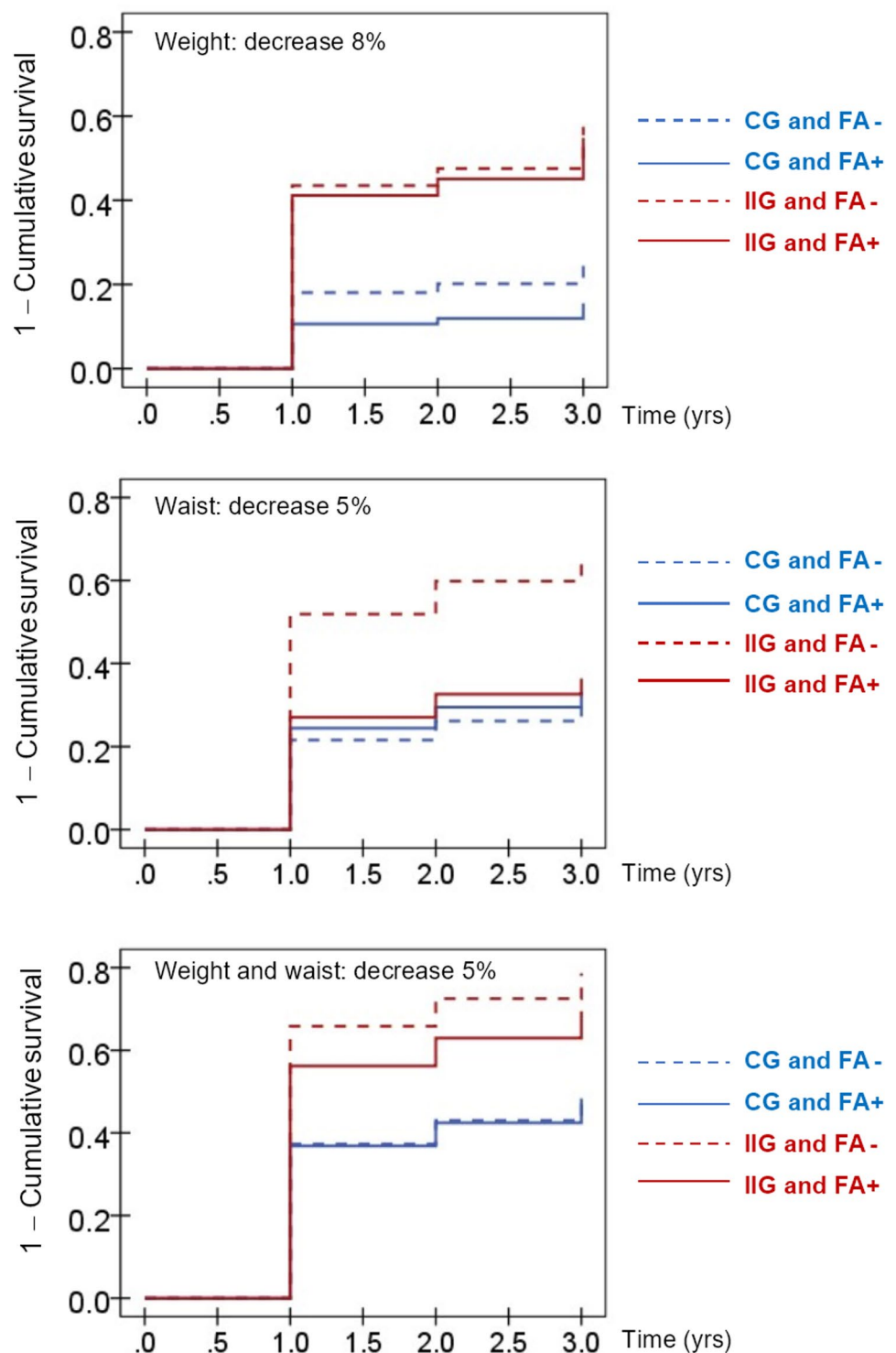
In summary, the path analyses highlight clear differences according to FA status. While both groups showed strong stability of anthropometric and QoL measures over time, adherence to the MedDiet played a central mediating role linking group assignment and long-term outcomes (anthropometric and QoL) in participants without FA at baseline. In contrast, among participants with FA+, long-term anthropometric and QoL outcomes were largely explained by baseline levels rather than by changes in dietary adherence and/or intervention group allocation.

Discussion

The present study aimed to provide a better understanding of the role of food addiction (FA) within a multidomain psychosocial lifestyle intervention combining an energy-reduced MedDiet and physical activity promotion. Overall, the findings suggest that such intervention can effectively reduce FA severity over 3 years of follow-up. Furthermore, our results lend support to the hypothesis that FA impacts long-term outcomes, as individuals with FA demonstrated a reduced or absence of response in comparison to those without FA. Nevertheless, the IIG produced modest favourable effects on weight, QoL and adherence response to the intervention guidelines even in the presence of FA, thereby underscoring its clinical effectiveness.

The longitudinal analysis of FA severity revealed significant differences between the two randomisation groups. Although both groups showed significant reductions in FA severity during the first year of intervention, suggesting that the initial engagement in a structured plan may yield early improvements, their subsequent trajectories diverged substantially. In the CG, FA severity showed an initial decline from baseline to 1 year, and this reduction was sustained at 3-year follow-up, with values remaining lower than baseline. Conversely, the individuals allocated to the IIG showed a progressive and sustained reduction in FA severity across all follow-up time points. The linear downward trajectory, together with the significant improvement between the 1-year and 3-year follow-ups, suggests that the intervention may have facilitated more durable changes in the psychological or behavioural mechanisms underlying FA. The significant differences between groups at three-year follow-up further support the long-term superiority of the IIG programme, despite the absence of differences at baseline or at the one-year

Fig. 4 Survival functions obtained in the Cox regression. Note: CG and FA−: control group and food addiction negative screening group. CG and FA+: control group and food addiction positive screening group. IIG and FA−: intensive intervention group and food addiction negative screening group. IIG and FA+: intensive intervention group and food addiction positive screening group. Results adjusted by sex, age and baseline BMI. OR: odds ratio. 95%CI: 95% confidence interval. *Significant contrasts are displayed



follow-up. Previous studies have shown that lifestyle interventions can reduce FA symptom burden, but the evidence is uneven [20]. In adults with obesity or overweight, reductions in YFAS symptoms have been reported after behavioural weight-loss programmes [34], whole-food dietary fibre-focused behavioural intervention [20, 35], and metabolic health programmes [36].

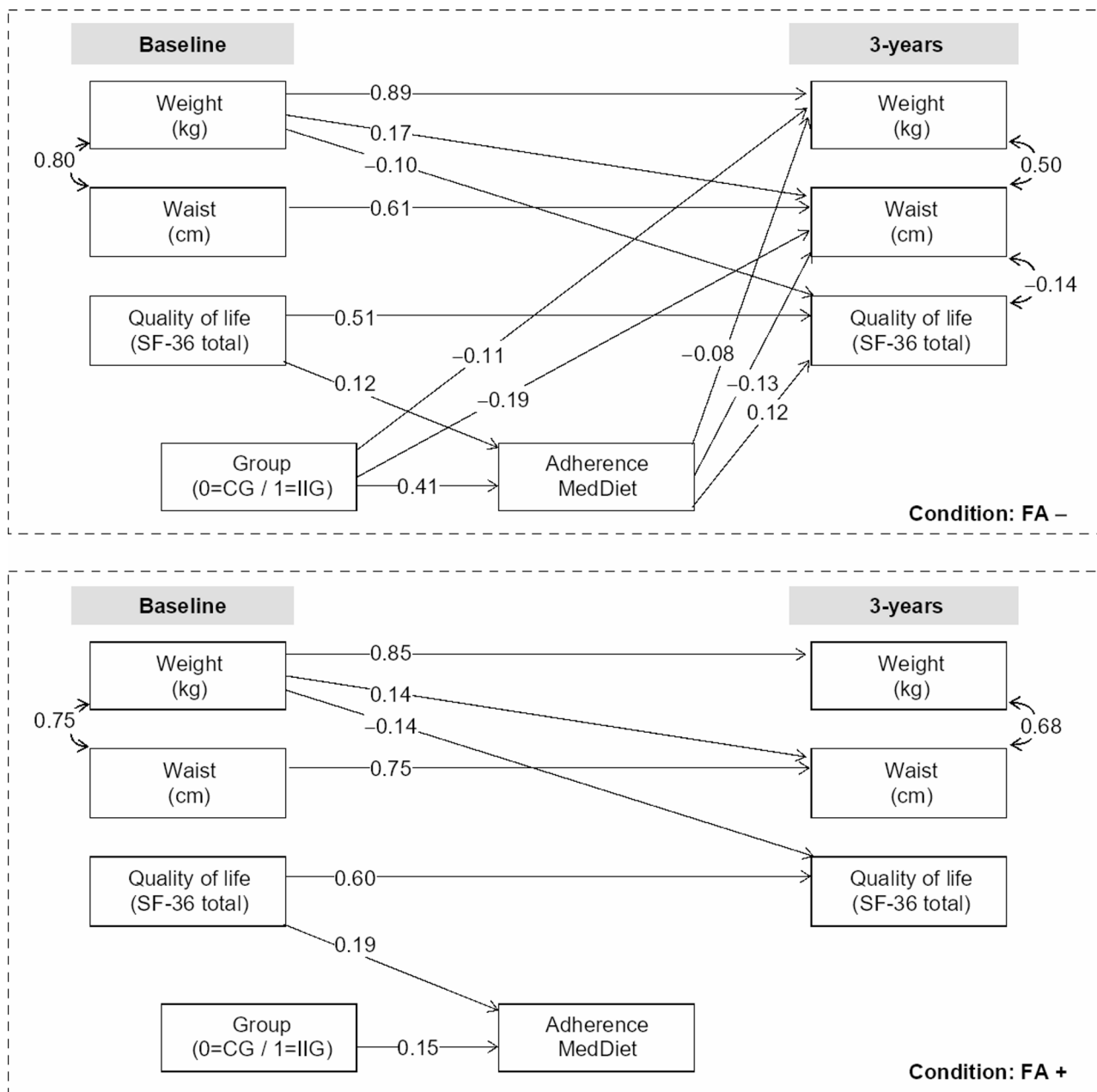


Fig. 5 Path diagram with the standardized coefficients obtained in the SEM. Note: CG: control group; IIG, intensive intervention group; MedDiet, Mediterranean diet. Only significant parameters retained in the final models. Results adjusted by sex, age and BMI at baseline

Furthermore, our study also focused on the longitudinal effects of the presence of FA across anthropometric, behavioural, and psychosocial outcomes. Our findings suggest consistent and clinically significant improvements associated to the IIG, particularly among participants without FA at baseline. While both intervention arms exhibited early improvements, the magnitude, stability, and long-term maintenance of these changes were consistently greater in the IIG. Notably, a reduction in weight and waist circumference was observed in all groups following one year of intervention; however, these decreases were larger and more consistent over time in the IIG. Individuals without FA demonstrated sustained improvements over the three-year period, while those with FA showed a partial regain. These results are consistent with prior evidence linking FA symptoms to difficulties in sustaining

weight loss and heightened vulnerability to relapse [37]. The IIG appears to attenuate this vulnerability, as individuals with FA in this group reached mean weight levels comparable to those without FA in the CG, suggesting a reduction in the adverse effects of FA, potentially by targeting processes that interfere with long-term weight regulation. Although the mechanisms cannot be inferred directly from our data, this pattern is consistent with the notion that structured, high-support lifestyle programmes may help counteract behavioural and regulatory processes such as impaired self-control, heightened reward sensitivity, or difficulties in sustaining dietary adherence that characterise FA and contribute to poorer weight-loss maintenance [38, 39]. Waist circumference followed a similar trend, with early reductions observed across all groups and more pronounced improvements in the experimental group. Given the strong association between central adiposity and cardiometabolic risk [40], these findings underscore the clinical relevance of sustained improvements in this parameter.

Behavioural outcomes, as MedDiet adherence, leisure-time physical activity and QoL followed a similarly favourable pattern. Adherence to MedDiet increased significantly during the first year of follow-up and remained higher in the IIG at all time points, regardless of FA status. This finding aligns with evidence that intensive lifestyle programmes enhance long-term adherence [41–43]. Improvements in MedDiet adherence may be indicative of a reduce UPF intake, one of the primary triggers of FA, and previously demonstrated to ameliorate the FA symptoms [44]. Leisure time physical activity also improved across groups, with consistently higher levels observed in the IIG, consistent with prior findings on structured interventions [45]. In relation to QoL, our findings indicated improvements over time, which is consistent with previous research showing that adherence to MedDiet, especially in combination with structured physical activity plans, enhances psychological wellbeing and health-related QoL [46]. The most significant improvements were observed among participants with FA, who started with lower baseline scores, which provided a wider window for improvement. Given that individuals with addictive-like eating behaviours often present with greater psychological distress [47, 48], it is possible that our results reflect a broader psychosocial benefit of the intervention, which may be mediated by improvements in behavioural regulation and reductions in psychological distress. These results suggest that individuals with FA may experience significant benefit from behaviourally oriented lifestyle support. Previous studies have demonstrated that lifestyle interventions, encompassing dietary modification, structured physical activity programmes, and behavioural or psychological support, have the capacity to reduce FA symptoms [49]. These types of interventions have reported improvements in craving regulation, emotional eating, and loss of control eating suggesting that FA represents a meaningful behavioural phenotype that responds to target lifestyle strategies [50, 51]. The integration of FA assessment within obesity management protocols, could, therefore improve the precision of treatment by identifying individuals who are more likely to benefit from intervention components that address addictive eating patterns.

The analysis of predictors of good outcomes revealed that the IIG not only increases the likelihood of achieving clinically meaningful improvements, but also accelerates their occurrence. While these findings were primarily evidenced among individuals without FA at baseline, results were weaker and more heterogeneous among those with FA. These findings are consistent with evidence that FA symptoms predicted lower weight-loss success after behavioural interventions [18]. This is coherent with the characterisation of FA that involves loss of control over eating, and intense and persistent craving for highly palatable foods, mechanisms that can be directly impairing adherence to dietary prescriptions [14, 52]. The results of the path analysis further emphasise these observations, indicating that among participants with FA, long-term anthropometric and QoL outcomes were predominantly explained by baseline status rather than by changes in MedDiet adherence or group allocation. These results suggest that while the IIG is effective for individuals without FA, addictive mechanisms may limit the capacity of those with FA to fully benefit from the programme, with their long-term outcomes more strongly shaped by initial clinical characteristics than by behavioural changes achieved during the intervention.

This study presents several notable strengths. Firstly, the study was conducted within the framework of the PREDIMED Plus trial, a large, multicentre, randomised controlled study with long-term follow-up. This provides a robust methodological foundation and enhances the internal validity of the findings. An additional strength is the low dropout rate and high follow up retention, which further reinforces the reliability of the longitudinal

assessments. A further important strength lies in the comprehensive nature of the intervention, which combined an energy-reduced MedDiet, structured physical activity promotion, and behavioural support. This multicomponent approach allowed for the evaluation of FA within an ecologically valid lifestyle programme, as opposed to an isolated or single modality interventions. The study also benefited from repeated assessments at baseline, 1 year, and 3 years, enabling the examination of both short-term and sustained changes in food addiction symptoms, adherence, anthropometric outcomes, and quality of life. In addition, the use of well-validated instruments with high internal consistency, together with advanced statistical modelling provided a rigorous analytical framework to explore both outcomes and underlying mechanisms.

Despite these strengths, several limitations should be acknowledged. The analysis was based on a subsample of 448 participants from four centres, which may limit statistical power for subgroup comparisons, particularly for individuals with FA, and may reduce generalizability within the broader PREDIMED Plus cohort. The present sample exclusively comprised older adults with overweight or obesity and metabolic syndrome, which restricts the extrapolation of findings to younger populations or to individuals with different sociodemographic or clinical characteristics. The prevalence of FA was relatively low, resulting in an imbalance between FA+ and FA− groups that may have reduced sensitivity to detect differences in intervention effects. Several key variables including FA symptoms, MedDiet adherence, physical activity, and QoL were assessed through self-report measures, which are subject to recall and social desirability biases. Moreover, the control group received an active MedDiet intervention, including provision of extra virgin olive oil, which may have attenuated between group differences and underestimated the true effect of the intensive programme. Finally, the study was conducted exclusively in Spain, where cultural familiarity with the MedDiet may influence adherence patterns, potentially limiting generalizability to non-Mediterranean settings.

Conclusions

To summarise, a psychosocial lifestyle intervention grounded in an energy-reduced MedDiet, structured physical activity, and behavioural support, was associated with sustained improvements in FA. Although these improvements were observed in both the intervention and control groups, only participants receiving the intensive intervention further enhanced these progresses over time. These findings underscore the capacity of comprehensive lifestyle programmes to modify addictive-like eating behaviour patterns in older adults with overweight/obesity and metabolic syndrome. Furthermore, baseline FA was identified as a pivotal factor influencing the intervention response. Participants without FA consistently showed the most favourable trajectories in the different outcomes, including greater reductions in weight and waist circumference, higher odds of achieving clinically meaningful outcomes, and faster attainment. Taken together, these findings suggest that FA is both a modifiable behavioural phenotype and a clinically relevant moderator of long-term intervention effectiveness.

Clinical implications

The present findings highlight the clinical relevance of FA as a behavioural phenotype that meaningfully shapes adherence and long-term response to lifestyle interventions in obesity. These findings support the clinical relevance of assessing FA prior to lifestyle interventions and suggest that FA may represent an important stratification variable for personalised obesity management. Standard lifestyle interventions appear highly effective for individuals without FA, but those with FA may require additional or alternative therapeutic strategies, potentially incorporating psychological, addiction informed, or neurobehavioral components, to improve long term efficacy. The incorporation of FA assessment into obesity management has the potential to enhance the precision of lifestyle interventions and support the development of tailored strategies that address the specific behavioural vulnerabilities associated with addictive-like eating behaviours. Future interventions should explicitly address the addictive dimension of eating to enhance outcomes in this high-risk subgroup.

Abbreviations

χ^2	Chi square tests
ANOVA	Analysis of variance
BMI	Body Mass Index
CFI	Comparative Fit Index
CG	Control group
DSM	5–Diagnostic and Statistical Manual of Mental Disorders 5th edition
er	MEDAS–energy–restricted Mediterranean Adherence Screener
FA	Food Addiction
IIG	Intensive intervention group
MedDiet	Mediterranean Diet
QoL	Quality of Life
SEM	Structural Equation Modelling
SF	36–Short Form–36 Health Survey
UPF	Ultra–Processed food
YFAS 2.0	Yale Food Addiction Scale 2.0
RMSEA	Root Mean Square Error of Approximation
SRMR	Standardized Root Mean Square Residual
TLI	Tucker–Lewis index

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1186/s12916-026-05283-z>.

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Author contributions Principal PREDIMED-Plus-Cognition investigators SJ-M, RT, DC, XP, MF, JS-S and FF-A, contributed to study design and data extraction. RG conducted statistical analyses and, with LCB, interpreted results. LCB, RG, SG and FFA drafted the manuscript, and SJ-M, RdIT, NB, XP, DC, FF, AR-M, MF, AC-R, CG-M, AG, LF and JS-S substantively revised it. All authors read, reviewed and approved the final manuscript.

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the report, or in the decision to submit the manuscript for publication.

Data availability Due to signed consent agreements regarding data sharing, there are restrictions on data availability for the PREDIMED-Plus trial. These only allow access to external researchers for studies following the project purposes. Requestors wishing to access the PREDIMEDPlus trial data used in this study can make a request to the PREDIMED-Plus trial Steering Committee chair: jordi.salas@urv.cat. The request will then be passed to members of the PREDIMED-Plus Steering Committee for deliberation.

Declarations

Ethics approval and consent to participate All participants provided written informed consent. According to the ethical standards of the Declaration of Helsinki by the Research Ethics Committees, all the participating institutions approved the study protocol and procedures (Clinical Research Ethics Committee (CEIC) from the Bellvitge University Hospital-IDIBELL: PR240/13; CEIC Parc de Salut Mar, and IDIAP Jordi Gol—IMIM: PI13/130; CEIC Corporativo de Atención Primaria de la Comunitat Valenciana—University of Valencia: CEIC del Hospital Universitari Sant Joan de Reus y IDIAB Jordi Gol—Universitat Rovira i Virgili: 2011-005398-22; 13-07-25/7proj2).

Consent for publication All authors consent for publication.

Competing interests FF-A reports consultation fees from Novo Nordisk. X.P. reports personal fees from AMGEN, Astra-Zeneca, Esteve, Ferrer, Merck, Mylan and Sanofi, outside the submitted work. JS-S reported receiving research support from Ministerio de Educación y Ciencia, Departament de Salut Pública de la Generalitat de Catalunya, and the USA National Institutes of Health; receiving nonfinancial support from Hojiblanca, Patrimonio Comunal Olivarero, the Almond Board of California, Pistachio Growers and Borges S.A; serving on the board of and receiving grant support through his institution from the International Nut and Dried Foundation; serving in the Scientific Board of Danone Institute International (nonpaid member); and personal fees from Instituto Danone Spain.

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References

1. Chu DT, Minh Nguyet NT, Dinh TC, Thai Lien NV, Nguyen KH, Nhu Ngoc VT, et al. An update on physical health and economic consequences of overweight and obesity. *Diabetes Metabolic Syndrome: Clin Res Reviews*. 2018;12(6):1095–100. <https://doi.org/10.1016/j.dsx.2018.05.004>.
2. Phelps NH, Singleton RK, Zhou B, Heap RA, Mishra A, Bennett JE, et al. Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. *Lancet*. 2024;403(10431):1027–50. [https://doi.org/10.1016/S0140-6736\(23\)02750-2](https://doi.org/10.1016/S0140-6736(23)02750-2).
3. WHO. Obesity and overweight [Internet]. 2025 [cited 2026 Apr 7]. Available from: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
4. Blüher M. Obesity: global epidemiology and pathogenesis. *Nat Rev Endocrinol*. 2019;15(5):288–98. <https://doi.org/10.1038/s41574-019-0176-8>.
5. Dixon JB. The effect of obesity on health outcomes. *Mol Cell Endocrinol*. 2010;316(2):104–8. <https://doi.org/10.1016/j.mce.2009.07.008>.
6. Martínez-González MA, Gea A, Ruiz-Canela M. The Mediterranean Diet and Cardiovascular Health. *Circ Res*. 2019;124(5):779–98. <https://doi.org/10.1161/CIRCRESAHA.118.313348>.
7. Estruch R, Ros E. The role of the Mediterranean diet on weight loss and obesity-related diseases. *Rev Endocr Metab Disord*. 2020;21(3):315–27. <https://doi.org/10.1007/s11154-020-09579-0>.

8. Losavio J, Keenan MJ, Gollub EA, Silver HJ. Factors that predict weight loss success differ by diet intervention type. *Front Nutr*. 2023;10. <https://doi.org/10.3389/fnut.2023.1192747>.
9. Gearhardt AN, Corbin WR, Brownell KD. Preliminary validation of the Yale Food Addiction Scale. *Appetite*. 2009;52(2):430–6. <https://doi.org/10.1016/j.appet.2008.12.003>.
10. Gearhardt AN, Bueno NB, DiFeliceantonio AG, Roberto CA, Jiménez-Murcia S, Fernandez-Aranda F. Social, clinical, and policy implications of ultra-processed food addiction. *BMJ*. 2023;383:e075354. <https://doi.org/10.1136/bmj-2023-075354>.
11. Praxedes DRS, Silva-Júnior AE, Macena ML, Oliveira AD, Cardoso KS, Nunes LO, et al. Prevalence of food addiction determined by the Yale Food Addiction Scale and associated factors: A systematic review with meta-analysis. *Eur Eat Disord Rev*. 2022;30(2):85–95. <https://doi.org/10.1002/erv.2878>. PubMed PMID: 34953001.
12. Senol E, Mohammad H. Current perspectives on brain circuits involved in food addiction-like behaviors. *J Neural Transm*. 2024;131(5):475–85. <https://doi.org/10.1007/s00702-023-02732-4>.
13. Hough K, Friuli M, Avena NM, Romano A. The addicted brain: How processed foods hijack reward pathways. *Pharmacol Res*. 2026;224:108097. <https://doi.org/10.1016/j.phrs.2026.108097>.
14. Krupa H, Gearhardt AN, Lewandowski A, Avena NM. Food Addiction. *Brain Sci*. 2024;14(10):952. <https://doi.org/10.3390/brainsci14100952>.
15. Meule A, Gearhardt A. Food Addiction in the Light of DSM-5. *Nutrients*. 2014;6(9):3653–71. <https://doi.org/10.3390/nu6093653>.
16. Burrows T, Kay-Lambkin F, Pursey K, Skinner J, Dayas C. Food addiction and associations with mental health symptoms: a systematic review with meta-analysis. *J Hum Nutr Dietetics*. 2018;31(4):544–72. <https://doi.org/10.1111/jhn.12532>.
17. Camacho-Barcia L, Munguía L, Lucas I, de la Torre R, Salas-Salvadó J, Pintó X, et al. Metabolic, Affective and Neurocognitive Characterization of Metabolic Syndrome Patients with and without Food Addiction. Implications for Weight Progression. *Nutrients*. 2021;13(8):2779. <https://doi.org/10.3390/nu13082779>.
18. Halbeisen G, Pahlenkemper M, Sabel L, Richardson C, Agüera Z, Fernandez-Aranda F, et al. The prognostic role of food addiction for weight loss treatment outcomes in individuals with overweight and obesity: A systematic review and meta-analysis. *Obes Rev*. 2025;26(2). <https://doi.org/10.1111/obr.13851>.
19. Camacho-Barcia L, Munguía L, Gaspar-Pérez A, Jimenez-Murcia S, Fernández-Aranda F. Impact of Food Addiction in Therapy Response in Obesity and Eating Disorders. *Curr Addict Rep*. 2022;9(4):268–74. <https://doi.org/10.1007/s40429-022-00421-y>.
20. Gordon EL, Merlo LJ, Durning PE, Perri MG. Longitudinal Changes in Food Addiction Symptoms and Body Weight among Adults in a Behavioral Weight-Loss Program. *Nutrients*. 2020;12(12):3687. <https://doi.org/10.3390/nu12123687>.
21. Guerrero Pérez F, Sánchez-González J, Sánchez I, Jiménez-Murcia S, Granero R, Simó-Servat A, et al. Food addiction and preoperative weight loss achievement in patients seeking bariatric surgery. *Eur Eat Disorders Rev*. 2018;26(6):645–56. <https://doi.org/10.1002/erv.2649>.
22. Pape M, Herpertz S, Färber T, Seiferth C, Schoemann N, Wolstein J, et al. Food Addiction in Individuals With Overweight and Obesity Undergoing a 12-Week Long Tailored mHealth Weight Loss Intervention. *Eur Eat Disorders Rev*. 2025;33(5):931–40. <https://doi.org/10.1002/erv.3196>.
23. Reche-García C, Piernas C, García-Vizcaíno EM, Lorente-Gallego AM, Piuvezam G, Frutos MD, et al. Bariatric-Metabolic Surgery is the Most Effective Intervention in Reducing Food Addiction Symptoms: A Systematic Review and Meta-Analysis. *Obes Surg*. 2024;34(9):3475–92. <https://doi.org/10.1007/s11695-024-07107-6>.
24. 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(2):387–o388. <https://doi.org/10.1093/ije/dyy225>.
25. Predimed Plus. – Estudio de la dieta mediterránea [Internet]. [cited 2026 Apr 10]. Available from: <https://www.predimedplus.com/>
26. Alberti KGMM, Eckel RH, Grundy SM, Zimmet PZ, Cleeman JI, Donato KA, the International Diabetes Federation Task Force on Epidemiology and Prevention; National Heart, Lung, and Blood Institute; American Heart Association. Harmonizing the metabolic syndrome: a joint interim statement of. *Obes Circulation*. 2009;120(16):1640–5. <https://doi.org/10.1161/CIRCULATIONAHA.109.192644>. World Heart Federation; International Atherosclerosis Society; and International Association for the Study ofPubMed PMID: 19805654.
27. Papadaki A, Martínez-González MÁ, Alonso-Gómez A, Rekondo J, Salas-Salvadó J, Corella D et al. Mediterranean Diet and Risk of Heart Failure: Results from the PREDIMED Randomized Controlled Trial. *Eur J Heart Fail* 2017; 19:1179–1185. <https://doi.org/10.1002/ehf.750>. *Eur J Heart Fail*. 2019;21(3):389–91. doi:10.1002/ehf.1346.
28. Gearhardt AN, Corbin WR, Brownell KD. Development of the Yale Food Addiction Scale Version 2.0. *Psychol Addict Behav*. 2016;30(1):113–21. <https://doi.org/10.1037/adb0000136>.
29. Granero R, Jiménez-Murcia S, Gearhardt AN, Agüera Z, Aymamí N, Gómez-Peña M, et al. Validation of the Spanish Version of the Yale Food Addiction Scale 2.0 (YFAS 2.0) and Clinical Correlates in a Sample of Eating Disorder, Gambling Disorder, and Healthy Control Participants. *Front Psychiatry*. 2018;9(MAY):354067. <https://doi.org/10.3389/fpsy.2018.00208>.

30. Alonso J, Prieto L, Antó JM. [The Spanish version of the SF-36 Health Survey (the SF-36 health questionnaire): an instrument for measuring clinical results]. *Med Clin (Barc)*. 1995;104(20):771–6. PubMed PMID: 7783470.
31. Molina L, Sarmiento M, Peñafiel J, Donaire D, Garcia-Aymerich J, Gomez M, et al. Validation of the Regicor Short Physical Activity Questionnaire for the Adult Population. *PLoS ONE*. 2017;12(1):e0168148. 10.1371/. JOURNAL. PONE.0168148 PubMed PMID: 28085886.
32. Schröder H, Zomeño MD, Martínez-González MA, Salas-Salvadó J, Corella D, Vioque J, et al. Validity of the energy-restricted Mediterranean Diet Adherence Screener. *Clin Nutr*. 2021;40(8):4971–9. <https://doi.org/10.1016/j.clnu.2021.06.030>. PubMed PMID: 34364236.
33. McNeish DM, Stapleton LM. The Effect of Small Sample Size on Two-Level Model Estimates: A Review and Illustration. *Educ Psychol Rev*. 2016;28(2):295–314. <https://doi.org/10.1007/s10648-014-9287-x>.
34. Chao AM, Wadden TA, Tronieri JS, Pearl RL, Alamuddin N, Bakizada ZM, et al. Effects of addictive-like eating behaviors on weight loss with behavioral obesity treatment. *J Behav Med*. 2019;42(2):246–55. <https://doi.org/10.1007/s10865-018-9958-z>.
35. Braun A, Corcoran S, Godsey T, Lucas E, McCann M, Hosseininasab D, et al. A Whole Food Dietary Fiber-Focused Behavioral Intervention Decreases Food Addiction in Adults With Obesity. *Curr Dev Nutr*. 2024;8:103229. <https://doi.org/10.1016/J.CDNUT.2024.103229>.
36. Saner E, Kalayjian T, Buchanan L, Calkins M, Soto-Mota A, Jun D, et al. TOWARD: a metabolic health intervention that improves food addiction and binge eating symptoms. *Front Psychiatry*. 2025;16. <https://doi.org/10.3389/fpsy.2025.1612551>.
37. Palacio AC, Cuello C, Díaz-Torrente X. Food addiction in patients on weight loss treatment. *Front Nutr*. 2024;11. <https://doi.org/10.3389/fnut.2024.1459274>.
38. Deslippe AL, Soanes A, Bouchaud CC, Beckenstein H, Slim M, Plourde H, et al. Barriers and facilitators to diet, physical activity and lifestyle behavior intervention adherence: a qualitative systematic review of the literature. *Int J Behav Nutr Phys Act*. 2023;20(1):14. <https://doi.org/10.1186/s12966-023-01424-2>. PubMed PMID: 36782207.
39. Maqsood S, Ahmed F, Arshad MT, Ikram A, Abdullahi MA. Comparative Analysis of Food Addiction and Obesity: A Critical Review. *Food Sci Nutr*. 2025;13(8):e70799. <https://doi.org/10.1002/fsn3.70799> PubMed PMID: 40822524.
40. Ruano GR, Nogueira GA, Dadson P, Ferreira SRG, Sapienza MT, Velloso LA, et al. Abdominal obesity and cardiometabolic risk markers: A comparative analysis of waist circumference, dual-energy X-ray absorptiometry, and magnetic resonance imaging techniques. *Nutr Metabolism Cardiovasc Dis*. 2025;35(3):103801. <https://doi.org/10.1016/j.numecd.2024.103801>.
41. Recio-Rodriguez JJ, Garcia-Ortiz L, Garcia-Yu IA, Lugones-Sanchez C, del Olmo EZ, Bolibar B, et al. Effectiveness of a multiple health-behaviour-change intervention in increasing adherence to the Mediterranean Diet in adults (EIRA study): a randomized controlled hybrid trial. *BMC Public Health*. 2022;22(1):2127. <https://doi.org/10.1186/s12889-022-14590-y>.
42. Cano-Ibáñez N, Bueno-Cavanillas A, Martínez-González MÁ, Salas-Salvadó J, Corella D, la Freixer G, et al. Effect of changes in adherence to Mediterranean diet on nutrient density after 1-year of follow-up: results from the PREDIMED-Plus Study. *Eur J Nutr*. 2020;59(6):2395–409. <https://doi.org/10.1007/s00394-019-02087-1>.
43. Prieto-González P, Yagin FH, Alghannam AF, Canli U. Effects of a Mediterranean diet and structured exercise intervention on selected anthropometric, cardiovascular, and metabolic variables in physically inactive adults: a randomized controlled trial. *Front Nutr*. 2025;12. <https://doi.org/10.3389/fnut.2025.1695412>.
44. Camacho-Barcia L, Jimenez-Murcia S, Granero R, De R, Torre LA, Salas-Salvadó J, et al. Comprehensive analysis of the relationship between ultra-processed food consumption and food addiction at one-year follow-up in older adults with metabolic syndrome. *J Behav Addict*. 2026;15(1):471–87. <https://doi.org/10.1556/2006.2025.00363>.
45. Schröder H, Cárdenas-Fuentes G, Martínez-González MA, Corella D, Vioque J, Romaguera D, et al. Effectiveness of the physical activity intervention program in the PREDIMED-Plus study: a randomized controlled trial. *Int J Behav Nutr Phys Act*. 2018;15(1):110. <https://doi.org/10.1186/s12966-018-0741-x>.
46. Godos J, Guglielmetti M, Ferraris C, Frias-Toral E, Domínguez Azpíroz I, Lipari V, et al. Mediterranean Diet and Quality of Life in Adults: A Systematic Review. *Nutrients*. 2025;17(3):577. <https://doi.org/10.3390/nu17030577>.
47. da Cruz VL, Appolinario JC, Sichieri R, Hay P, de Souza Lopes C. Food addiction and its associations with mental and physical health comorbidities and with quality of life in the general population. *J Eat Disord*. 2025;13(1):205. <https://doi.org/10.1186/s40337-025-01400-0>.
48. Kalon E, Hong JY, Tobin C, Schulte T. Psychological and Neurobiological Correlates of Food Addiction. In: International review of neurobiology [Internet]. *Int Rev Neurobiol*; 2016 [cited 2026 Apr 24]. pp. 85–110. Available from: <https://linkinghub.elsevier.com/retrieve/pii/S0074774216301106><https://doi.org/10.1016/bs.irn.2016.06.003>
49. Leary M, Pursey KM, Verdejo-Garcia A, Burrows TL. Current Intervention Treatments for Food Addiction: A Systematic Review. *Behav Sci*. 2021;11(6):80. <https://doi.org/10.3390/bs11060080>.
50. Santiago VA, Cassin SE. The MotivATE randomized controlled trial: treating food addiction with adapted motivational interviewing and cognitive behavioural therapy versus a waitlist control condition. *J Eat Disord*. 2026;14(1):56. <https://doi.org/10.1186/s40337-025-01522-5>.

51. Skinner JA, Leary M, Whatnall M, Hay PJ, Paxton SJ, Collins CE, et al. Do no harm' - the impact of an intervention for addictive eating on disordered eating behaviours in Australian adults: secondary analysis of the TRACE randomised controlled trial. *J Eat Disord.* 2025;13(1):65. <https://doi.org/10.1186/s40337-025-01241-x>.
52. Camacho-Barcia L, Lucas I, Miranda-Olivos R, Jiménez-Murcia S, Fernández-Aranda F. Applying psycho-behavioural phenotyping in obesity characterization. *Rev Endocr Metab Disord.* 2023;24(5):871–83. <https://doi.org/10.1007/s11154-023-09810-8>.

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